Proceedings

The First Annual International Satellite Surveillance and Communication Symposium

September 24-26, 1991

Federal Aviation Administration Technical Center
Atlantic City, New Jersey

U.S. Department of Transportation
Federal Aviation Administration

DOT/FAA/RD-91/21

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PREFACE

The Federal Aviation Administration (FAA) is pleased to welcome you to The First Annual International Satellite Surveillance and Communication Symposium at the FAA Technical Center in Atlantic City, New Jersey.

Last year's highly successful Automatic Dependent Surveillance Symposium has been expanded this year to include the Federal Aviation Administration's Satellite Communication (SATCOM) Program.

"ADS/SATCOM Today and Tomorrow"

ADS - Recent technological advancements provide the aviation community with the opportunity to significantly improve the level of air traffic services. ADS in conjunction with Satellite Communication is the vehicle to accommodate real growth in oceanic traffic while preserving the excellent safety aspects demanded by the aviation user community.

SATCOM - To realize these new services, it is necessary to introduce satellite-based communication into the Air Traffic Service (ATS) inventory. Aircraft position reports will be relayed to ground controllers via satellite. Two way data link via satellite will augment and ultimately replace the present HF communications. These two programs, ADS and SATCOM together form the basis for improved oceanic air traffic service.

The objectives of the symposium are to:

- Coordinate ADS and SATCOM developments and applications throughout the aeronautical community;
- Review and discuss current progress, issues, international testing and developments associated with ADS/SATCOM programs; and
- Provide a forum for both industry and government to present and discuss status and implementation issues.

This symposium should provide you with an overview of international programs and developments related to ADS/SATCOM. These will be discussions on engineering trials, international coordination activities, development of standards and user programs. The keynote of this symposium will focus on the benefits of the FAA ADS/SATCOM programs for the aviation community. The theme of this symposium is to inform the attendees of current ADS/SATCOM developments by government and industry of participating countries and to project the future activities required for successful implementation of the ADS/SATCOM programs.

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SYMPOSIUM CO-CHAIRPERSON

Joseph J. Fee
Oceanic Systems Manager
Federal Aviation Administration

Joseph J. Fee joined the FAA Research and Development Service in June 1980. Prior to being selected as Oceanic Systems Manager in April 1991, he managed the FAA's Satellite, Data Link and Traffic Alert and Collision Avoidance Systems (TACS) programs. He received the Department of Transportation Silver Medal for Meritorious Service for his leadership in the TCAS program. Mr. Fee has over thirty years experience in system engineering and applied research in navigation, surveillance and communications. He holds both an MSEE and BSEE from the University of Kansas.

SYMPOSIUM CO-CHAIRPERSON

Peter L. Massoglia
ADS Program Manager
Federal Aviation Administration

Peter L. Massoglia is the Program Manager of the Automatic Dependent Surveillance (ADS) Program with the Federal Aviation Administration in Washington, D.C. Mr. Massoglia holds a Baccalaureate degree (BSAE) in aeronautical engineering from Saint Louis University and has done graduate work at George Washington University.

In addition to a broad background in flight test engineering of U.S. Army and Navy aircraft he has extensive experience in reliability, maintainability and system standards. He has been with the Federal Aviation Administration (FAA) since 1976 and is presently assigned to the Research and Development Service. This organization has principal responsibility within the FAA for the development and acquisition of new technology systems. In his present assignment Mr. Massoglia is responsible for: the research, development, and implementation of the ADS program within the FAA; The development of Memorandum of Cooperation (MOC) with various states; and the coordination of international standards.

TECHNICAL CHAIRPERSON

Robert D. Till
Technical Program Manager
ADS/SATCOM
Federal Aviation Administration

Robert D. Till is a Senior Technical Program Manager in the Airborne Systems Technology Branch of the Concepts Analysis Division in the Engineering, Research, and Development Service at the Federal Aviation Administration (FAA) Technical Center. He is responsible for the Automatic Dependent Surveillance, Satellite Navigation, and Satellite communication activities at the Technical Center. He is active in the development of Aeronautical Mobile Satellite Service (AMSS) standards domestically and internationally. Mr. Till was the navigation program manager supporting the implementation of Loran C for nonprecision approaches.

OPENING SESSION

Tuesday, September 24, 1991

Master of Ceremonies - Peter L. Massoglia, ADS Program Manager, Federal Aviation Administration

9:00 **Opening Remarks** - Peter L. Massoglia, Master of Ceremonies

Welcome Address and Federal Aviation Administration Technical Center Overview Video - Harvey B. Safeer, Director, Federal Aviation Administration Technical Center

Keynote Address - Joseph M. Del Balzo, Executive Director for System Development, Federal Aviation Administration

Introductory Address - Martin T. Pozesky, Associate Administrator for System Engineering and Development, Federal Aviation Administration

Looking Beyond ADS: How Do We Fill in the Rest of the Squares? - Joseph J. Fee, Oceanic Systems Manager, Federal Aviation Administration

10:00 **FAA Research and Development Oceanic Program Office** - David W. Ford, Research and Development Oceanic Program Manager, Federal Aviation Administration

10:10 **Automatic Dependent Surveillance (ADS) Program Summary** - Peter L. Massoglia, ADS Program Manager, Federal Aviation Administration (Co-authors Lonnie H. Bowlin, President, AERA and Guy T. Germana, Chief Systems Engineer, AERA)

10:20 **BREAK** sponsored by **MITRE**

10:50 **Satellite Communications "SATCOM" Project Summary** - Joseph F. Dorfler, Satellite Program Manager, Federal Aviation Administration

11:00 **Overview of International Civil Aviation Organization (ICAO) Panel Activities** - Francisco Castro-Rodriguez, Secretary for the ICAO ADS Panel

11:15 **International Civil Aviation Organization (ICAO) ADS Panel Activities** - W. Frank Price, Manager, International Procedures Branch, Federal Aviation Administration (Co-author Faye I. Francy, Program Manager, MiTech, Inc.)

11:30 **International Program Summary** - Peter L. Massoglia, ADS Program Manager, Federal Aviation Administration

Countries:

Australia	Canada
Fiji	Iceland
Japan	New Zealand
Portugal	Spain
Singapore	United Kingdom
USSR	

12:00 **Air Transport Association (ATA)** - Raymond J. Hilton, Director, Air Traffic Management, Air Transport Association of America

WELCOME SPEAKER

Harvey B. Safeer
Director
Federal Aviation Administration
Technical Center

Harvey B. Safeer is the Director of the Federal Aviation Administration Technical Center. As Director, Mr. Safeer is responsible for the FAA activities conducted at the Center to advance civil aviation safety through research, development, test and evaluation of future air traffic control and safety technologies. He was appointed to this position in May 1990.

The Technical Center is at the forefront of FAA's efforts to update and automate the air traffic control system through the Capital Investment Plan (CIP). The Technical Center serves as the primary test and evaluation site for the advanced technology being developed under the advanced automation system, a subsystem of the CIP. All equipment under this program will be tested at the Center prior to field implementation.

A 29-year career federal employee, Mr. Safeer has held several senior management positions in the FAA, and has worked in other government agencies and private industry. He was director of FAA's Management Control Service, Office of Air Traffic Evaluation and Analysis, and Aviation Policy.

A one-time labor economist, Mr. Safeer also has been manager of the agency's Quality Assurance Staff and the Aviation Policy Analysis Division. Mr. Safeer holds a Master's degree in Economics from the University of Minnesota, and a Bachelor's degree in Economics from the City College of New York. Originally from Brooklyn, New York, Mr. Safeer now resides with his wife Gail in Absecon, New Jersey. He has two daughters, one son and four grandchildren.

WELCOME ADDRESS

BY

HARVEY B. SAFEER
DIRECTOR, FEDERAL AVIATION ADMINISTRATION (FAA)
TECHNICAL CENTER

Welcome to the FAA Technical Center and the First International Satellite Surveillance and Communication Symposium. The use of satellite technology for communications, navigation and surveillance in aviation is an exciting and rapidly progressing field that has evoked tremendous interest. The FAA Technical Center is proud to play a leading role in this activity.

Only two years ago the seeds were planted to develop the Pacific Engineering Trials (PET) to demonstrate the potential of satellite communication and Automatic Dependent Surveillance to solve a pressing need for improved oceanic communications and surveillance. The Pacific Engineering Trials are in progress today, thanks to the cooperation of industry and the civil aviation agencies around the world.

We can be proud of the progress made. As the trials mature more aircraft will be equipping with satellite communication avionics. The FAA has awarded the Automatic Dependent Surveillance contract which will result in operational Automatic Dependent Surveillance function in the oceanic centers in about two years. The future will bring more. Satellite position reports will replace the oceanic mandatory High Frequency (HF) radio reports. Oceanic air traffic control clearances will be delivered and approved using satellite data link. The final benefit will be improved safety and a reduction in oceanic separation standards.

We at the FAA Technical Center are proud to be partners with industry and other governments to develop this technology to achieve the operational and economic benefits that will result. We hope you'll find the next three days enlightening and rewarding.

KEYNOTE SPEAKER

Joseph M. Del Balzo
Executive Director for
System Development
Federal Aviation Administration

Joseph M. Del Balzo is the Executive Director for System Development at the Federal Aviation Administration. Mr. Del Balzo is responsible for the agency's research, engineering and development programs, as well as the acquisition of air traffic control systems. His organizational mission is to lead in the development and implementation of a global aviation system that exceeds user demand for system safety, capacity and productivity.

Mr. Del Balzo previously served as Director of the FAA's Technical Center from 1979 through 1981, then became Director of FAA's Eastern Region until July 1988, when he assumed his current position.

He began his federal career in 1958 as an electrical engineer with the FAA. He holds a B.S. in Electrical Engineering from Manhattan College, an M.S. in Engineering Management from Drexel University and an Honorary Doctorate in Aeronautical Science from Embry-Riddle Aeronautical University. He also completed a one-year fellowship at Princeton University in public policy and international affairs.

INTRODUCTORY SPEAKER

Martin T. Pozesky
Associate Administrator for
System Engineering and Administration
Federal Aviation Administration

Martin T. Pozesky is Associate Administrator for System Engineering and Development for the Federal Aviation Administration (FAA). He is responsible for executive direction and coordination of the systems engineering activities of FAA's research and capital investment programs, including formulation and management of the agency's Facilities and Equipment and Research, Engineering, and Development programs, all leading to the modernization of the national airspace system.

This assignment follows twenty-seven years of Federal government service where Mr. Pozesky successfully directed several large-scale, multi-million dollar programs involving command and control, radar surveillance, and aeronautical telecommunications for the Federal Aviation Administration and the Department of the Navy. This experience includes providing management direction for a wide range of system development and implementation programs in air traffic control, data processing and automation, radar and sensor systems, avionics and flight control, meteorology and weather systems, and display technology.

Mr. Pozesky holds a Bachelor's Degree in Electrical Engineering and a Master's Degree in Engineering Management. He is the recipient of numerous professional and academic honors, including the President's Meritorious Executive Award, the Secretary of Transportation's Gold Medal for Outstanding Leadership, and the Air Traffic Control Association's prestigious Quesada Award for Outstanding Contributions to its Industry.

A member of Tau Beta Phi, the Institute of Electronic and Electrical Engineers, the American Management Association, Armed Forces Communications and Electronics Association, the Air Traffic Control Association, Mr. Pozesky is active in these and other professional engineering and aeronautical events held throughout the country.

The 80's Were Great
The 90's Will Be Better
(abstract)

by
Martin T. Pozesky
Associate Administrator
for
System Engineering and Development

Ten years ago, specifically during the summer and fall of 1981, we were franticly busy creating the original National Airspace System Plan, benevolently known since then as the "Brown Book." We went through endless reviews of the multitude of programs with Administrator Helms and the various staffs until it was finally completed.

The document was totally embraced by Congress and the other members of the air transportation community. As such, this document, and the succeeding annual updates, have become the "road map" of FAA's major engineering effort in the upgrading of the existing systems. The "Brown Book" provided the 20 year FAA program plans, primarily for the terrestrial systems and included:

- System Demand
- ATC Systems
  - En Route
  - Terminal
- Ground-to-Air Systems
- Interfacility Communication Systems
- Maintenance and Operations Support Systems
- Other Capital Needs
- Transition

During the 80's, we have achieved a large number of major accomplishments, with more than 25% of the original NAS Plan Projects completed and most of the remaining are in the production/implementation phase. Some of the more visible include:

- Microwave Landing Systems (MLS)
- Advanced Automation System (AAS)
- Automated Radar Terminal Systems (ARTS) upgrading
- Flight Service Automation Systems (FSAS)
- National Airspace Data Interchange Network (NADIN) II
- Remote Maintenance Monitoring Systems (RMMS)

The 80's, as can be seen from this list of major activities, have been naturally focused on the terrestrial side of FAA's interests because of the urgency of operational requirements. Now the current interest is shifting to the Oceanic activities as the estimates for projected growth over both the Atlantic and Pacific basins are significant. There is a major shift in emphasis by the FAA as well as the international community to the utilization of satellites. This has reflected major technological advances in the areas of:

- Surveillance
- Communication
- Navigation

These, in turn, will have a major impact on:

- Separation Standards
- Capacity Improvement
- Increase Efficiency

- Maintenance of High Safety Standards
- Continued International Cooperation

Extensive satellite utilization by both governments and private enterprise, on a daily basis, have resulted in:

- Cost reductions
- Increased reliability and life expectancy
- Expanded user utilization

Specifically some of the FAA's satellite surveillance and communication developmental activities include:

- Satellite Communication (SATCOM) Program
- Automatic Dependent Surveillance (ASD) Program
- Oceanic Display and Planning System (ODAPS)
- Dynamic Oceanic Tracking System (DOTS)
- Experimental Testing

In supporting this effort, the FAA has established a very close "coordination network" with a large variety of interested and participating organizations:

- International governments
- United Nation's Internation Civil Aviation Organization (ICAO)
- National/International Trade Organizations
- National Standards Organizations
- Airlines
- Aeronautical Mobile Communication Service Providers
- Communication Satellite Service Providers

So, with this cast of characters, programs, organizations and congressional support, we are off in the 90's to expand the oceanic systems much the same way that we expanded the terrestrial systems during the 80's. The next two and a half days here at the symposium will unfold what has been accomplished, what's being planned and how it will be executed. The 90's will be another exciting decade.

OPENING SESSION

Joseph J. Fee
Oceanic Systems Manager
Federal Aviation Administration

Joseph J. Fee joined the FAA Research and Development Service in June 1980. Prior to being selected as Oceanic Systems Manager in April 1991, he managed the FAA's Satellite, Data Link and Traffic Alert and Collision Avoidance Systems (TACS) programs. He received the Department of Transportation Silver Medal for Meritorious Service for his leadership in the TCAS program. Mr. Fee has over thirty years experience in system engineering and applied research in navigation, surveillance and communications. He holds both an MSEE and BSEE from the University of Kansas.

LOOKING BEYOND ADS: HOW DO WE FILL IN THE REST OF THE SQUARES?

Joe Fee, Oceanic Systems Manager

Federal Aviation Administration, Washington, D.C.

This symposium will present numerous papers reporting on results of experiments and trials which were only ideas a few short years ago. Government agencies, airlines and equipment manufacturers have all shown considerable ingenuity and expended significant effort to turn the idea called Automatic Dependent Surveillance (ADS) into the practical reality of todays trials. I congratulate all of you on your successes, knowing that this is only the beginning of the technology revolution which is transforming oceanic ATC.

Satellite communications is becoming an operational fact in Oceanic Aviation. The expected growth in oceanic air traffic and the rapid rate at which airlines are expected to equip with satellite communications is a major factor in the modernization of oceanic ATC. Figure 1 presents a projection of traffic growth over the current decade together with an estimate of the worldwide rate for aircraft satellite communications equipage.

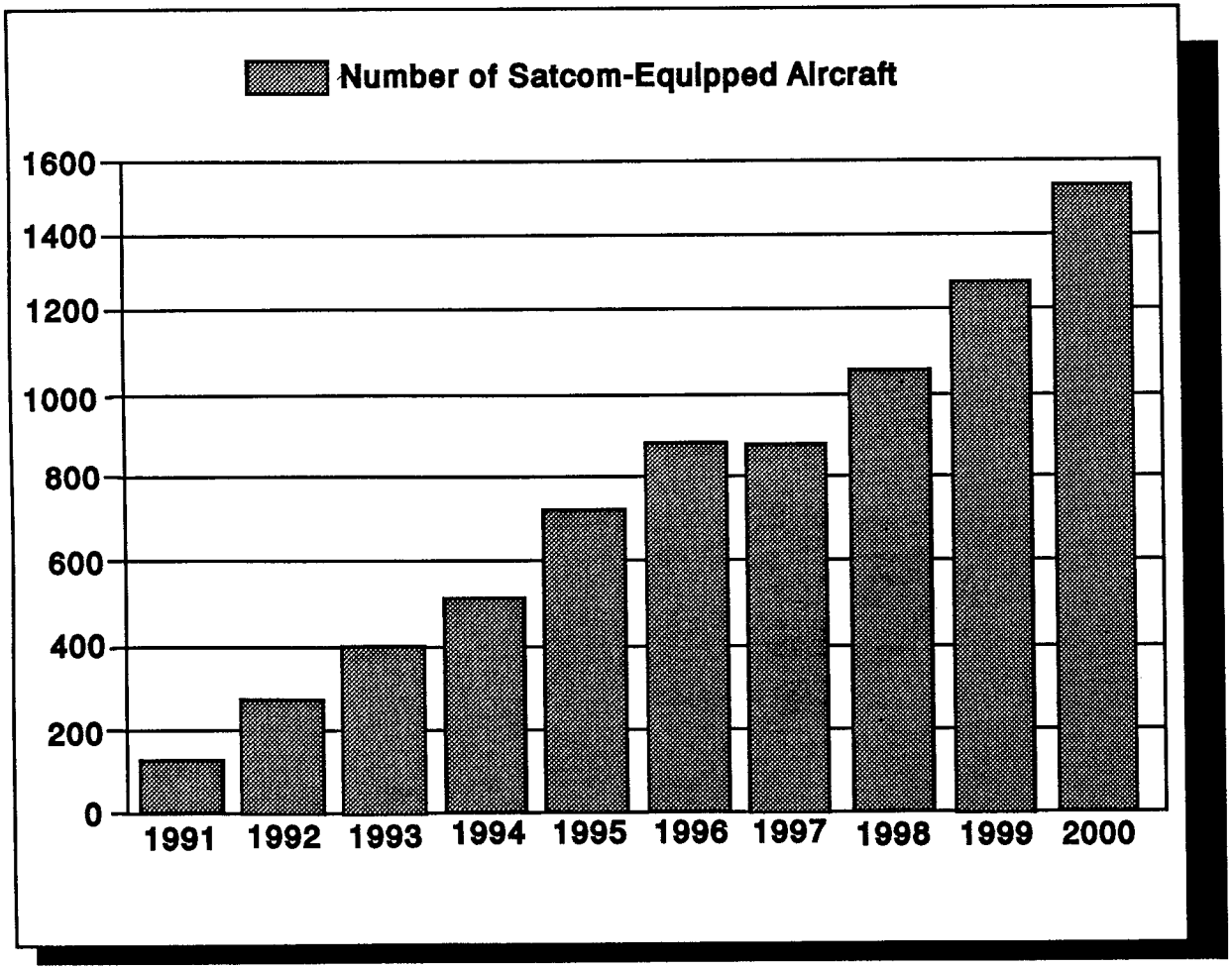
As you can see I've recently taken on a new job as the Oceanic System Manager. In this position one of my first tasks has been to review the U.S. oceanic system. Based upon my initial look at today's system, I can say we're going to have our hands full for the rest of the decade in bringing the whole oceanic ATC system up to the level required to provide the ATC services desired without any degradation in the level of safety. In the following comments, I'll try to point out some key areas in which I believe we need to make more progress and what the FAA plans to do to help the process.

BIG OCEAN, LITTLE SYSTEM

Figure 2 depicts the oceanic system as viewed from the North American viewpoint. What this figure cannot show is the complexity of the route structures which cover the Atlantic, Caribbean and Pacific regions. Depending on the region, aircraft equipment, altitude, and relative speed, the longitudinal separation minima can vary between 5 and 30 minutes, the lateral minima between 50 and 120 nautical miles and required altitude separation between 1000 and 2000 feet (for subsonic aircraft below FL600) As shown in the figure, we will soon be dealing with a mix of HF and satellite communication equipped aircraft (hereafter referred to as satellite-equipped) which could complicate matters for the air traffic controller who as shown in the figure, is still separating aircraft in the traditional manner using flight strips.

The low level of ATC automation worldwide is one of the major shortcomings of oceanic ATC. To the best of my knowledge, only the United Kingdom and Canada routinely utilize an automated conflict probe in oceanic airspace. While satellite-equipped aircraft can expect rapid contact with ATC facilities and while the position of such aircraft will be accurately

Oceanic Air Traffic Environment Changes



Traffic Increases by the year 2000

North Atlantic	36%
Pacific	86%

Figure 1

The Oceanic System

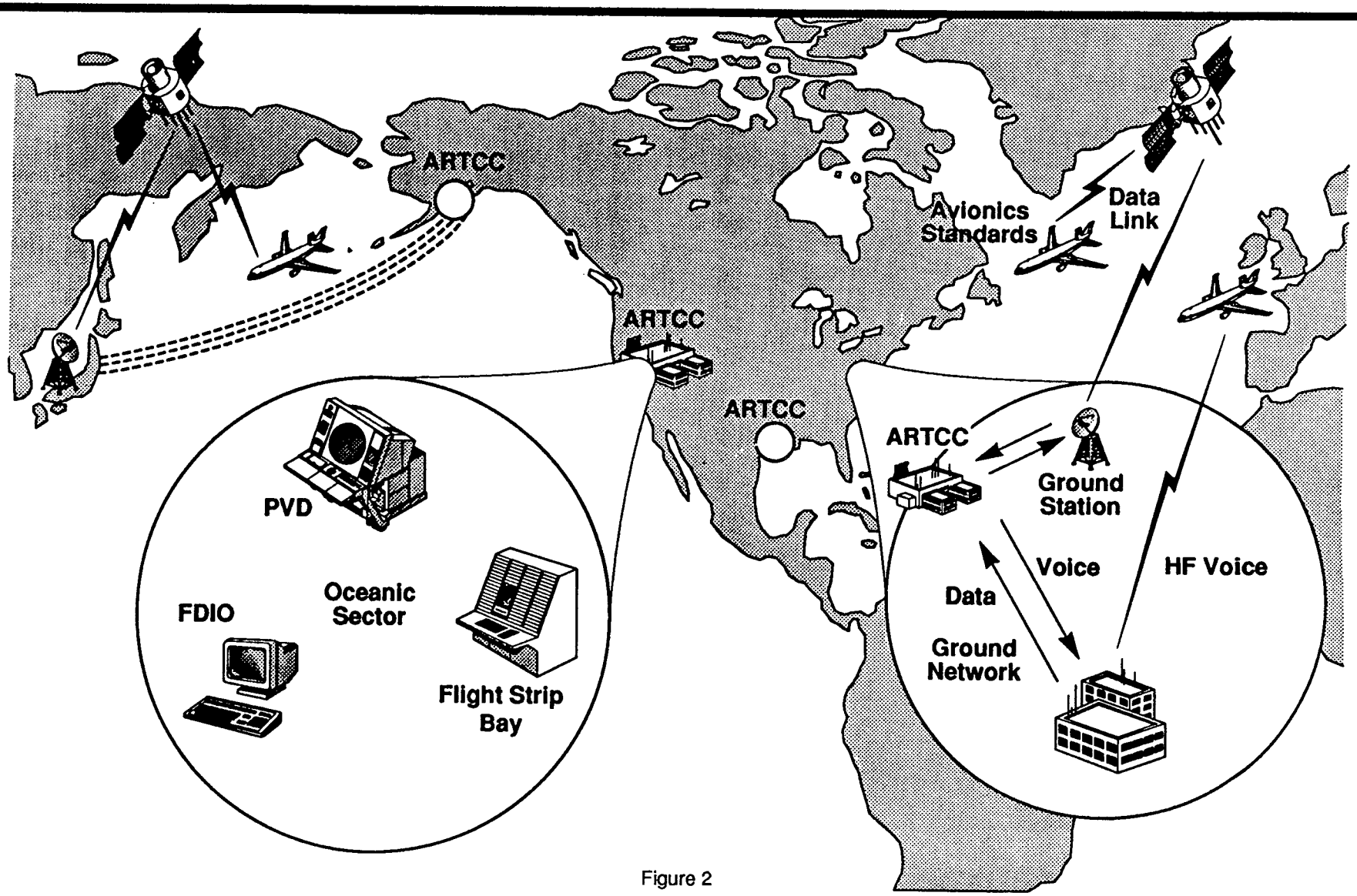


Figure 2

provided by ADS, only modest benefits can be provided without the automation aids of conflict probe and conflict resolution. In other words, controllers' ability to manually provide clearance amendments is not expected to improve dramatically because of satellite-based communications and automatic dependent surveillance. As another illustration of the improvements needed at the oceanic ATC centers, the sole "automation system"-to-"automation system" data link used for oceanic traffic is in place between Gander and Shanwick. The U.S. and all other countries use dial-up phone lines for voice relay of flight plan information.

WHERE WILL ALL THE AIRPLANES GO?

Recall that in Figure 1 the traffic growth projection for the Atlantic region was 40 percent, and almost 90 percent for the Pacific by the end of the decade. Even with improvements in ATC automation to handle the increased traffic, capability of the existing route structure to handle this increased load is not promising. In addition, airlines equipping with satellite communications and ADS reporting will expect a greater capability to optimize flight path by means of step climbs and fuel optimal routings. Without significant modification of the air route structure, this expectation is not likely to occur.

The answer to both concerns lies in the modification of airspace structure and the separation minima used in oceanic routes. First of all, some new routes, particularly in the Pacific, will be developed. The trial routes now being flown by Northwest Airlines over the USSR are an early example of the potential for more routes. However, it seems clear that the best way to increase capacity is by more efficient use of existing route structures. Specifically, we need to develop preferred routings within the existing airspace structure which will support reduced separations for appropriately equipped aircraft. By reducing the required separation between aircraft we effectively create more "slots" in which to put aircraft, thereby increasing capacity and the possibility of clearance amendments. The provision of preferred airspace for aircraft with advanced CNS capability is supported by the ICAO FANS committee and should be a major factor in improving capacity in oceanic airspace. However, since oceanic airspace is international airspace, the means by which this can be accomplished is not immediately evident. What is clear is that the entire aviation community needs to begin the process to modify airspace now if we expect to provide the capacity needed by the end of this decade.

In much of the oceanic airspace today, the separation standards are out-of-date for the navigation capabilities of conventional airline aircraft and with the advent of satellite navigation and communication, these standards are clearly in need of revision. As a first step, the level of safety must be reassessed as a function of aircraft equipage, route structure and proposed separation minima to determine the best way to increase capacity. Factors such as the effect of aircraft with satellite CNS capability in a separate route structure, the effect of TCAS carriage and the capability of ATC automation to manage the separation process must all be considered in the analyses and validated in measurable performance data. At the same time, we need to start planning, now, on the most expeditious way to initiate improved oceanic route separation procedures and standards.

ENTER THE SYSTEM MANAGER

In recognition of the need to coordinate and integrate separate efforts to modernize oceanic ATC underway in its engineering and operational services, the FAA created the position of Oceanic System Manager (OSM) in April 1991. The OSM is responsible for the entire oceanic ATC system, end-to-end, and coordinates all development efforts to assure that the entire system evolves expeditiously. The OSM serves as the key FAA spokesman for the oceanic area coordinating with both the national and international aviation community. Figure 3 depicts the various functions of the OSM as planner, integrator, reporter, and coordinator.

A major challenge to the OSM was to provide the requisite planning, direction, and coordination without introducing another layer of bureaucracy. The approach taken as shown in Figure 4 was to utilize teams which are chartered to manage the principal areas being developed in the advanced oceanic system. The System Requirement Team (SRT), which has already played a major role in the ADS application, is developing the operational concept and overall system requirements for the next evolutionary step in oceanic ATC. It will then translate and validate this concept into system requirements utilizing the Oceanic Development Facility at the FAA's Technical Center. The SRT has a strong ATC operational flavor with significant engineering and standards support. The Oceanic Engineering Team joins the R&D and F&E Services together with Systems Engineering to develop cooperative plans for the rapid prototype development and implementation of the system defined by the SRT. By coordinating across Service lines throughout the entire engineering cycle from prototype to fielded system, we expect to avoid many of the problems that occur during the transition from an R&D system to operational system.

The Oceanic Standards Team is concerned with the coordination of the standards required for satellite communications and navigation equipment as well as the separation standards developed for the advanced capability aircraft in oceanic airspace. This team is led by Flight Standards and Air Traffic Service representatives, supported by Operations Research and Systems Engineering resources.

The Oceanic System Manager, advised by a Steering Committee of recognized experts, coordinates the overall oceanic system development by providing direction and focus to the three teams, which in turn provide guidance for individual program efforts. Only time will tell how well this organization structure will work in practice. However, I believe we have already produced something useful by providing a mechanism in which all oceanic "stakeholders" in the FAA meet and coordinate with each other at regular intervals.

ORGANIZING THE PARADE

The modernization of oceanic ATC presents one of these rare cases where there is very little difference of opinion on the overall approach. The Government, airlines, avionics manufactures, and communications providers are all generally in agreement on the advantages and general direction of plans to utilize satellite communication, satellite navigation and advanced automation to achieve the desired improvement in efficiency, capacity, and safety. However, unless these goals are

Roles of the Oceanic System Manager

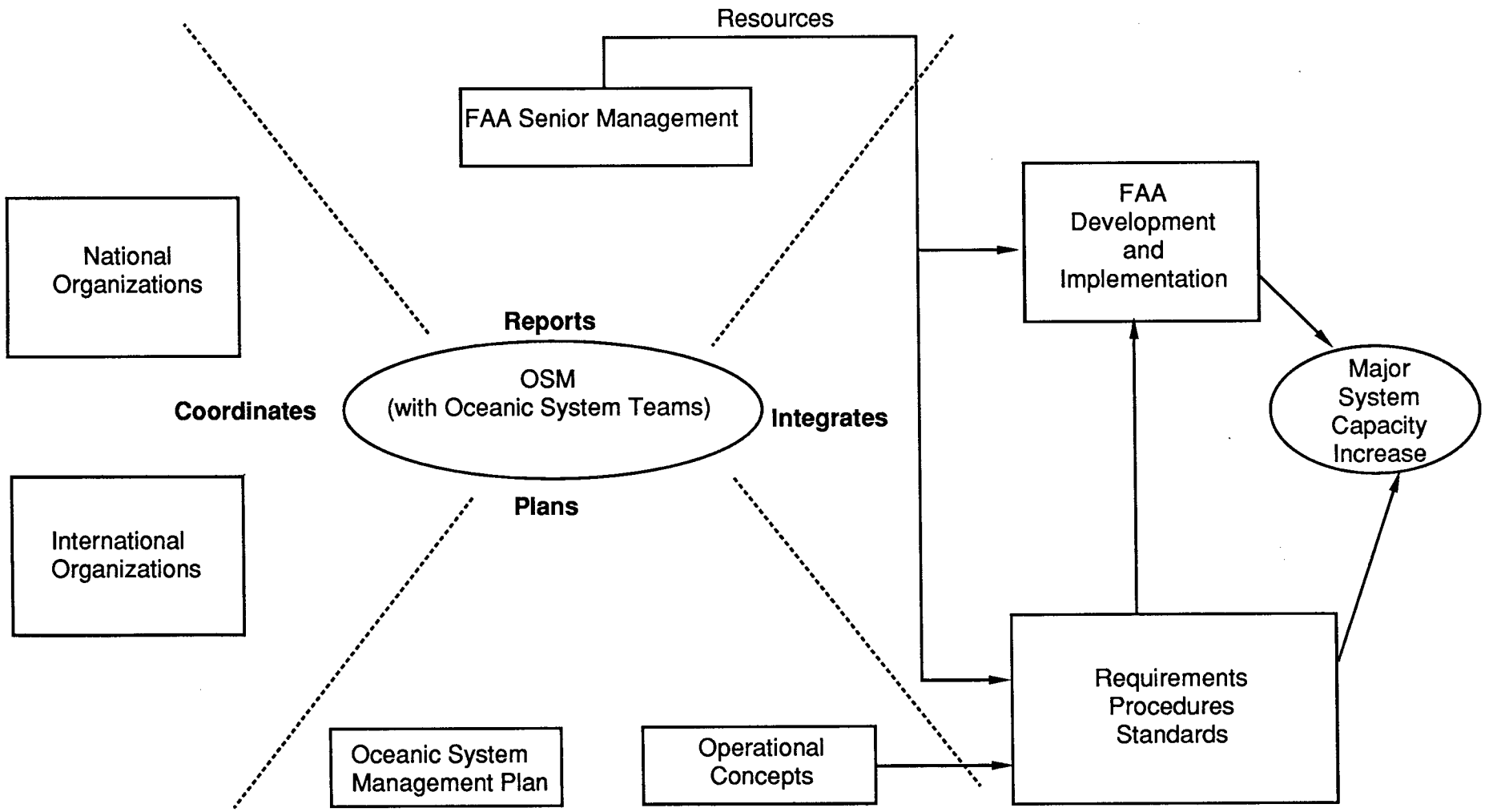


Figure 3

Oceanic System Management Organization and Teams

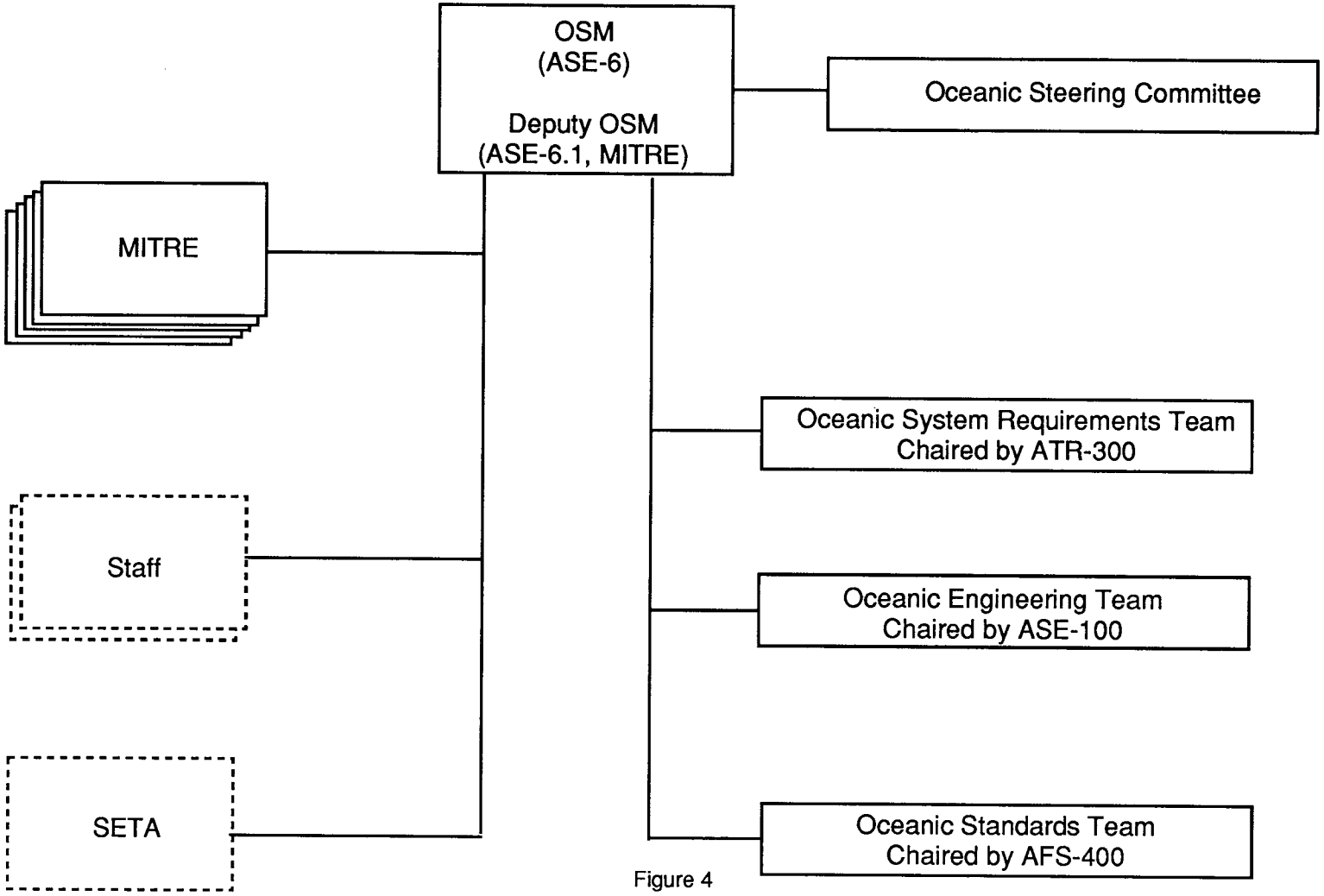


Figure 4

pursued in a coordinated fashion, the full benefit will not be achieved and our progress will be limited to marginal improvements.

The inherently international nature of oceanic ATC will require unusually close cooperation and coordination of the nations involved to make the advanced system operational. Because of the pace of satellite communications equipage we are faced by the need to endorse, in nearly simultaneous fashion, both national and international standards for avionics, satellite signalling and automatic dependent surveillance characteristics. I can personally attest to the fact that simply keeping these standards mutually consistent at the national level is no simple task. In addition, as stated earlier the international aviation community needs to begin the planning for the new procedures, the new air routes and related means by which the benefits of satellite-based ATC can be obtained.

The tasks confronting us as we move forward to the advanced oceanic ATC system are truly daunting. However, the fact that we have already made so much progress, that we are here to share our experiences, and to plan for the next steps make me optimistic for the future.

OPENING SESSION

David W. Ford
Research and Development
Oceanic Program Manager
Federal Aviation Administration

David W. Ford is currently the Research and Development Oceanic Program Manager. His responsibilities in this position are to coordinate all new oceanic development with the FAA Oceanic Systems Manager and with the implementation side of the FAA. Concurrently, he is the program manager for the Dynamic Ocean Track System (DOTS).

Mr. Ford's 15 years at the FAA have been in the offices of Environment and Energy, Operations Research, and Research and Development. He holds a BSME form the University of Portland, Oregon and an MS in Energy Technologies from the George Washington University.

FAA R & D Oceanic Program Office

David W. Ford, Program Manager
Federal Aviation Administration
Washington, D.C.

Presented at The
First Annual International Satellite Surveillance
and Communication Symposium

GOOD NEWS !

The FAA has begun a major push in providing the oceanic air traffic control and planning environment with the latest technology available. Upper management has committed to bring oceanic technology into the 1990s. Responsibilities have been given and teams are being formed to produce plans and programs for delivering this technology in the 2 to 5 year time period.

A newly designated oceanic systems manager (OSM) has been given the responsibility for orchestrating the rapid development and smooth implementation of new oceanic automation. The R&D Program Manager is responsible to the OSM for the research and development phase of this effort. The following is an overview of this task.

R & D ORGANIZATION

The Research and Development Service (ARD) of the FAA is currently restructuring many of its program areas into program offices that will report directly to the service director. Oceanic is included in this new structure. Current development programs within ARD such as Automatic Dependent Surveillance (ADS) and the Dynamic Ocean Track System (DOTS) now fall within this office. Staff and resources from these programs have been combined and will now focus on delivering automation ready for implementation.

GOAL

R&D's near term goal is simple: Get today's technology into the field. It's available now. The knowledge is there to build it. There just needs to be agreement on how to use it. This amounts to providing controllers with high resolution displays and processors, that are capable of communicating via two way data link with pilots and dispatchers, and with the ability to track aircraft electronically.

Longer term goals will concentrate on better ways of doing business. Together with industry R&D will develop plans to provide more flexibility in routes to achieve better fuel and time performance, direct research and development efforts to reduce separation requirements, examine better ways to control and handle the ever increasing traffic in the oceanic areas, and work closer with other provider states for the smooth planning and

transition of aircraft between air traffic control areas.

Ultimately, the FAA goal is to achieve in the ocean, the implementation of the FANS Air Traffic Management (ATM) concept. In this concept the automation capabilities of the cockpit, the air traffic service provider, and the user air carriers will be effectively linked by the Aeronautical Telecommunication Network (ATN).

OBJECTIVE/APPROACH

The objective of the Oceanic Program Office is to develop and test new automation for the control and planning of oceanic airspace. R&D will participate in engineering team meetings conducted by the OSM, to insure complete coordination with the implementation organizations and others, to develop and maintain plans to accomplish the FAA goals.

R&D will look at the ocean as a total system connected from cockpit to controller. Development will concentrate on maintaining and strengthening this thread in an effort to optimize the system as a whole.

R&D will contribute to the oceanic system team's effort to get automation into the field, now!

OCEANIC DEVELOPMENT FACILITY

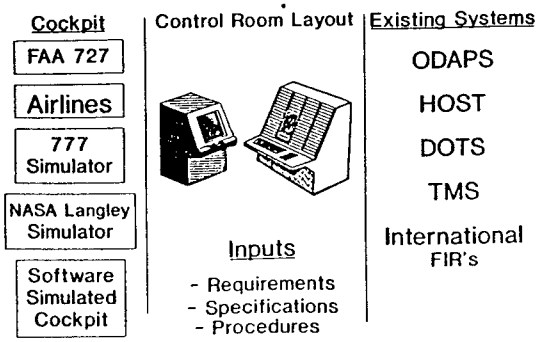
An oceanic development facility (ODF) at the FAA Technical Center in Atlantic City N.J. will be established. All new automation will be validated through here. Real world field conditions will be simulated. Sectors will be constructed identical to those in our oceanic facilities so that operational scenarios can be played out.

OCEANIC DEVELOPMENT FACILITY

- - Simulate Field Conditions.
- - Validate New Requirements.
- - Introduce Automation.
  Verify Benefits.
  Fine Tune CHI.
  Resolve Space Problems.
  Develop Procedures for use.
- - Perform Testing for Operational Use.
- - Located at FAATC.

Facility space problems will be resolved where new hardware is required and human factors associated with the placement will be accounted for. Interfaces will be established with other oceanic systems such the Oceanic Display and Planning System (ODAPS) and DOTS, and with actual and simulated cockpits in order to evaluate the impact and performance from a total system view point. Cockpit interfaces will allow developers to coordinate with airlines and other system users. Benefits will be verified. Air Traffic requirement teams will work with system developers to validate requirements. Controller teams will work with developers to fine tune the computer human interfaces, and develop procedures for using the new automation.

ODF



In addition, this facility will act as a final testing facility for integration and shakedown testing prior to field implementation.

INTERNATIONAL COORDINATION

Coordination with other countries on new automation is essential to the success of developing the 'total' picture. R&D will continue to participate in the work being done by panels and international groups in the areas of creating standards and procedures. R&D will support these activities by developing plans for demonstrating and testing these recommendations. Agreements will be expanded with other governments for joint testing.

NEAR TERM PROGRAM AREAS

The first objective of the FAA oceanic program is to ensure a stable functioning ODAPS. This is being accomplished through complete FAA coordination and support. High technology workstations, similar to those planned for the Advanced Automation System (AAS), will be introduced during this time along with the capability to process ADS position reports.

The R&D office will begin by designing automation that will use the ODAPS as its core. Initial work will concentrate on updating two functional areas of ODAPs; the flight data input and output (FDIO) and the aircraft situation display. These enhancements will serve to improve the working environment and efficiency for the oceanic controller. Simultaneously, development will begin on two way data link between controllers and pilots.

NEAR TERM PROGRAM AREAS

- - Controller FDIO Replacement.
- - Situation Display Replacement.
- - ADS
  SAT Position Report Processing.
  Two Way Message Data Link.
- -Traffic Management
  DOTS
  ETMS

DOTS will continue to be the main thrust for oceanic traffic management. Prototype work will begin on the traffic advisory function so that traffic management and industry can agree on designs and procedures for its use. Work will begin on interfacing DOTS with the domestic traffic management system (TMS) in order to provide continuity between domestic and oceanic operations.

We are confident that our new effort will succeed. Strong teams have been assembled that are ready and dedicated to getting the job done.

OPENING SESSION

Peter L. Massoglia
ADS Program Manager
Federal Aviation Administration

Peter L. Massoglia is the Program Manager of the Automatic Dependent Surveillance (ADS) Program with the Federal Aviation Administration in Washington, D.C. Mr. Massoglia holds a Baccalaureate degree (BSAE) in aeronautical engineering from Saint Louis University and has done graduate work at George Washington University.

In addition to a broad background in flight test engineering of U.S. Army and Navy aircraft he has extensive experience in reliability, maintainability and system standards. He has been with the Federal Aviation Administration (FAA) since 1976 and is presently assigned to the Research and Development Service. This organization has principal responsibility within the FAA for the development and acquisition of new technology systems. In his present assignment Mr. Massoglia is responsible for: the research, development, and implementation of the ADS program within the FAA; The development of Memorandum of Cooperation (MOC) with various states; and the coordination of international standards.

Automatic Dependent Surveillance (ADS) Program Summary

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and

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INTRODUCTION

Non-radar Air Traffic Control (ATC), and in particular oceanic ATC, is on the verge of a revolution in capabilities brought about by the utilization of data link communications services [1]. The International Civil Aviation Organization (ICAO) Committee on Future Air Navigation Systems (FANS) has identified satellite data link as the primary means of providing Air/Ground (A/G) communications and surveillance services in its concept of a future ATC system [2]. Currently, both communications and surveillance in oceanic regions depend on High Frequency (HF) radio links, which are subject to fading. Controllers interact with flight crews via a radio operator in this type of environment. A/G communications can require up to several minutes to initiate and complete, thereby limiting the timeliness of the message. This delay can have a serious safety impact. In addition, the difficulty in establishing a contact and the flight crew workload associated with filing a position report limits surveillance reporting to approximately once per hour.

In contrast, A/G satellite data links can be established within a matter of seconds. These links provide reliable, timely, and direct pilot/controller communications. The links can also be used to transfer Automatic Dependent Surveillance (ADS) data, which is position information generated by the aircraft's navigation system, to ground ATC systems. This data can be used to track aircraft in a manner similar in some ways to radar tracking. Airline operational and passenger communications can also be supported using satellite links. In the future, digital voice capabilities for ATC purposes will also be possible.

The FANS committee completed its work in 1988. However, it was realized that additional work was necessary to implement the concepts defined by the committee. ICAO then established several panels and study groups to continue the work, including the Aeronautical Mobile Communications (AMC) Panel, which examines many of the communications-related issues, and the ADS Panel, which developed further the concept of a data link-based ATC system.

The ADS Panel's charter is to develop the necessary guidance material and Standards and Recommended Practices (SARPs) for operational implementation of the FANS ATC system concept. This material must be consistent with the overall goals of maintaining or improving current safety levels, increasing airspace capacity, and improving user services while reducing operator cost. In doing this, the Panel chose to take a broad view of what constitutes such a system, since it was realized that an improved surveillance capability without a corresponding intervention capability would be of limited use. Therefore, issues related to direct pilot/controller data link communications are also being examined.

This paper discusses the system architecture and components of a satellite data link- based oceanic ATC system. Topics such as the role of the Aeronautical Telecommunications Network, the status of avionics development, and the ICAO's ADS Panel efforts will be addressed from an ATC

perspective as part of the paper. Material developed by the ICAO ADS Panel [3] is used in the following.

SYSTEM ARCHITECTURE OVERVIEW

An end-to-end system perspective is needed to take full advantage of all the capabilities inherent in the A/G data link. As defined in the ICAO ADS Circular [3], there are six major components forming an integrated data link-based ATC system as depicted in Figure 1:

1. ATC controller and system interface, including data link communications;

2. ATC automation, including new functions which utilize the information contained in ADS reports;

3. terrestrial communications network, which connects the ATC system with the satellite service provider;

4. satellite service provider, which supplies the space segment;

5. aircraft avionics, which collects, formats, and transmits and receives messages over the communications channel; and

6. pilot and system interface, including data link communications.

Each component resides within the same ATC procedures environment. The integration of all the components into one overall system will result in a synergistic effect. For example, the capabilities of the avionics would be of no use without a means of receiving the generated ADS data and applying it to ATC. The remainder of this section discusses issues related to each system component defined above. A summary of some of the major issues is contained in Table 1.

Controller Interface

Air Traffic Service (ATS) providers will define and develop specific controller interfaces tailored to their particular needs. However the ADS Panel has developed several guidelines, which are taken from [3]:

1. Display traffic situation information in a relevant manner;

2. Alert the controller to potential and actual violations of separation standards;

3. Provide tools for the composition of A/G data link messages;

4. Display received A/G messages;

5. Provide a voice channel for emergency and non-routine communications; and

6. Provide a rapid response method to the pilot via voice communications.

The FAA is currently investigating how the oceanic controller interface contained within the Oceanic Display and Planning System (ODAPS) can be improved and modified to support ADS and data link messaging. It has been determined that initially the Flight Data Input/Output (FDIO) equipment must be replaced with a graphics-based interface commonly found on workstations. This new interface would support an enhanced FDIO function, and later support data link communications. Two modes of data link support will be provided: a free text mode and a message template mode. The first mode will allow the controller to enter any desired text and send it to the selected aircraft. The second mode provides templates for commonly used messages, such as clearances, thereby allowing quick message entry. The Plan View Displays (PVDs) will also be replaced with higher resolution displays - the same displays being used in Advanced Automation System (AAS). Oceanic sectors tend to be several times larger in area than typical domestic sectors,

Table 1. Summary of Major Issues

System Component	Comment
Controller Interface	(1) Definition of the Data Link messages. (2) Human factors aspects of data presentation (situation display, data link CHI, electronic strips, etc.). (3) Aids for monitoring separation.
ATC Automation	(1) Need to develop other ATC applications in addition to Conformance Monitoring, e.g., Clearance Validation, Tracking, Wind Grid Updating. (2) What other useful ATC information is generated by the avionics but not currently downlinked? For example, full route readout and turn rates may be of use in an operational environment. (3) New automation functions for ADS: Conflict Alert, Conflict Resolution.
Terrestrial Communications Network	(1) Multiple dissemination of ADS reports. (2) Will the service provider networks (e.g., ARINC and SITA) be ATN compatible? (3) Integration of Satcom, Mode S, VHF, and HF data link into one user transparent service.
Satellite Communications System	(1) Coverage in the high polar regions. (2) Spectrum allocation.
Avionics	(1) AEEC/ADS Panel Coordination. (2) Capability to define new data groups for ADS messages. (3) Time delays, particularly differences between when the position data is generated and when it is time stamped. (4) Support for non oceanic environments, like terminal areas, where a 5 second update rate may be required. (5) Coupling the FMS avionics with the ATC system to account for aircraft performance characteristics.
Pilot Interface	(1) Cockpit interface to the ATC system. (2) Pilot's role in initiating and terminating ADS contracts. (3) Generic pilot operational procedures.
ATC Procedures	(1) What immediate benefits can be provided to early users? (2) Transition from a strategic to a tactical control environment. (3) How can ADS be employed in the continental en-route and terminal airspace? (4) Transfer of control between centers. (5) Joint ADS and radar surveillance. (6) What role/effect will GPS have on the future oceanic ATC system.

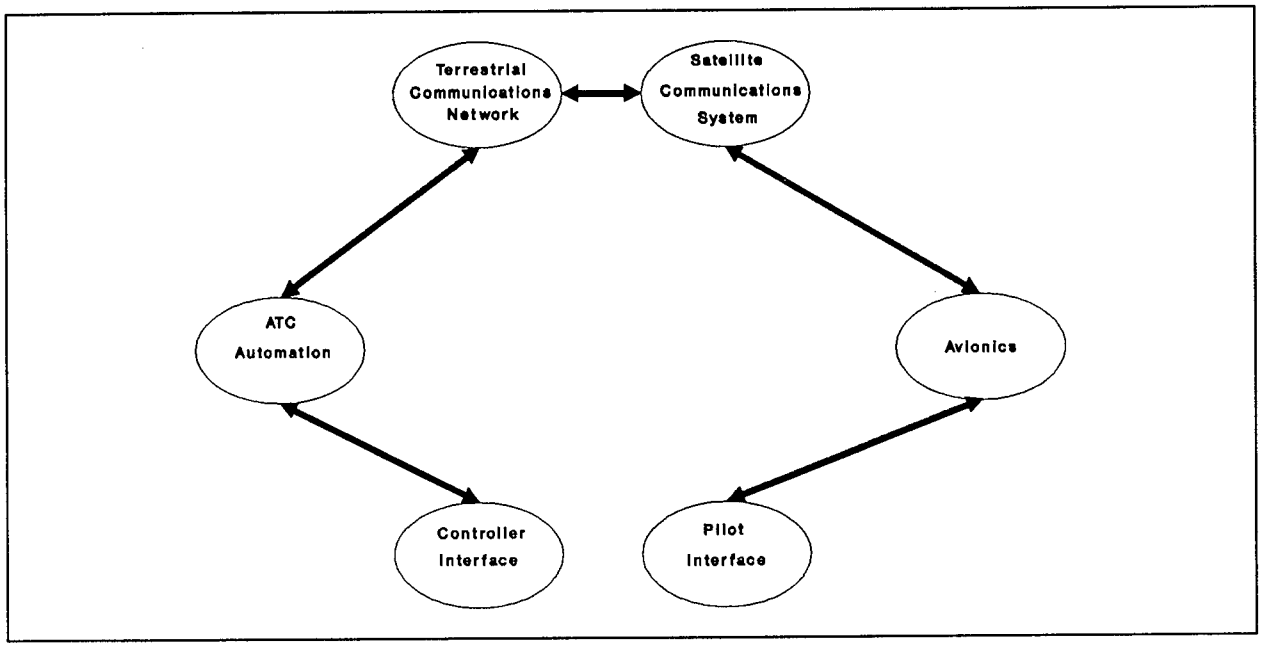

Figure 1 System Components

and a larger display area is needed. This will be critical in the future when oceanic ATC transitions from a procedures-based, strategic approach to an ADS-based, tactical approach. In a tactical oceanic environment, the display will be used by the controller to assist in separating aircraft, similar to what is done today in the domestic radar environment.

ATC Automation

Satellite data link communications will support the transfer of information derived from the aircraft's onboard navigation system to an ATC Center. This data can then be used for ATC purposes. Four principal applications have been defined so far:

Clearance Validation. Waypoint data read out from the navigation system is compared with the ATC-issued clearance, and any discrepancies reported immediately to the controller. Currently, the waypoint the aircraft is proceeding towards and the subsequent waypoint can be downlinked.

Conformance Monitoring. The ADS reported position is compared to the flight plan predicted position. Longitudinal deviations are used to adjust arrival times at downstream fixes. This process provides feedback which is used to automatically update the flight plan. Lateral deviations are ignored if within defined tolerance limits. Otherwise, an out-of-conformance alert is issued to the controller.

Tracking. Current tracking interpolates between endpoints of a route segment. With ADS, track angle and groundspeed are available. This information can be used to develop a more accurate tracker.

Wind Grid Estimation. Winds play a pivotal role in any Flight

Data Processing System. Winds are used to convert airspeed into groundspeed, which in turn is used to calculate arrival times at the fix points composing a flight plan. The limiting factor in this process today is the accuracy of the forecast wind grids, which are received every twelve hours. Real-time in situ measurements of upper winds are possible with ADS. This new data source can be used to update the forecast, thereby greatly improving accuracy.

The ICAO ADS Panel has defined several other required functions in addition to the above ADS-supported functions.

Conflict Prediction, in which potential violations of separation standards are detected;

Conflict Resolution, in which the automation generates possible solutions to potential conflicts; and

Data Presentation to the controller, which consists of Computer-Human Interface (CHI)-related items such as Situation Display and Conflict and Out-of-Conformance Lists.

Conflict resolution will initially be tailored to track systems, where the Mach or altitude of conflicting aircraft will be changed. Later, in a more tactical environment, vectoring (changes to the track angle or equivalently, heading) may be employed.

One important area that promises major service improvements and reduced operations cost is the integration of ATC automation with aircraft Four-Dimensional (4D) navigation capabilities. New aircraft are capable of flying an optimum profile to a specified point in space, and arriving at that point at a specified time (within constraints, of course). Having the ATC automation generate optimum conflict free clearances, including time restrictions, acquiring controller approval, and then uplinking the clearance to the aircraft's navigation system, with pilot approval, will support fuel saving techniques such as cruise and step climbs. With this approach, aircraft performance characteristics must be considered when generating the clearances.

Terrestrial Communications Network

The ATC Center will be connected to the Ground Earth Station (GES) via a terrestrial communications network. This network could be either government owned, or supplied by a communications service provider such as ARINC or SITA. It could even be supplied by the satellite or GES provider. Regardless of the network source, however, it must conform to the protocol suite defined as part of the Aeronautical Telecommunications Network (ATN) concept.

The ATN is based on a combination of international and aeronautical industry standards. This architecture provides transparent data transfer, allowing applications to be designed independently of the communications subnetworks. It also eliminates the need for dedicated data link I/O devices and application processes by supporting shared avionics. The key ATN elements are the use of a standard internetwork protocol, a standard addressing scheme, and a standard routing protocol.

Peer-to-peer protocols are employed within this concept. For example, a connection would be set up between an ATC application on the ground and the aircraft's ADS Unit (ADSU) to transmit ADS reports. Once the connection is established, the data would flow through this "pipe".

ATS Providers have an operational requirement for multiple dissemination of ADS reports. For example, when an aircraft is in the vicinity of an FIR boundary, both ATS Providers must receive the surveillance data [4]. However, the protocols employed do not directly satisfy this requirement. One end of the pipe is connected to the aircraft, while the other end is connected to a unique ATC Center.

There are several different approaches that can be

taken to provide this service. Both ATS Providers can establish a separate surveillance contract with the aircraft. This means that essentially the same data will be down-linked from the aircraft, thereby wasting channel capacity and increasing communications cost. A second approach requires a router, which is an intelligent device that would somehow know when a surveillance report should be multiply disseminated. ATN Router development is currently underway. A third approach, making the ATS Providers themselves responsible for multiple dissemination, would work. However, the North Atlantic (NAT) region Provider States have clearly stated that this is an unacceptable solution, and that the communications service providers must supply this capability.

The ATN concept is not limited to just satellite data links. Other data links, such HF, VHF, and Mode S can all be accommodated. A standard application interface will be provided independent of the link employed. The network and onboard avionics then selects the optimum path based on time-varying considerations such as geographic location, cost, delay, throughput, and link availability. For example, in the ocean satellite links will most likely be employed, while in domestic airspace VHF or Mode S may be used. The resulting system will appear seamless from a human user's perspective.

Satellite Communications System

Satellite communications is the key to providing improved services in oceanic airspace. The near-term space segment will be provided by INMARSAT, which has geosynchronous satellites providing coverage up to ±81° in place. These satellites provide a core service to aircraft consisting of 600 bps data transmission, as well as 9600 bps data and toll quality voice communications for appropriately equipped aircraft (i.e., a high gain antenna is needed for this service). INMARSAT Block 2 satellites are now being deployed, and INMARSAT Block 3 satellites, currently being designed, are scheduled to begin service in 1994. These satellites will utilize spot beams and have increased channel capacity.

The Block 1 satellite constellation will support a basic ATC service consisting of ADS data downlinking. Data link communications can also be provided; however, this function will be better supported when the Block 2 satellites are commissioned. Digital voice for ATC purposes will only be required for emergency and non-routine situations once data link becomes the common means of A/G messaging. Both Block 2 and 3 satellites will support this capability.

Avionics

Three principle components comprise the avionics: (1) the ADSU, defined in ARINC Characteristic 745 [5]; (2) the Satellite Data Unit (SDU), defined in ARINC Characteristic 741; and the antenna subsystem (AS), available from a variety of manufacturers. The ADSU collects ADS-related information from the aircraft, reformats the data into the required form, and transfers it to the SDU. The SDU then transmits the data to the satellite via the AS. The ADSU will also accept up-linked messages that set the reporting rate, select the fields to be transmitted, and other similar functions related to establishing, maintaining, updating, and terminating a connection.

The avionics will also support direct two-way pilot/controller communications. Messages entered at the pilot interface are encoded and transferred to the SDU, then transmitted to the controller. Controller-initiated messages are displayed to the pilot using a similar process.

Two organizations are driving the design of ADS message formats: the ICAO ADS Panel and the Airlines Electronic Engineering Committee (AEEC) 745 Subcommittee. Table 2 lists the data groups defined by in ARINC Characteristic 745. The ADS Panel data group definitions are included within the corresponding ARINC Characteristic 745 definitions, which also contain a group tag. The AEEC has also defined flight ID and airframe ID groups, which will be of use in initially correlating position reports with a particular flight. In addition, the AEEC has defined contract initiation, update, and cancellation groups. Avionics manufacturers are currently using ARINC Characteristic 745 to build equipment that will be installed in aircraft.

Table 2. AEEC Data Groups	
Data Group	Data Element
Basic ADS	Basic ADS Group Tag
	Latitude
	Longitude
	Altitude
	Time
	Figure of Merit
Ground Speed Vector Information	Ground Speed Vector Information Tag
	Track Angle
	Ground Speed
	Vertical Rate
Mach Vector Information	Mach Vector Information Tag
	Track Angle
	Mach Speed
	Vertical Rate
Predicted Route	Predicted Route Tag
	Latitude at Next Waypoint
	Longitude at Next Waypoint
	Altitude at Next Waypoint
	Latitude at Next+1 Waypoint
	Longitude at Next+1 Waypoint
	Altitude at Next+1 Waypoint
Meteorological	Meteorological Tag
	Wind Speed
	Wind Direction
	Temperature

Pilot Interface

One of the principle objectives in employing satellite communications within oceanic regions is to improve pilot/controller communications. Current communications utilizes HF radio and an intermediary radio operator. The pilot's interface with the future system will be primarily data link. Routine messages, which form the vast majority of communications, will employ this mode. The most prevalent messages in this category are ATC Clearances, a pilot request for a change to a flight's existing ATC Clearance and a Clearance Read-back. In today's environment, these messages are transmitted using HF radio. Standard formats can, however, be devised that will make these messages amenable to routine data link communications.

Digital voice will gradually replace HF communications for emergency and non-routine situations. The amount of voice communications will be drastically reduced, however, by the increased use of data link. It will also be some time before the entire oceanic aircraft fleet is switched to digital voice, as the existing HF equipment will be used until replaced.

For the most part, the pilot plays a minimal role in the transmission of ADS data. All operations involved in establishing and maintaining a surveillance link will be performed automatically. However, the pilot must be able to monitor system operations. He must also must have the capability of forcing an ADS report during emergency and non-routine situations.

PROCEDURAL ISSUES

The most important procedural issue concerns separation standards. The current track systems, which are typically employed in high density corridors such as the NAT, are operating very near maximum capacity. Many flights operating within these systems can not obtain the optimum track or altitude, resulting in increased fuel cost.

Capacity can be increased by decreasing separation standards. For example, it appears that 1000 ft vertical separation will be feasible in the NAT, thereby approximately doubling the airspace capacity at turbojet altitudes in the NAT track system. Further capacity increases, however, will only be possible when there are improvements in surveillance and intervention (communications) capabilities. Data link communications and ADS together will support a reduction in separation standards, though the precise extent is currently being analyzed by the FAA using a collision risk model. Reductions on the order of 50-75% laterally seem to be possible, though [6]. Longitudinal standards may migrate from 10 minutes in trail (a typical value) down to 5 minute separation.

It is essential that ADS and data link communications aircraft equipage be followed as soon as possible by tangible user benefits. Reducing separation standards so that more aircraft can fly better profiles is one way. Another way is to develop preferential route systems, altitudes, or airspaces for equipped aircraft. As a possible example, the optimum track within the North Atlantic Track System could be reserved for equipped aircraft. These aircraft could then be packed closer, assuming the required safety margins are maintained, thereby increasing system capacity.

Increased support for random routings must also be developed. Random routings are generated by the carriers using departure/destination pairs and upper winds forecast, and represent user preferred trajectories, typically fuel-optimal profiles. Route structures were introduced to help the controller efficiently manage complex or dense traffic patterns, and do not usually correspond to optimum profiles. The increased use of automation is the only way to provide increased support for random routings. The automation will be employed to perform complex but mundane mathematical calculations, such as separation monitoring and conflict prediction, while the controller will continue to be responsible for separation assurance, conflict resolution, and overall strategic airspace management.

Another important procedural area concerns the exchange of data between ATC Centers, particularly international ATC Centers. Coordination data must be exchanged between

adjacent centers prior to penetrating a new FIR. How this data will be exchanged is currently being discussed in several international forums. The North Atlantic System Planning Group's (NATSPG) On-Line Data Interchange (OLDI) subgroup is perhaps furthest along in this effort, with a draft version of an interface control document describing the messages to be used for OLDI within the NAT region completed.

The FAA is establishing an advanced Oceanic Development Facility at the FAA Technical Center to investigate these and other issues. Controllers from the US and other countries will be able to determine the effects of procedural changes, ADS, and data link communications in a simulation environment prior to operational implemented. New ideas and techniques will be developed and refined with the goal of providing better services to airspace users.

CONCLUDING REMARKS

This paper has described the A/G system that will be used for ATC purposes within US oceanic FIRs. However, ADS and satellite data link communications are not being developed by the US alone, but by the international aviation community through organizations such as ICAO (ADS Panel, AMC Panel, NATSPG, etc.) RTCA, and AEEC. Most of the remarks contained in this paper are generic, and apply to other oceanic ATS Provider States also. In fact, the communications and surveillance functions described herein are being extended to environments other than oceanic. The system concept is equally applicable today in areas such as the Australian Outback, the Chinese, African or South American interior, Northern Canada, and the Soviet Siberian airspace. Ongoing work by the ADS Panel in terminal area applications is of interest to many Provider States. Though the US does not currently plan to use ADS and satellite communications in the terminal or domestic en-route environment, many countries see this approach as a cost effective means of modernizing their ATC system and providing increased user services, without having to invest in an expensive radar and VHF radio network.

Preliminary testing of some of the components described in this paper has been performed as part of the Pacific Engineering Trials. These trials have employed prototype systems to send and receive data from aircraft, including position reports and free text data link messages. They have been conducted in conjunction with United Air Lines. Results to date have been encouraging from both an airspace user and ATS Provider perspective.

Implementation of the FANS ATC system concept is dependent on acceptance by both the ATS providers and airspace users. Both must accrue tangible benefits if the concept is to replace existing systems and procedures. For users, the equipage costs must be offset by reduced operating costs. For ATS providers, both the risk of collision and controller workload must not increase, and preferably, be lowered.

Lastly, the capabilities of current and next generation avionics and aircraft must be coupled with increased ATC automation support to provide more efficient airspace management and increased user services. Modern Flight Management Systems (FMSs) are capable of flying 4D trajectories; however, ATS providers can not currently support this function efficiently. For example, most ATC systems today will not issue cruise climb clearances, even though users desire cruise climbs and aircraft are capable of flying a cruise climb trajectory. Better conflict prediction and resolution, Global Positioning System-based aircraft navigation systems, ADS, and clearance delivery via data link directly from the ATC automation to the FMS (with human acknowledgement and override) will form the basis for this future service.

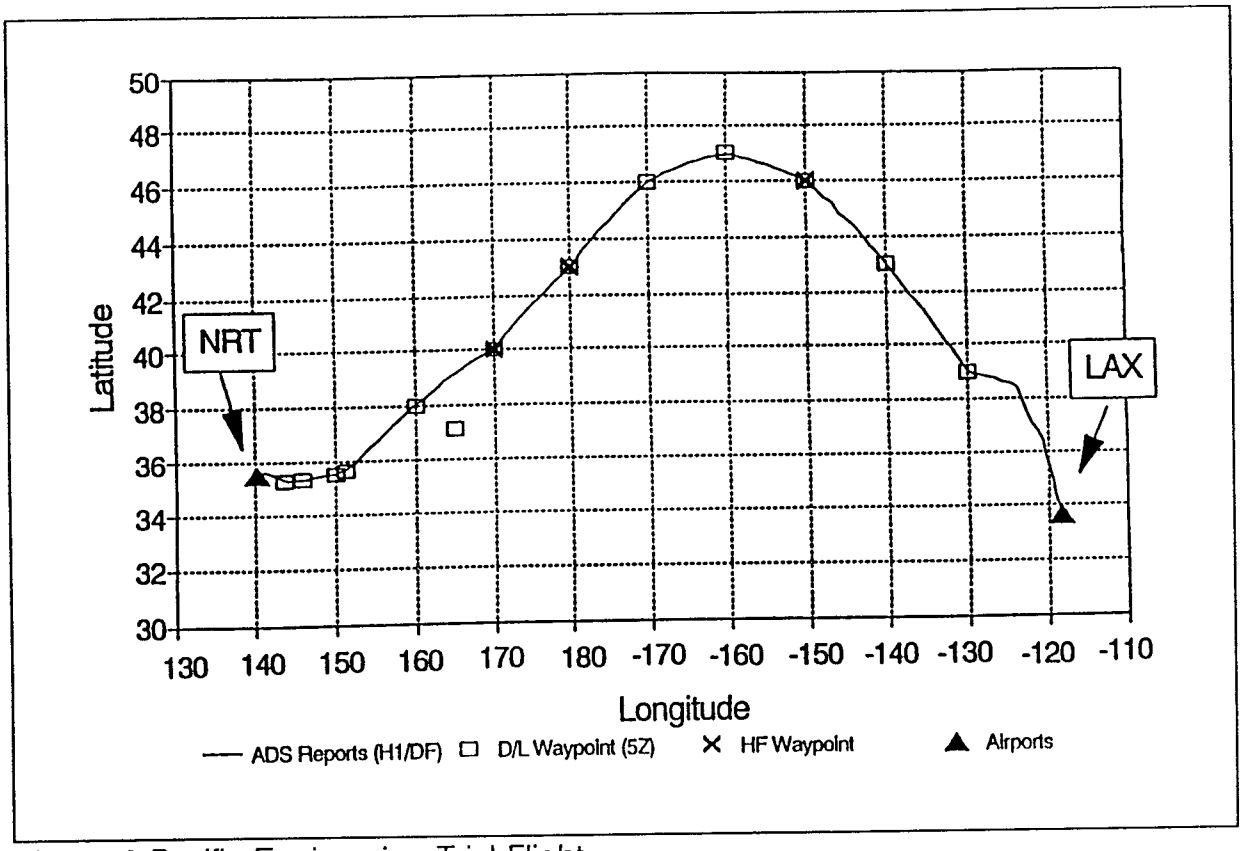

Figure 2 Pacific Engineering Trial Flight

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CO-AUTHORS

Lonnie H. Bowlin
President & Chief Engineer
Aerospace Engineering and Research Associates, Inc.

Lonnie H. Bowlin is President and Chief System Engineer of Aerospace Engineering and Research Associates, Inc. In this position Mr. Bowlin provides systems engineering and integration support to the FAA ADS program. He is currently serving as a technical advisor to the ICAO ADS Panel and the North Atlantic Special Planning Group. Mr. Bowlin also led the development of AERALIB software libraries for ATC automation development. Previously, he led the conceptual design of the ADS step 1 system and Oceanic Display and Planning System. He has more than 17 years experience in the development and integration of computer systems.

Guy T. Germana
Chief Systems Engineer
Aerospace Engineering and Research Associates, Inc.

Guy T. Germana is the Chief Systems Engineer for Aerospace Engineering and Research Associates, Inc. Previously, Mr. Germana led the design and implementation of the ODAPS Communications processor. He was also involved in the design and implementation of the ADS functional enhancement to the ODAPS, and the development of oceanic air traffic control systems for international applications. He was also involved in the development of data processing systems for NASA. He has over 14 years experience in computer systems development. Mr. Germana earned a B.S. and M.S. in Electrical Engineering from the University of Maryland.

OPENING SESSION

Joseph F. Dorfler
Satellite Program Manager
Federal Aviation Administration

Joseph F. Dorfler is a retired Air Force pilot possessing operational, technical, and research experience in the field of aviation and space technology. Prior to joining the FAA, Mr. Dorfler led the operational phase-in of the Global Positioning System (GPS) for the Department of Defense (DoD). As the FAA Satellite Program Manager, Mr. Dorfler is responsible for research and development activities in both the satellite communications and navigation areas.

SATELLITE COMMUNICATIONS (SATCOM)

PROJECT SUMMARY

Joseph F. Dorfler, Satellite Program Manager (FAAHQ/ARD-330)

Washington, D.C.

INTRODUCTION

The Federal Aviation Administration (FAA) Satellite Program consists of two complimentary activities: the Satellite Communications (SATCOM) Project and the Satellite Navigation (SATNAV) Project. The objectives of this program are twofold: to determine the capabilities of satellites for civil aviation, and to verify, test, and demonstrate applications of satellites, including Automatic Dependent Surveillance (ADS), within the National Airspace System (NAS). The elements of the Satellite Program are depicted in Figure 1. This paper introduces and overviews the SATCOM Project, which will be described in greater detail in a companion paper entitled "FAA Aeronautical Satellite Communications Project Plan" to be presented during Session Two on Wednesday.

At present, satellite communications are planned to replace High Frequency (HF) communications in oceanic airspace and Very High Frequency (VHF) communications in the majority of coastal and some domestic en route airspace. Since satellite communications, both data and voice, will be provided at a cost to the user and since data communications are more efficient and less prone to error than voice communications, it is expected that satellite communications will encourage and promote the expansion of the data link capability for air-ground and ground-air communications. The use of data link will support the establishment of ADS, which may make possible the reduction of separation standards and increased capacity in oceanic airspace. It is anticipated that, at least in oceanic airspace, routine voice communications for the majority of Air Traffic Service (ATS) applications (about 95%) will be replaced by data communications. As such, voice communications will be used only for emergency and non-routine situations, and as a back-up to data communications. In oceanic airspace, the use of satellites will reduce the delays associated with voice communications and will improve the quality of voice communications.

The research and development of satellite communications within the FAA is being performed by the Research and Development Service (ARD) and is sponsored by the Flight Standards Service (AFS). AFS interfaces with the users, the airlines, and the aviation public. In fulfilling their safety responsibility, AFS determines operational capability, training requirements, equipment suitability, and operational concepts to safely and efficiently introduce SATCOM worldwide.

SATCOM PROJECT SUMMARY

The specific objectives of the SATCOM Project are to enhance the efficiency of Air Traffic Management (ATM) in oceanic airspace first and in the NAS later, and to enhance the efficiency of

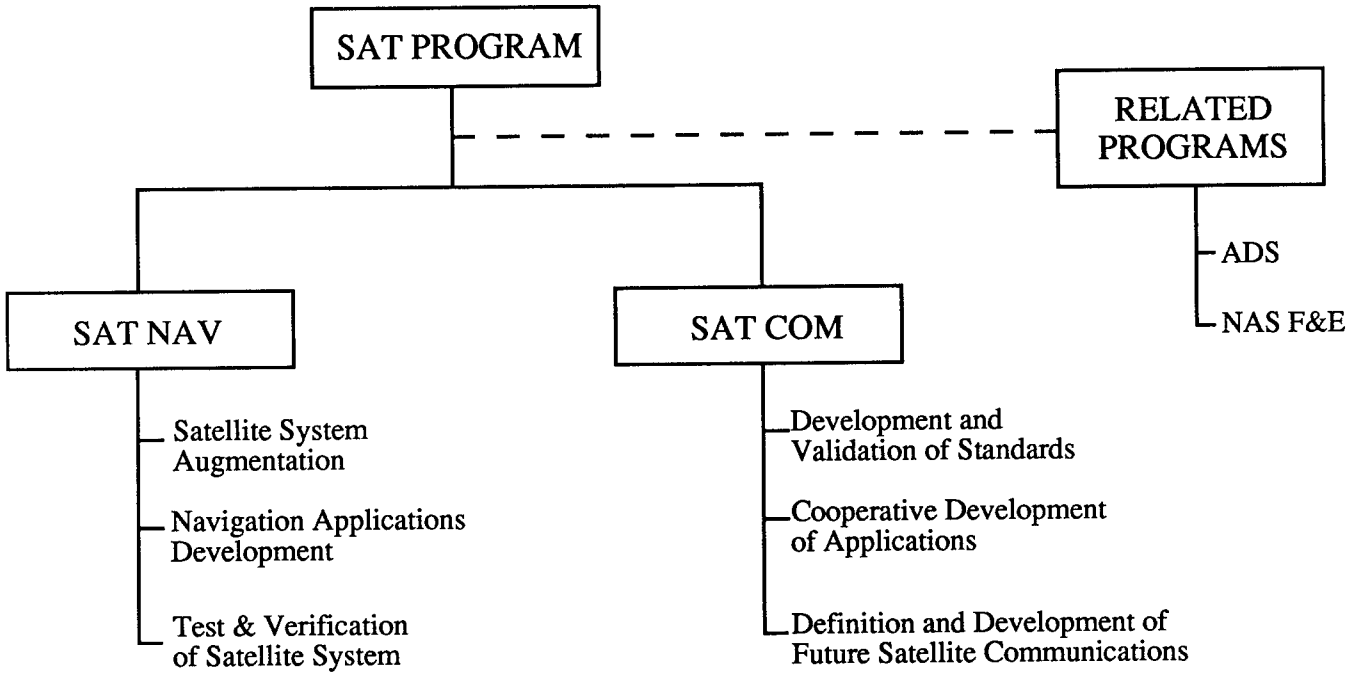


FIGURE 1. FAA SATELLITE PROGRAM

air carrier operations. To exploit satellite communications for maximum benefit of both the FAA and the aviation community, the SATCOM Project is divided into three complimentary activities, shown in Figure 2, whose objectives are as follows:

- To guide the development, test, and validation of national and international standards for the establishment and certification of the Aeronautical Mobile Satellite Safety (Route) Service (AMS(R)S).

- To select and test, in cooperation with the aviation community, several satellite communications applications in key areas (e.g., oceanic, offshore, polar, and low altitude communications) in order to demonstrate the substantial benefits gained by their implementation.

- To extend the benefits of satellite communications to general aviation through a study of the potential for future widespread use of satellite communications in the NAS considering the prospects of availability of new and innovative technologies and approaches to affect the desired benefits.

The first of these activities involves the development and validation of standards for the Aeronautical Mobile Satellite Service (AMSS). This includes the development of Standards and Recommended Practices (SARPs), the development of Minimum Operational Performance Standards (MOPS), the correlation of the SARPs and the MOPS with other evolving standards, and the validation and evaluation of the SARPs and the MOPS. The FAA will also collect data for avionics certification and validation of oceanic ATS. The goals of this activity are to ensure that standards are practical, that they satisfy user requirements, and that they are consistent with the goals of the FAA. The current plans call for the submission of the AMSS MOPS to the Radio Technical Commission for Aeronautics (RTCA) Executive Committee early in 1992 and for the support of the development of the associated Technical Standards Order (TSO). The draft International Civil Aviation Organization (ICAO) AMSS SARPs are expected to be submitted to the Air Navigation Commission (ANC) in the second quarter of 1993. Validation and evaluation of the AMSS MOPS and SARPs will be initiated in 1992 and will be completed in 1995. Collection of data for avionics certification and validation of oceanic ATS will be initiated at the end of 1993 and will be completed in 1998, by which time full scale world-wide implementation of satellite data and voice communications for oceanic ATS is anticipated.

The second of these activities involves the cooperative development of domestic applications. This includes the joint evaluation (FAA and airlines) of the effectiveness of high data rate digitized voice communications for oceanic ATS, the joint evaluation (FAA and satellite communications service providers) of the effectiveness of low data rate digitized voice and data communications for offshore (rotorcraft) applications, and the implementation of an Aeronautical Telecommunications Network (ATN) for satellite communications. The goals of this activity are to demonstrate to the user community the substantial benefits gained through the implementation of these techniques. A cooperative agreement with a major airline is being planned for late 1991 to conduct oceanic operational tests of the AMSS voice capability. A similar agreement with a satellite communications service provider is also being planned for 1991 to conduct low data rate satellite communications tests that will lead to recommendations for rotorcraft air traffic voice services in 1996. The FAA will provide test aircraft and test support for flight evaluations of avionics leading to an ATN functional specification in 1996.

The third of these activities involves the definition and development of future satellite communications. The FAA will initiate a study of the potential for widespread satellite communications use in the NAS considering the prospects for new technical approaches to provide the desired benefits. This study will consider as many of the available options as possible and will attain consensus support within the aviation community; it will consider transition strategies, user equipment costs, and other key parameters to assess the sensitivity of the results to the assumptions; and it will investigate promising approaches and will evaluate them in comparison with the existing

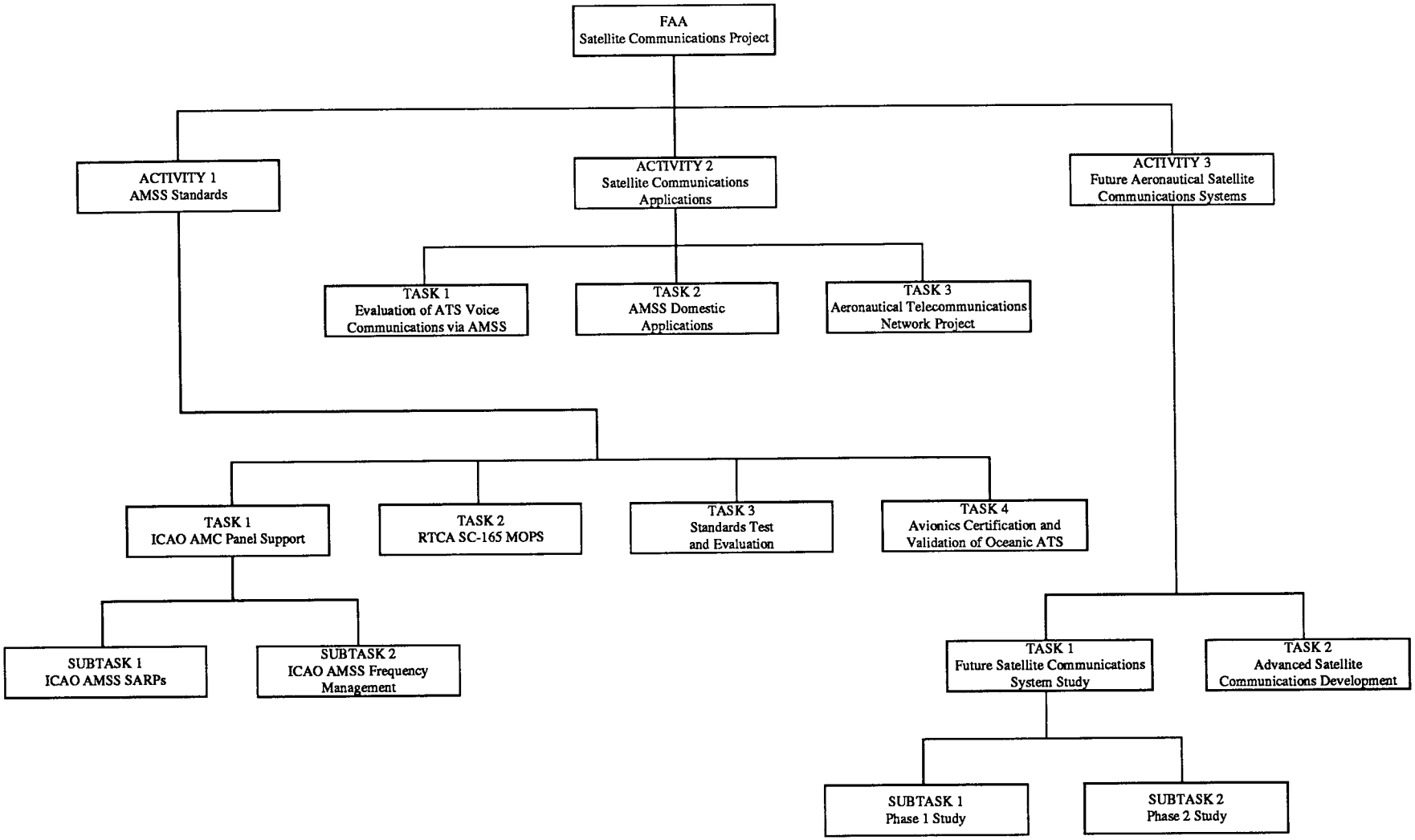
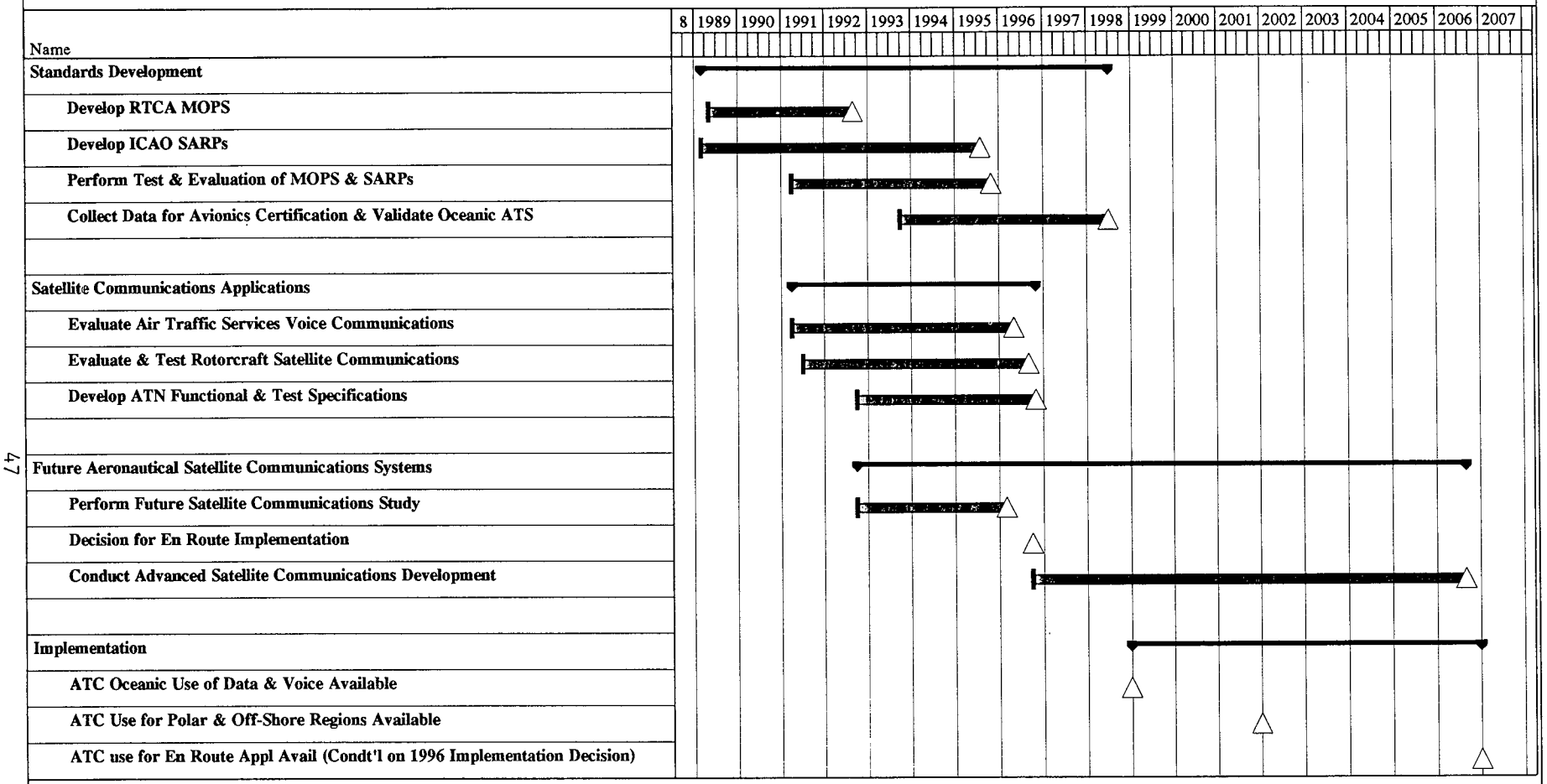


FIGURE 2. HIERARCHY OF SATCOM ACTIVITIES AND TASKS

NAS techniques. This study will assess the benefits of satellite communications to general aviation ATM and will initiate development of innovative technologies to extend the user base. The goal of this activity is to assess the advantages of satellite communications in the FAA's long-range plans for surveillance and communications. In FY 1993, a solicitation for a study of an advanced satellite communications system will be announced. The results of this study will be available in FY 1996 and will form the basis for further research and development of an advanced satellite communications system.

The proposed schedule for the performance of the above mentioned activities is shown in Figure 3. Note that the full implementation of the use of satellite data and voice communications for ATS using SARPs-compliant equipment is projected to occur in oceanic airspace at the end of the 1990's, in U.S. coastal airspace early in 2000's, and in U.S. domestic en route airspace by 2010.

Figure 3.
Satellite Communications Project Schedule



Milestone, Scheduled △ Activity In Progress Summary Bar

Milestone, Completed ▲ Activity Progress Completed

* Estimated Dates

OPENING SESSION

Francisco Castro-Rodriguez
Technical Officer
Rules of the Air, Air Traffic Services and Search and Rescue Section
International Civil Aviation Organization
ICAO - Montreal

Francisco Castro-Rodriguez, with an educational background in Electronics Technical Engineering, has been an Air Traffic Controller since 1968 specializing in ATC data processing. From 1974 to 1982, Mr. Castro-Rodriguez shared Controller activities with that of ATC Computer Systems Analyst participating in the preparation of technical and operational specifications and development of ATC radar and flight data processing systems at the Eurocontrol Experimental Centre in Paris, the Electronic Systems Division, USAF/MITRE Corporation in Boston and the ATC Automated System SACTA Office in Madrid.

Mr. Castro-Rodriguez joined ICAO's Technical Assistance Programme in 1983 with the initial assignment of developing specifications for an en-route radar simulator, presently installed at the Instituto de Protecao ao Voo-Centro Tecnico Aerospacial, IPV/CTA in Brazil. In 1985, Mr. Castro-Rodriguez was transferred to ICAO Headquarters in Montreal where, among other responsibilities, he is presently the Secretary of the Automatic Dependent Surveillance (ADS) Panel of the Air Navigation Committee.

INTERNATIONAL STANDARDIZATION OF FUTURE AIR NAVIGATION SYSTEMS AUTOMATIC DEPENDENT SURVEILLANCE (ADS) ICAO ADS PANEL ACTIVITIES

Francisco Castro-Rodriguez

International Civil Aviation Organization (ICAO)
Montreal, Canada

ROLE AND FUNCTION OF ICAO

During flight, the crew of an aircraft frequently communicates with stations on the ground. They obtain air traffic control clearances and receive an update of weather conditions ahead, or the operational status of navigation aids en route or at destination. There is a continuous link between the aircraft and the ground stations, and among the ground stations themselves. Many ground facilities and supporting services are needed for the safe and efficient operation of aircraft. To achieve harmonious functioning of all these ground facilities and services, international standardization is necessary. To ensure safety, regularity and efficiency of international civil aviation operations, such international standardization is essential in all matters concerning the operation of aircraft and all facilities and services required in the different disciplines in the air navigation field.

The ICAO Council has the responsibility for adoption of Standards and Recommended Practices and approval of procedures. The principal body concerned with their development is the ICAO Air Navigation Commission. The Commission is assisted in this work by the technical secretariat of the Organization's Air Navigation Bureau. In the advancement of solutions to problems requiring specialized expertise, the Commission is also assisted by panels. These are groups of experts, nominated by Contracting States and international organizations and approved by the Commission.

TECHNICAL WORK AND STANDARDIZATION

The main feature of the technical work of the Organization deals with achieving agreement of the Contracting States on the necessary level of standardization for the operation of safe, regular and efficient air services. The necessary standardization has been achieved by the Organization primarily through the creation, adoption and amendment by the Council as Annexes to the Convention on International Civil Aviation of specifications known as International Standards and Recommended Practices (SARPs). A Standard is a specification, the uniform

application of which is recognized as necessary for the safety or regularity of international civil air navigation and to which Contracting States will conform in accordance with the Convention. A Recommended Practice is a specification for physical characteristics, configuration, material, performance, personnel or procedure, the uniform application of which is recognized as desirable in the interests of safety, regularity or efficiency of international air navigation.

Specifications proposed to be given the status of Standards or Recommended Practices are, after consultation with all Contracting States, finalized by the Air Navigation Commission and submitted to the Council for adoption. SARPs become effective and subsequently applicable at dates set by the Council.

ICAO also formulates Procedures for Air Navigation Services (PANS). The PANS are developed by the Air Navigation Commission. Following consultation with all Contracting States, they are approved by the Council and recommended to Contracting States for worldwide application.

In addition, specifications known as Regional Supplementary Procedures have been developed, approved by the Council and recommended to Contracting States for application in the flight information regions to which they are relevant. These procedures may indicate modes of implementing procedural provisions in SARPs and PANS or specify additional procedural options for regional applications.

To facilitate the implementation and to promote the uniform application of SARPs and PANS, technical manuals or guidance material in other forms are issued by the Organization under the authority of the Secretary General.

REGIONAL PLANNING AND IMPLEMENTATION

In dealing with international civil aviation, there are many subjects which ICAO considers on a regional basis as well as on a worldwide scale. To facilitate detailed planning of the facilities and services which are required to support the development of air navigation, regional air navigation meetings are held periodically to determine the future requirements. These meetings result in the enumeration of the requirement for facilities and services as presented in Air Navigation Plans Publications covering the nine regions of ICAO.

Continuing attention is being given by ICAO to implementation of the required facilities and services. Seven ICAO regional offices are maintained, in Bangkok, Cairo, Dakar, Lima, Mexico City, Nairobi and Paris, each one accredited to a group of Contracting States. These offices consult with States in the region for the purpose of coordinating implementation plans, and provide all possible advice and assistance in air navigation matters.

TECHNICAL DEVELOPMENTS

In keeping pace with the rapid development of interna-

tional civil aviation, ICAO is conscious of the need to adopt in its specifications reference to modern systems and techniques. In recent years, ICAO has been actively involved in the development and implementation of new principles and techniques aimed at facilitating the safe and orderly growth of international civil aviation throughout the world.

SPECIAL COMMITTEE ON FUTURE AIR NAVIGATION SYSTEMS (FANS)

In June 1983, the ICAO Council established a Special Committee on Future Air Navigation Systems (FANS) in support of its continuing policy to develop a projection of air navigation requirements for international civil aviation.

The FANS Committee concluded its task during the fourth meeting held in May 1988. The report of FANS/4 (Doc 9524), the final report of the Committee, contains a consolidated set of material as developed by all four meetings.

CNS system concept

The envisaged changes in air traffic management (ATM) and the shortcomings and future needs identified by FANS constitute the basis which underlies the FANS approach to a future communications, navigation and surveillance (CNS) system concept. Essentially, the Committee concluded that the application of satellite technologies was the only viable solution that would enable international civil aviation to overcome the shortcomings of the present CNS systems and to fulfil the needs and requirements of the foreseeable future on a global basis. Indeed, the Committee saw very little prospect of substantial improvement in ATM if it were to continue having to rely upon the present CNS systems. Therefore, in response to its terms of reference, the Committee developed "an overall long-term projection for the co-ordinated evolutionary development of air navigation for international civil aviation over a period of the order of twenty-five years", in which, complementary to certain terrestrial systems, satellite CNS systems would be the key to worldwide improvement of ATM systems.

Automatic dependent surveillance

In the absence of long-range radar surveillance of air traffic operations over extensive oceanic and certain land areas, the procedural air traffic control system was necessarily based upon position reports provided by pilots via voice communications channels. The introduction of air-ground data links, together with sufficiently accurate and reliable aircraft navigation systems, gives the opportunity to provide surveillance services in areas which lack such services in the present infrastructure, particularly in oceanic and other areas where the current systems prove difficult, or even impossible, to implement.

Automatic dependent surveillance (ADS) was defined by FANS as a function for use by air traffic services in which aircraft automatically transmit, via a data link, data derived from

on-board navigation systems. As a minimum, the data include aircraft identification and four-dimensional position. Additional data may be provided as appropriate. The ADS data would be used by the automated ATC systems to display air traffic situation to the controller. In addition to areas which are at present devoid of traffic position information other than pilot-provided position reports, ADS would permit beneficial application in other areas, including high-density areas, where ADS may serve as an adjunct and/or back-up for secondary surveillance radar, and thereby reduce the need for primary radar.

The functional objectives of ADS, which could vary in different areas of application, may be characterized as the enhancement of flight safety through the ability to provide a means of surveillance of aircraft operating outside surveillance radar coverage. It requires the timely detection and correction of deviations from the cleared track. Reduction in separation would be possible by improved communications, and improved air traffic control (ATC) data processing and display capability. An increased level of tactical control is envisaged, enabling a more flexible use of airspace. An early application of ADS is likely to be in oceanic areas.

ATC automated system based on ADS

It is foreseen that the functional capabilities of an ATC automated system based on ADS will include the processing of aircraft position, tracking, air-ground and ground-to-ground data message processing as well as flight plan data processing and graphical display for traffic situation and tabular information. Air-ground communication system would be mainly via satellite data link.

EVOLUTION AND TRANSITION

In considering the overall CNS system concept, the questions of evolution and transition are most important. For instance, careful planning will be necessary to ensure that aircraft of the future are not required to carry a multiplicity of existing and new communications, navigation and surveillance equipment. In addition, there is a close relationship between the required CNS services and the desired level of air traffic management and finally, for reasons of both economy and efficiency, there is a need to ensure that differences in the pace of development around the world do not lead to imbalance and incoherence in the global air navigation system. In particular, due to the wide coverage of satellite CNS systems, the above considerations call for conscientious worldwide co-ordination of the planning and implementation if such systems are to be optimized.

FANS-PHASE II

Following development of the FANS global concept, the ICAO Council in July 1989 established a special committee for the monitoring and co-ordination of development and transition planning for the Future Air Navigation Systems (FANS-Phase II). Its terms of reference

require the committee to identify, and make recommendations for, acceptable institutional arrangements, to develop a global co-ordinated plan with appropriate guidelines for transition, and to monitor the nature and direction of research and development programmes, trials and demonstrations in CNS and ATM so as to ensure their co-ordinated integration and harmonization. The second meeting of the committee was held in Montreal, April/May 1991.

RELATED ICAO TECHNICAL BODIES

Although the technical work of FANS was completed at the fourth meeting in May 1988, the detailed work was only beginning and, as a result, existing or new ICAO technical bodies were required to undertake work on the key issues identified by the committee. These technical bodies include:

a) The Aeronautical Mobile Communications Panel (AMCP).

b) The Automatic Dependent Surveillance Panel (ADSP).

c) The Secondary Surveillance Radar (SSR) Improvements and Collision Avoidance Systems Panel (SICASP).

d) The Review of the General Concept of Separation Panel (RGCSP)

The third meeting of the Aeronautical Mobile-Satellite Services (AMSS) Panel was held in Montreal, February 1990. The panel completed tasks related to studies on satellite resources sharing and frequency spectrum requirements for aeronautical safety services. In addition, several working groups of the panel further refined the AMSS SARPs which are expected to be completed by the next panel meeting. The Communications/ Meteorology/Operations Divisional Meeting (1990) held in Montreal, September 1991, identified the need for better utilization of the 118-137 MHz VHF band and the development of SARPS for VHF data link to be used for air traffic control and operational control services. The Air Navigation Commission decided that work could begin promptly if the new task were assigned to the AMSS Panel. As result, the terms of reference of the panel were modified accordingly and the name changed to the Aeronautical Mobile Communications Panel (AMCP).

The ADS Panel held its first meeting in Montreal, January 1991. The panel progressed work on the conceptual evolution of automatic dependent surveillance and the development of operational requirements for the use of ADS in air traffic control. The meeting considered issues related to the expansion of the ADS definition, the content of ADS report messages to include new data elements and to built-in flexibility in the composition of ADS messages and the establishment of a framework for further development of the operational requirements for ADS systems. The existing guidance material on ADS published in the ICAO Circular 226, was considered valuable information for the future work of the ADS panel. Following consideration of the concept of ADS and how the function could be

used in ATC, the panel considered that aircraft position reporting through ADS by itself as a single application of the future digital data link systems would not meet the requirements of ATC. It was felt that the reduction of separation minima will only be achieved on the basis of the efficient use of ADS and rapid controller intervention capability. The Air Navigation Commission requested the Review of the General Concept of Separation Panel (RGCSP) to give a high priority to the question of separation minima for use with ADS. The panel recognized the need to standardize ADS messages and two-way pilot-controller data communications as to the format and content of air-ground ATS applications messages and ground-to-ground communications. The next meeting of the ADS Panel is tentatively scheduled for the second quarter of 1992.

The SICAS Panel developed SARPs for SSR Mode S to support implementation of the system compatible with the existing SSR. Also, provisions for application of 24-bit addresses were developed. SSR Mode S standardization is essentially complete, with the exception of possible modifications of SARPs resulting from implementation experiences. The panel developed guidance material on Mode S data link and published it in ICAO Circular 212. The panel is expected to develop SARPs for Mode S data link at its fifth meeting. Regarding airborne collision avoidance systems (ACAS), ICAO will continue to encourage operational evaluations of ACAS II that are being conducted on the basis of ICAO guidelines and procedures developed by the SICAS Panel. Guidance material relating to the Aeronautical Telecommunication Network (ATN) is to be published shortly. The Panel is continuing work on developing SARPs for the ATN.

The RGCS Panel is progressing three tasks related to FANS. At the seventh meeting held in Montreal, October/November 1990, the panel completed guidance material on the implementation of a 300 m (1 000 ft) vertical separation minimum above FL 290. The panel developed material for a manual of Area Navigation (RNAV) Operations, reflecting the experience gained to date with RNAV. This ICAO manual (Doc 9573) is expected to facilitate the early implementation of RNAV routes on a global basis. Progress was also made in the development of the required navigation performance (RNP) concept, which is part of the communications, navigation and surveillance (CNS) system envisaged by FANS. In addition, the panel considered that an airspace planning methodology should be developed for determining the separation minima that addresses the use of RNP as well as expected traffic, route configuration, and communications, surveillance and air traffic control services provided.

CONCLUSION

To ensure safety, regularity and efficiency of international civil aviation operations, international standardization is essential in all matters concerning the operation of aircraft and the facilities and services required such as aerodromes, telecommuni-

cations, navigation aids, meteorology, air traffic services, search and rescue, aeronautical information services and aeronautical charts. Participation in this process of standardization by all countries is absolutely necessary. The ICAO Council adopts (or amends when necessary) International Standards and Recommended Practices and approves procedures for the safety, regularity and efficiency of air navigation.

ICAO is actively involved in the evolutionary development of the air navigation system and in global implementation planning for the communications, navigation and surveillance systems. Automatic dependent surveillance is the key to improvements in air traffic management on a worldwide basis, and its development and implementation is being guided by ICAO through the FANS Committee (Phase II) and panels of the Air Navigation Commission.

OPENING SESSION

W. Frank Price
Manager
International Procedures Branch
Federal Aviation Administration

W. Frank Price is a veteran of 20 years of Federal Aviation Administration (FAA) experience. In various capacities, he has served in 5 towers, 2 ARTCCs, and FAA headquarters. Mr. Price has also held the position of FAA Military Liaison Officer at Myrtle Beach AFB, South Carolina.

During his tenure as Manager of the Anchorage ARTCC, Mr. Price was instrumental in reestablishing cooperative air traffic control agreements with the Union of Soviet Socialist Republics (USSR) Ministry of Civil Aviation. These agreements provided for the exchange of air traffic services information between Anchorage ARTCC and Anadyr Area Control Center.

Mr. Price holds a general aviation commercial pilot license and instrument rating.

Mr. Price is presently the Manager of the International Procedures Branch, Air Traffic Operations Service, at FAA headquarters, Washington, D.C.

International Civil Aviation Organization (ICAO) Automatic Dependent Surveillance Panel (ADSP) Activities

W. Frank Price, Manager
International Procedures Branch,
Federal Aviation Administration
and
Faye I. Francy, ADS Program Manager
MiTech, Incorporated

Introduction

Automatic Dependent Surveillance (ADS), with ATC Automation data link, has the potential to upgrade the efficiency and safety of air traffic control over much of the world's airspace. The system must be standardized, however, to the extent that hardware and message formats are compatible, regardless of which satellite is being used. This will maximize the potential usefulness of the system and thus provide the motivation for international aircraft operators to equip their fleets with necessary avionics. But if only a few countries were to adopt the system, its potential usefulness would be reduced correspondingly.

Fortunately a number of countries, including Australia, Canada, France, Iceland, Japan, Portugal, Spain, the Union of Socialist Soviet Republics, the United Kingdom, and the United States of America, are actively supporting ADS.

Background

The various developments are being coordinated through the Committees of the International Civil Aviation Organization (ICAO), which has been the forum for international development and standardization efforts for ADS and for satellite-based communications, navigation and surveillance (CNS). An initial study was performed in 1978 by the Committee to Review the Applications of Satellite and Other Techniques to Civil Aviation, in conjunction with the United States Federal Aviation Administration (FAA).

This study resulted in the Oceanic Area System Improvement Study (OASIS) report, which was completed in 1981. It presented a survey of alternative approaches to improving air traffic services in oceanic areas, including the use of satellites in the application of ADS. It also provided the basis for subsequent ADS work. Since then, ICAO has continued to develop the concept of a global CNS system approach, through the work of its various committees, panels and working groups.

The Special Committee on Future Air Navigation Systems (FANS) Committee was established by the ICAO Council at the end of 1983 to identify and assess new concepts and technology, including satellite technology, in the field of air navigation, and to make recommendations for the development of air navigation for international civil aviation, over

the next 25 years. The final FANS Committee Report (Doc 9524, FANS/4), published in 1988, consolidated the recommendations of all of the FANS meetings.

Upon completion of the FANS work program and the formulation of its blueprint for future air navigation systems, the Aeronautical Mobile Communication (AMC) Panel, formerly Aeronautical Mobile-Satellite Service (AMSS) Panel, the ADS Study Group, and subsequently the ADS Panel, were established within ICAO, to further the FANS work and develop the necessary detailed specifications and procedures. Additionally, a new ICAO Committee (FANS II) was established to carry out the overall monitoring and coordination of developments in transition planning, so that implementation of the future CNS system will take place on a global basis in a cost-effective manner.

The Aeronautical Mobile Communication Panel (AMCP) was established in 1987 to undertake specific studies as approved by the Air Navigation Commission. Its objective was to develop Standards, Recommended Practices (SARPs), procedures and suitable guidance material related to air-ground digital data and voice communications of aeronautical mobile-satellite services. The results were required to be compatible with other air-ground data links and ground air traffic services (ATS) communication networks, and consideration of ADS requirements.

The Secondary Surveillance Radar Improvements and Collision Avoidance System Panel (SICASP) was established in 1981 to develop Standards and Recommended Practices (SARPs) and suitable guidance material concerning secondary surveillance radar (SSR) enhancements and related data links and collision avoidance systems.

In 1987, as a result of FANS/3 Recommendation 7/3, the Panel was given the task of developing protocols to permit commonality and interoperability between Mode S and other ATS data links, including satellite data links. In the specific area of ADS, the SICAS Panel is working on the development of the upper layer Open System Interconnection (OSI) protocols to support the periodic reporting requirements of ADS so that the AMC Panel can define the satellite sub-network (lower OSI reference model) layers. In particular, this effort will include the interface between ADS and the aeronautical telecommunications network (ATN). The ATN is being designed to operate as a single, cooperative virtual data network using airborne and ground-based subnetworks based on standardized protocols. The ATN provides data communications connectivity among various communications interfaces that are user transparent.

SICASP working groups have been making progress in connection with the development of SARPs and guidance material for SSR Mode S systems based on the aeronautical telecommunications network, and on matters relating to SSR Mode S data link and interoperability considerations between Mode S and other ATS data link systems.

The North Atlantic Systems Planning Group (NAT/SPG) is composed of Member States directly involved with airspace within the North Atlantic. This group is charged with continuously studying, monitoring and evaluating the system in the light of evolving traffic characteristics, technological advances and updated traffic forecasts, so that the North Atlantic Regional Plan may be adjusted on a timely, evolutionary basis. NAT/SPG established a Task Force to develop a common future Air Traffic Management (ATM) system concept for the North Atlantic, on the basis of which a regional

implementation plan will be prepared. It is envisaged that several tasks will be finalized in time for their results to be reviewed by a NAT Regional Air Navigation Meeting scheduled for late 1992.

In defining the common future ATM concept, the Task Force assessed the problems related to the operational concepts that must be developed to accommodate the transition to the new technologies.

On December 10, 1987, the Air Navigation Commission agreed to the establishment of the Automatic Dependent Surveillance (ADS) Study Group to assist the Secretariat in developing urgent tasks related to the ADS. The group held its first meeting in Montreal, Canada, March 1989 and developed operational communication requirements as requested by AMSSP/1 **Recommendation 2.1/1**. The second meeting of the group was held in Montreal, December 1989, with the purpose of developing guidance material for the ICAO Circular on ADS.

ICAO ADS Panel

On April 24, 1990, the Air Navigation Commission established the Automatic Dependent Surveillance (ADS) Panel. The first ADS Panel meeting was held in Montreal, Canada, January 14 to 25, 1991. The meeting was attended by fourteen members and three observers nominated or designated by States and international organizations. The FAA's International Procedures Branch Manager, Mr. Frank Price, (ATP-140) was elected as Chairman of the meeting. The Secretary of the meeting was Mr. F. Castro-Rodriguez, Technical Officer of the Rules of the Air, Air Traffic Services and Search and Rescue (RAC/SAR) Section.

Terms of Reference (TOR)

The Terms of Reference of the ADS Panel were to undertake specific studies, as approved by the Air Navigation Commission, with a view toward developing Standards and Recommended Practices (SARPs), procedures and, where appropriate, suitable guidance material on automatic dependent surveillance (ADS), using as a basis the ADS material presented in the third meeting of the Special Committee on Future Air Navigation Systems (FANS/3) and the fourth meeting of the Special Committee on Future Air Navigation Systems (FANS/4) Reports, while maintaining close coordination with the Aeronautical Mobile Communication (AMC), Secondary Surveillance Radar Improvements and Collision Avoidance Systems (SICAS), AFS Systems Planning for Data Interchange (ASP), and Review of the General Concept of Separation (RGCS) Panels, and other bodies, as necessary, in order to facilitate the timely exchange of up-to-date information and working documentation, and to prevent, to the extent possible, duplication and fragmentation of work.

Work Program

In line with the TOR, the ADS Panel's Work Program was outlined as follows:

1. Undertake the necessary studies and coordination for the development and implementation of ADS;
2. Develop operational requirements for automatic air-ground data interchange necessary for ADS;
3. Develop operational requirements for two-way pilot-controller data interchange necessary to support the effective application of ADS in air traffic services;

4. Develop operational requirements for the processing and display of ADS data for use in air traffic services (ATS) with a view to facilitating the harmonization of ATS systems;
5. Develop a comprehensive assessment of the effect of ADS on air traffic services, including separation between aircraft in an exclusive ADS and mixed air traffic environment; and
6. Develop SARPs, procedures and guidance material, as required, relating to the use of ADS in the provision of air traffic services.

ADSP/1 Meeting Agenda

The agenda for the first ADS Panel meeting included the following:

Agenda Item 1: Review of ADS related developments, interrelationship of activities of related panels, on-going programs and planned ADS experiments;

Agenda Item 2: Development of the operational requirements for automatic air-ground data interchange necessary for ADS;

Agenda Item 3: Development of the operational requirements for two-way pilot-controller communications for the effective use of ADS;

Agenda Item 4: Review of the panel's work program and determination of the approach to be taken to ensure timely progress on the priority tasks at hand; and

Agenda Item 5: Future work assignments.

Review of ADS Activities

During its first meeting, the ADS Panel was provided with information on the activities performed by ICAO in the field of ADS and related developments. The Panel was presented with an update on the progress of ADS activities by different ICAO bodies, individual States and international organizations. Worldwide on-going programs and planned experiments were presented and discussed. Also, the FAA provided information on the ADS program and the real-time simulation of satellite-based ADS developed by EUROCONTROL.

Operational Requirements for ADS

The meeting began the study of operational requirements for ADS by considering the studies and work on communications and surveillance systems that had been completed by various ICAO specialized bodies. The meeting reviewed the ADS material contained in ICAO Circular 226-AN/135, developed by the Secretariat with the assistance of the ADS Study Group. It was recognized that the publication of the Circular was timely and that its content was extremely valuable to States and international organizations.

The concept of ADS and the ATS use of this function were discussed extensively. It was argued that ADS could be considered as a single application of the future air-ground communications system to provide only aircraft position information for surveillance purposes, in a manner similar to secondary surveillance radar systems. The establishment of a base line ADS message limited to the capability of the "basic ADS report" message type defined by FANS was proposed.

ADSP concluded that, from an operational point of view, ADS should be considered as a service rather than as a function, and that future air-ground data link communications systems will be used for both ADS and the interchange of all ATS messages and data elements necessary for two-way pilot-controller communications. Such

communications were considered essential if ADS were to be an effective component of the ATC system.

ADS Definition

The Panel reviewed the ADS definition as detailed in the FANS/4 report and the ICAO Circular 226-AN/135, and recommended expanding the definition as follows:

"Automatic Dependent Surveillance" is a service for use by air traffic services (ATS) in which aircraft automatically provide, via a data link, data derived from on-board navigation and position-fixing systems. As a minimum, the data should include aircraft identification and four-dimensional position. Additional data may be provided as appropriate.

An "ADS-based ATC system" (ADS-ATC) is an ATC system with appropriate automation and communications facilities relying on ADS updates to provide surveillance.

The Panel agreed that ADS-ATC must also include the capability of exchanging messages between the pilot and the controller via data link and by voice for emergency and non-routine communications.

The ADS Panel simplified the definition of areas and selected four representative types of airspace as follows: en-route high density without radar, en-route low density without radar, terminal areas with radar and terminal areas without radar.

Benefits and Areas of Application

Also considered were other areas where ADS would be beneficial which included:

1. areas with low-altitude operations outside radar cover, such as oil rig support below radar coverage, and
2. areas where air traffic would normally be served by a small non-radar unit, which, due to unforseen circumstances, had to contend with temporary major increases of traffic density, such as the results of natural disasters, search and rescue operations, and other similar events.

System Components

The ADS system components as described in ICAO Circular 226-AN/135 are: Pilot Interface, Avionics, Data Links, Communications Interface, ATC Automation, and Controller Interface.

Effect of ADS on Separation

The meeting considered the probability that the use of ADS with its inherent capability for rapid intervention would permit reduced separation minima in various ADS-ATC environments. While it was considered beyond the scope of ADSP to define reductions in separation, the panel agreed that this issue should be referred to the RGCSP as a matter of urgency. The panel formulated **Recommendation 2.1 - ADS-ATC separation minima**: "That the RGCSP be requested to examine the question of separation minima in different ADS-ATC environments, taking into consideration the report of the first meeting of the ADSP."

The work being carried out in the North Atlantic Region in the recent past has served to indicate that horizontal separation could be reduced using current navigation equipment, provided that the incidence of gross navigation errors (GNEs) was reduced. The extended ADS message was expected to contribute to such reduction.

ADS-ATC Communications Procedures

The Panel discussed many aspects of the ADS-ATC system, including procedures for the initial establishment of data link communications between the avionics and the ground based ATC automation system and the agreement between aircraft and ground system on the data to be exchanged.

Clearance through ADS-ATC airspace should not be a separate function, but a system-driven automatic function using on line data interchange (OLDI) and based on the transfer of current flight plans between ATC units. However, in the early implementation stage, as an aircraft approaches the ADS-ATC airspace boundary, the pilot may be required to address the initial message to the relevant air traffic control center and request specific clearance into the airspace.

The ATC/Aircraft agreement would be established by the ATC system, with each aircraft, for portions of the aircraft flight. The agreement would include the basic ADS message and one or more message extensions. There is also a requirement to address ADS messages to more than one addressee.

ADS Message Format

The ADS message content and data blocks, as agreed by the Panel, are as follows:

A. Basic ADS

Latitude
Longitude
Altitude
Time
Figure of Merit

B. Ground Vector

Track
Ground Speed
Vertical Rate

C. Air Vector

Heading
Mach or Indicated Air Speed (IAS)
Vertical Rate

D. Projected profile

Next Way-point
Estimated altitude at next way-point
Next+1 way-point
Estimated altitude at (next+1) way-point

E. Weather

Wind speed
Wind direction
Temperature

Operational Communications Requirement

ADSP was aware of the urgent need for the timely exchange of information with the AMC Panel. The operational communications requirements for ADS, documented at Appendix B to the Report on Agenda Item 2, represent an initial assessment of values which would provide the information needed to progress work on developing the technical aspects of ADS. The panel formulated **Recommendation 2.2 - Operational Requirement for ADS**: "That the operational communications requirements at Appendix B to the Report on Agenda Item 2 be considered by the AMSS Panel and other technical bodies dealing with development of future communications systems used in air traffic services."

Operational Requirements for Two-Way Pilot-Controller Communications for the Effective use of ADS

The need for two-way pilot-controller communications to support the effective use of ADS was recognized by FANS. It was for this reason that the ANC had tasked the ADS Panel to develop operational requirements for this link to support air traffic services in an ADS environment.

The initial scope of work contained three main interrelated subjects:

1. Development of operational communication requirements,
2. Data messages, and
3. Operational scenarios.

The Panel identified a lack of available information to develop the operational requirements and concluded that only preliminary data could be made available for the AMC Panel meeting in November.

A third recommendation was proposed: **Recommendation 3/1 - Studies and evaluation of ADS**: "Taking into consideration the urgent need to progress work in this area, States and interested international organizations be urged to conduct studies of operational requirements, data messages and operational scenarios in order to evaluate the effective use of ADS and also to make the results of these efforts available to ICAO for high priority distribution."

ADS Work Program

The objective of the ADSP is to develop a set of SARPs which fully define the operational ADS-ATC system. In order to fulfill this goal, the Panel defined the scope of work as follows:

* Develop ADS-ATC operational requirements;
* Expand and identify scenarios;
* Translate operational requirements into the requirements for the SARPs; and
* Develop proposals for Annex material and guidance material on procedures for the use of ADS-ATC.

The Panel identified the work which would be performed through two working groups:

A. Working Group A: ADS Operational Requirements

Working Group A shall develop the operational requirements matrices by collecting data on ADS from ICAO bodies and other groups. This group will coordinate the compilation and presentation of the data leading to the development of a complete set of operational requirements for the ADS service.

B. Working Group B: SARPs for ADS

Working Group B shall use the scenarios and operational requirements as they develop to produce SARPs and guidance material.

The work program, Terms of Reference for each Working Group, and schedules were developed and selected to enable possible rapid progress in completing the work.

Working Group Meetings

The first Working Group Meeting was held in Montreal, Canada, 8-20 April, 1991. Working Group A completed the matrices "ADS Non-Radar En Route Flight Scenario (Near Term)" and "ADS Non-Radar Terminal Flight Scenario (Near Term)". Further work

was necessary for the near term ADS non-radar TMA flight description and the need to address emergency and abnormal situations.

Working Group B identified and drafted an outline for the development of SARPs, but with the provision that this outline required further revision. This outline was intended for use as guidance material with the goal of producing a complete, efficient set of messages and rules which will meet the current and future needs of the ATC community.

The second Working Group Meeting was held in Lisbon, Portugal, 12-23 August, 1991. Retaining the configuration of both Working Groups, it was agreed that four sub-groups: Drafting, Communication, Technical, and Coordination, would be established to produce Guidance Material for presentation to ADSP/2 with a focus on developing SARPs.

The agenda for the second Panel meeting was outlined and the meeting was tentatively scheduled for the end of April, 1992. A third Working Group Meeting was scheduled for February to review the work to be presented to the Panel.

Conclusion

In a recent speech, Admiral Busey, FAA Administrator, told an international audience, "The time is gone when each nation can do its own thing, without regard to what the others are doing." We must achieve the degree of standardization or harmonization necessary to provide universal compatibility for ADS equipment. Otherwise, ADS cannot be a global system. Its effectiveness would be limited to those areas where the characteristics of the airborne equipment happened to match those of the satellite and the ground equipment. Such a limitation would reduce the potential economic benefit to international aircraft operators, and would reduce the incentive for such operators to purchase the airborne equipment.

The lower the percentage of aircraft which can participate in the advanced surveillance and the direct, reliable communications possible with ADS, the lower the gains which ADS could make in improving the efficiency and safety of flight operations in oceanic airspace, and over the vast land areas which lack adequate ATC surveillance or reliable, remote communications capabilities.

Therefore, we must achieve the necessary worldwide compatibility of ADS equipment. Universal interoperability is the goal and the key to the globalization of ADS.

CO-AUTHOR

Faye I. Francy
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Faye I. Francy is the ADS Program Manager for MiTech, Incorporated under contract with the Federal Aviation Administration (FAA). The contract furnishes technical, management, and administrative support to the FAA ADS Program Manager.

Ms. Francy has been involved with many aspects in supporting the ADS Program Office including various technical meetings such as the System Requirements Team, RTCA, AEEC, and the ICAO ADS Panel and its working groups. Additionally she assists in the multiple management and administration areas of the ADS program and is the focal point for the planning and execution of this symposium.

Ms. Francy has worked on various FAA programs including the Enhanced Traffic Management System (ETMS) where she provided controller training on the Aircraft situation Display (ASD) at Air Traffic Control Centers throughout the country, "Strategic Airport Research, Engineering and Development Plan" support, and "Compliance and Enforcement" course development for airport security.

Ms. Francy has a Bachelors degree in Chemistry and Mathematics and received her Masters of Science degree from the University of Pittsburgh in the area of Forensic Chemistry.

OPENING SESSION

Peter L. Massoglia
ADS Program Manager
Federal Aviation Administration

Peter L. Massoglia is the Program Manager of the Automatic Dependent Surveillance (ADS) Program with the Federal Aviation Administration in Washington, D.C. Mr. Massoglia holds a Baccalaureate degree (BSAE) in aeronautical engineering from Saint Louis University and has done graduate work at George Washington University.

In addition to a broad background in flight test engineering of U.S. Army and Navy aircraft he has extensive experience in reliability, maintainability and system standards. He has been with the Federal Aviation Administration (FAA) since 1976 and is presently assigned to the Research and Development Service. This organization has principal responsibility within the FAA for the development and acquisition of new technology systems. In his present assignment Mr. Massoglia is responsible for: the research, development, and implementation of the ADS program within the FAA; The development of Memorandum of Cooperation (MOC) with various states; and the coordination of international standards.

International Program Summary

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ABSTRACT

This paper identifies and describes the Automatic Dependent Surveillance (ADS) programs of those countries which, in addition to the United States, are most heavily involved in the operational implementation of ADS on an international basis. It also identifies and describes the past and on-going ICAO supported ADS activities that provide the overall guidelines for the individual country ADS programs.

INTRODUCTION

The existing manual dependent approach to air traffic control surveillance in oceanic airspace, as well as the airspace of other remote regions of the world, is in the process of being replaced with automatic dependent surveillance on a world-wide basis. In addition to replacing manual with automatic position reporting, ADS will replace the existing High Frequency (HF) analog voice link, for position reporting and other messages, with a satellite digital link for both data and voice messages.

Because the implementation of ADS is international in scope, implementation success depends on the cooperative and coordinated efforts among many national and international organizations, including the following:

- The United Nations (UN) International Civil Aviation Organization (ICAO) and its various committees, panels, study groups, etc. that are responsible for establishing international standards.
- The individual countries involved (and their respective civil aviation organizations) that have responsibility for portions of international airspace delegated to them by the UN.
- National standards organizations such as the Radio Technical Commission for Aeronautics (RTCA), and the Airline Electronic Engineering Committee (AEEC) in the United States.
- Airlines from the many countries with international routes.
- Providers of aeronautical mobile communications services such as SITA, ARINC, AVICOM, etc. whose services are impacted by ADS requirements.
- Providers of satellite communication services, such as INMARSAT and COMSAT, whose services must be adjusted to accommodate the needs of ADS.

- International and National Trade Organizations such at IATA, IFALPA, IFATA who represent the ultimate users of ADS.

Fortunately, the required cooperation and coordination among this complex set of organizations has been forthcoming and, as a result, ADS is well on its way to implementation internationally. Without this cooperation and coordination it would be impossible to achieve an international implementation of ADS and the benefits it promises in air safety, fuel economy, etc.

The objective of this paper is to identify and describe those individual and cooperative efforts of the countries which have been and continue to be actively involved in: a) ADS research and development; b) ADS operational engineering experiments and trials; and c) the development of the ICAO standards to provide the foundation for international implementation of ADS.

BACKGROUND

The United Nations International Civil Aviation Organization (ICAO) has been, and will continue to be, the forum for international development and standardization of ADS as well as other related satellite-based communications, navigation, and surveillance (CNS) programs. This is accomplished within ICAO by means of ICAO established committees, working groups, and panels whose membership is comprised primarily of the civil aviation authorities of ICAO member governments, and other supporting organizations.

Table 1 provides a brief chronology of some key world-wide ADS events resulting from ICAO sponsored activities. These events set the stage, and continue to provide a focal point, for the international ADS programs described later in this paper.

The single event, more than any other, that "triggered" the international development of ADS was the completion, in 1981, of the Ocean Area System Improvement Study (OASIS). This study developed and evaluated a number of alternative approaches to improving air traffic services in ocean areas; it initially developed the ADS technique and considered its implementation using both High Frequency (HF) and satellite based communication links. The 1981 OASIS report was prepared to support the informal international "Committee to Review the Applications of Satellite and Other Techniques to Civil Aviation", commonly referred to as the ICAO Aviation Review Committee (ARC), established three years earlier in 1978.

In 1983, two years after the publication of the OASIS report, the ICAO Council, acting on the recommendation of the ARC, established a new special committee on Future Air Navigations Systems (FANS). The objective of the FANS Committee, which included a Working Group on ADS, was an assessment of the use of satellite technology for international civil aviation looking 25 years ahead (or, 10 years into the twenty-first century). The FANS committee was supported by, among others, the U.S. Radio Technical Commission for Aeronautics (RTCA). The RTCA formed Special Committee #155 in 1984 to provide a consolidated view of user inputs; the Committee issued its report to FANS in 1986.

In 1988, five years after being established by ICAO, the FANS Committee held its fourth and final meeting (referred to as FANS/4) and issued its final report. As a part of this meeting, an ADS Working Group was established to continue the development and

Table 1. A Brief Chronology of Some World-Wide ADS Events

1978	The Aviation Review Committee (ARC) initially established by the Aerosat Council, and consisting of 18 ICAO nations and 7 organizations, initiated a reappraisal of the future use of satellites for civil aviation.
1981	The Ocean Area System Improvement Study (OASIS), completed in support of the ICAO ARC, initially developed the ADS technique and considered its implementation using both HF and satellite data link communications.
1983	Acting on the recommendation of the ARC, the ICAO Council formed a special committee on Future Air Navigation Systems (FANS) to identify and assess new concepts and technology, including satellite technology, for the development of international civil aviation looking ahead for a 25 year period. FANS included a working group on ADS.
1986	The RTCA SC-155, formed in 1984, issued its Final Report to the ICAO FANS Committee.
1987	In December, the ICAO Air Navigation Commission established on Automatic Dependent Surveillance (ADS) Study Group to assist the Secretariat in conducting urgent tasks related to ADS.
1988	In May, the Fourth and final Meeting of the full ICAO FANS Committee (referred to as FANS/4), formed in 1984, was held in Montreal. It initiated an ADS Working Group to continue the development and refinement of ADS based on the ADS concept and message format definitions developed by the FANS Committee. FANS continued to advise the ICAO Council until a new committee could be established.
1989	In March, the ADS Study Group held its first meeting in Montreal and developed operational communication requirements as requested by AMSSP/1 Recommendation 2.1/1
1989	In July, the ICAO Council established a new FANS Phase II Committee (referred to as FANS II) for monitoring, coordination of development and transition planning for the future air navigation system.
1989	In December, the ADS Study Group held its second meeting in Montreal to develop guidance material for the ICAO Circular on ADS (Circular 226-AN/135).
1990	In April, the ICAO Air Navigation Commission established the Automatic Dependent Surveillance (ADS) Panel (ADSP) to undertake specific studies with a view to developing SARPS, procedures and guidance material on ADS and to provide timely exchange with other ICAO bodies.
1991	In January, the ADS Panel (ADSP) held its first Meeting in Montreal, Canada.
1991	In August, the ADSP held its second Meeting in Lisbon, Portugal.

refinement of ADS based on the ADS concept and message formats developed by FANS.

In late 1987, just prior to the 1988 FANS/4 meeting, the ICAO Air Navigation Commission established an ADS Study Group to assist the SECRETARIAT in conducting "urgent tasks" related to ADS. This Study Group held two meetings in 1989, each with a specific objective. The objective of the first meeting, held in early 1989, was to develop ADS communication requirements in response to a request by the ICAO Aeronautical Mobile Satellite Service Panel (AMSSP). The objective of the second meeting, held in late 1989, was to develop guidance material for the preparation of the ICAO Circular on ADS (Circular 226/AN/135).

In 1990, the ICAO Air Navigation Commission established an ADS Panel (ADSP). This panel replaced both the ADS Study Group and the FANS/4 ADS Working Group. The primary objective of the ADS Panel is to develop ICAO Standards and Recommended Practices (SARPS). So far, the ADS Panel has held two meetings in 1991: the first in Montreal, Canada; the second in Lisbon, Portugal. As a result of these two ADS Working Group Meetings, guidance material is being prepared to present to the ADSP/2 for acceptance with a focus on developing SARPs.

The ADS Panel is currently the principal organizational entity empowered by ICAO to focus on ADS. In addition to the ADS Panel, ICAO is also currently sponsoring a number of additional organizations with efforts that are ADS related. These ADS related organizations are shown in Table 2 together with their terms of reference, dates established, and current status.

A more comprehensive version of the chronology contained in Table 1 is included in Appendix A. Appendix A covers some thirty five (35) international events, spanning twenty three (23) years from 1968 to the present (1991), that are either directly, or indirectly, related to the development of ADS.

INTERNATIONAL PROGRAM

In addition to the United States there are ten (10) countries with active ADS programs. The countries with such programs, together with the names of their civil aviation organizations, are shown in Table 3. The countries listed in Table 3 are interested in ADS because each has a responsibility, assigned to it by the United Nations, for a particular segment of oceanic airspace in which ADS will be implemented.

The ADS programs of the countries identified in Table 3 are summarized in Table 4. This table contains:

- Country Name
- ADS Program Elements
- Summary Description of each ADS Program Element

Each of the countries included in Table 4 has at least one program element that is being pursued more or less independently of any other country. In addition to these independent program elements, several of the countries included in Table 4 also have an ADS program element that includes the cooperative efforts of one or more other countries.

The three cooperative ADS program elements included in Table 4 are:

- ESA PRODAT ATC Experiment
- SITA PRODAT/AIRCOM Trials
- Pacific Engineering Trials (PET)

Table 2. ICAO Organizations Involved in ADS or ADS Related Efforts

ORGANIZATION		CHARTER/TERMS OF REFERENCE	DATE INITIATED	STATUS
FANS II	Phase II Committee on Future Air Navigation Systems (FANS)	Established for monitoring, coordination of development and transition planning for the future air navigation system. (FANS)	1989	On-Going
SICASP	Secondary Surveillance Radar (SSR) Improvements and Collision Avoidance Systems Panel	Established in 1981 to develop SARPs concerning SSR enhancements and related data links and collision avoidance systems. In 1987, tasked to develop protocols to permit commonality and interoperability between Mode S and other ATS data links, and to support ADS.	1981, 87	On-Going
AMSSP	Aeronautical Mobile Satellite Service Panel	Established to develop SARPs, using the OSI model, and guidance related to air-ground digital data link and ground ATS communications network giving due consideration to ADS requirements.	1987	See AMCP below
ADSP	Automatic Dependent Surveillance Panel	Established to undertake specific studies with a view to developing operational requirements and SARPs.	1990	On-Going
NATSPG	North Atlantic System Planning Group	Charged with creating and maintaining a North Atlantic airspace regional plan, a common future ATM system concept for the North Atlantic, and a plan for its implementation	1965	On-Going
AMCP	Aeronautical Mobile Communication Panel	AMSSP (see above) renamed to AMCP with scope expanded to include VHF data link.	1991	On-Going

ESA PRODAT ATC Experiment

PRODAT is an experimental satellite based communications system which provides low data rate communication (voice is not included) between mobile aeronautical and ground based users, and between mobile and fixed users (connected via terrestrial networks) to a satellite earth station.

PRODAT air traffic control (including ADS) experiments were initiated in 1987. The principal initial participants were: European Space Agency (ESA), Eurocontrol, British Civil Aviation Authority (CAA), Spanish Direcion General de Aviacion Civil (DGAC), Societe International de Telecommunication Aeronautique (SITA), and French CENA.

In addition, RACAL, ISEL, and the Madrid University of Technology participated on Technical matters. Portugal also joined as an additional participant in the PRODAT Experiment.

The components of the PRODAT experimental system, shown in Figure-1, include:

- Aircraft with aircraft earth station (AES) avionics for low data rate communications provided by ESA and SITA.
- A ground earth station (GES) provided by ESA.
- A PRODAT Network Management System (NMS), collocated with the GES, to provide message store and forward service (to interface the GES with the terrestrial communications network).
- ATC experimental centers provided by the participating countries and Eurocontrol.
- Terrestrial communications network to connect the NMS with the ATC experimental centers.

Each aircraft participating in the experiment was equipped with two sets of aeronautical mobile communication terminals. One was a standard SITA AIRCOM/ACARS VHF digital communications terminal compliant with ARINC 600 and 700 series characteristics. The second was an experimental PRODAT L-Band satellite communications terminal developed by ESA in accordance with aeronautical standards. The PRODAT and AIRCOM/ACARS terminals interface through an ARINC 429 port.

To provide the same interface to users, both on-board the aircraft and in ground facilities, (independently of whether the VHF or satellite communications link is being used) SITA developed the necessary software for the AIRCOM service processor, and the PRODAT Network Management System (NMS).

The PRODAT experimental satellite data link provides airlines participating in the trials with extended AIRCOM coverage over oceanic zones, and continental areas of low traffic density, plus an integrated system using the same airborne terminal equipment (supporting both VHF and satellite data link), identical crew procedures, and a common ground interface.

The experimental efforts of the countries participating in the PRODAT Experimental Program differ from each other based on their unique interests. Thus, as shown in Table 4, the United Kingdom evaluated satellite communications performance in term of communications success rates, and message delivery time. Portugal conducted experiments involving real-time simulations (at

Table 3. Government Civil Aviation Organizations Involved in ADS

Country	Name of Civil Aviation Organization	Civil Aviation Organization Acronym
United States	Federal Aviation Administration Department of Transportation	FAA
Japan	Japanese Civil Aviation Bureau Ministry of Transport	JCAB
Australia	Civil Aviation Authority	CAA
France	Civil Aviation Administration	CAA
Canada	Department of Transport Director General, Air Navigation	DGAN
United Kingdom	United Kingdom Civil Aviation Authority	CAA
Spain	Directorate General for Civil Aviation	DGCA
Portugal	Directorate General of Civil Aviation	DGCA
Iceland	Civil Aviation Administration Ministry of Communications	CAA
Singapore	Civil Aviation Authority of Singapore	CAAS
Soviet Union	Ministry of Civil Aviation	MCA

the Eurocontrol Experimental Center) of ADS based on traffic control for the Santa Maria Oceanic FIR. Spain conducted flight tests in which a satellite data link was employed for all messages (without voice communications) including enroute and terminal approach clearances until the aircraft was at 4000 ft. on a runway equalizer.

SITA PRODAT/AIRCOM Trials

The ESA PRODAT experimental system (designed for all potential applications of a satellite data link) was also used by SITA and cooperating airlines for air-ground data communications trials. These trials included data communications associated with various air traffic services (ATS) as well as ADS during regularly scheduled daily oceanic flights. Table 5 shows the various ATS applications that were explored by the airlines as part of these trials.

Pacific Engineering Trials (PET)

The ADS Pacific Engineering Trials (PET) are an engineering test program resulting from a trilateral memorandum of cooperation

Table 4. Summary of ADS Programs of Other Countries

COUNTRY	ADS PROGRAM ELEMENTS	SUMMARY DESCRIPTION OF ELEMENTS
AUSTRALIA	• Pacific Engineering Trials (PET)	• End to end testing of ADS based ATC including: evaluation of periodic ADS position reporting, and two way digital data link messages between pilot and air traffic controller on regularly scheduled flights in Northern Pacific airspace.
	• Experimental Display System Development and Evaluation	• Display system is designed to accept data from: ADS, flight data processing system, voice position reports, and radar data processing system. • Different symbols and colors used for: ADS, voice, radar position reports. • Employs twin Data General Work station displays. • One display for geographic representation of airspace and aircraft positions, another display for operational information and control. • Installation planned for 1991 in Sydney and Adelaide.
CANADA	• VHF ADS Experiments	• ADS commands to and position reports from aircraft sent as normal message text data using existing ACARS/AIRCOM message addressing and routing protocols. • Continental and intercontinental experiments - ie. aircraft originating in western Canada, Los Angeles in USA, and Nice France. • Intercontinental experiments involved three aeronautical mobile communications service providers: SITA, ARINC, AIR CANADA. • Data displayed in real time to Transport Canada Technical Systems Center.
	• Satellite Based ADS Experiments	• Will be initiated when equipped aircraft and GES are available.
FRANCE	• ATC Satellite Communications Experiments	• Develop experimental controller workstation. • Assess: basic ADS functions, pilot-controller data link dialogue, voice communications when available. • Evaluate improvements in ATC services.

Table 4. Summary of ADS Program of Other Countries (Cont'd)

COUNTRY	ADS PROGRAM ELEMENTS	SUMMARY DESCRIPTION OF ELEMENTS
ICELAND	• Air-Ground Data Link Trials	• Data Links to include: HF, VHF, Satellite. • Initially emphasize delivery of clearances. • Compares radar and ADS derived position reports.
JAPAN	• Navigation Experiments With ETS-5 Satellite	• Evaluate ATC surveillance based on: ADS, CIS, ARSR/SSR Data. • Evaluate message, data, and voice communications.
	• Pacific Engineering Trials (PET)	• End to end testing of ADS based ATC including evaluation of periodic ADS position reporting and two way digital data link messages between pilot and air traffic controller on regularly scheduled flights in Northern Pacific Airspace.
	• Satellite Data Link R&D Program	• Establish an experimental ADS based ATC data processing and display system. • Development and evaluation of ADS and other ATC data communications by controllers. • Verification of ICAO AMSSP SARPS based on OSI architecture.
PORTUGAL	• PROSAT/PRODAT Satellite Experiment	• Trials and experiments with SITA & participating airlines in evaluating satellite data link (no voice) communications for ATS including ADS. • Real-Time simulations in Eurocontrol Experimental Center of ADS based ATC for the Santa Maria Oceanic FIR.
	• Research with Lisbon University	• Application of AI to conflict resolution. • Optimization of man-machine interface at air traffic.
	• VHF ADS Experiments	• Trials and experiments with SITA and participating airlines in evaluating; VHF data link (no voice) communications for oceanic clearances.
	• Oceanic ATC System	• Replacing existing oceanic ATC system with a new system which includes options for ADS, direct Pilot/Controller communications, and interfacility communications.

Table 4. Summary of ADS Program of Other Countries (Cont'd)

COUNTRY	ADS PROGRAM ELEMENTS	SUMMARY DESCRIPTION OF ELEMENTS
SPAIN	• PROSAT/PRODAT Satellite Experiment	• Flight tests to evaluate satellite data link for ATS system. • Flight tests of satellite data link for all messages on flights from U.K. to Spain including en-route, decent and approach clearances, radar vectoring, and weather information until aircraft was at 4000 ft. on runway equalizer; voice not used at all.
	• Air Mobile Satellite Service Evaluation Programme	• Develop satellite communications test facility. • Conduct tests on ADS and other ATC applications. • Evaluate ICAO Satellite System. • Validate ICAO SARPS.
UNITED KINGDOM	• PROSAT/PRODAT Satellite Experiment	• Final report of UK PRODAT/PROSAT trial published; planning underway for surveillance development program; expect to have first aircraft with data link avionics in 1992. • Preparing for NAT trial with objective similar to NATSPG 27 agreed list.
	• SATCOM Development Program	• In Planning Stage.
UNION OF SOVIET SOCIALIST REPUBLICS	• Research	• Simulation of ATM using ADS for different control areas. • Air traffic controller and pilot display of simulated data. • Use of GLONASS/GPS-derived aircraft position data.
	• Experimental Evaluation	• Experimental implementation and testing of future ATM system elements using ADS.
	• Prototype ATC Center	• Develop and build a prototype ATC outer to complete development of ADS control procedures.

(MOC) between the Australian Civil Aviation Authority (CAA), the Japanese Civil Aviation Bureau (JCAB), and the United States Federal Aviation Administration (FAA). The airlines participating in the trials, through coordination with their civil aviation authorities, initially included Qantas, JAL, ANA, Northwest, and United. Subsequently, other governments and airlines became interested in participating in the PET including the governments of Singapore and the Union of Soviet Socialist Republics (USSR); and Cathay Pacific and Singapore Air airlines.

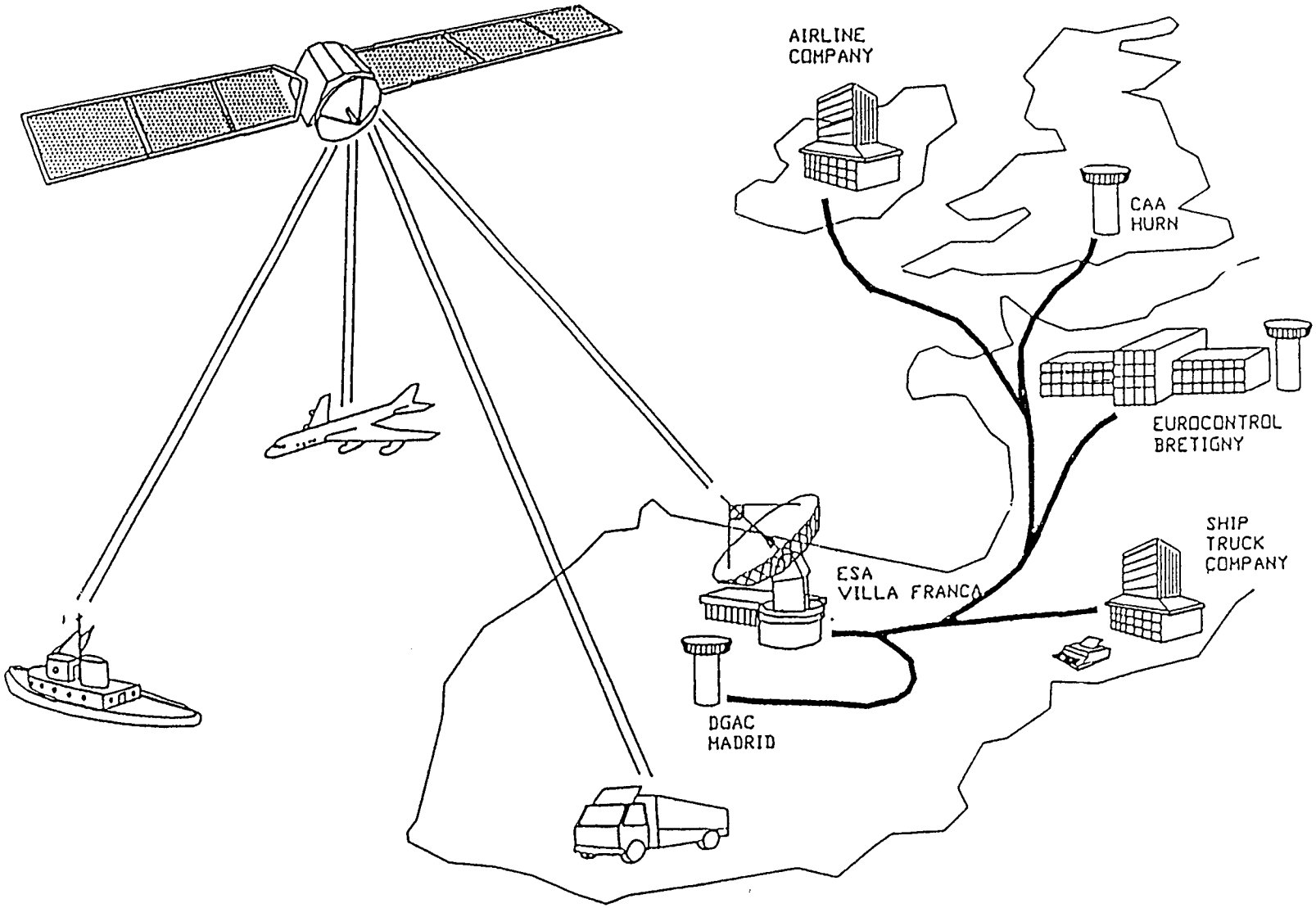


Figure 1. ESA PROSAT/PRODAT Experimental System

Table 5. SITA PRODAT/AIRCOM Trial Applications

Applications		Airlines*			
		TAP Air Portugal	Varig (Brazil)	Sabena (Belgium)	Saudi (Saudi Arabia)
AOC	Airline Operational Communications	X	X	X	X
AAC	Airline Administrative Communications	X	X	X	X
APC	Aeronautical Passenger Correspondence	X			X
ATC	Air Traffic Control			X	
ADS	Automatic Dependent Surveillance			‡X	

* Aircraft Used in Trials:
- TAP Air Portugal - One (1) Lockheed Tristar L1011
- Varig - One (1) Boeing B767-200ER
- Sabena - One (1) Airbus 310-300
- Saudi - One (1) Boeing B747-300

‡ ADS Trials conducted during regular, daily transoceanic flights.

The components of the experimental system used to carry out the Pacific Engineering Trials (PET), shown in Figure 2, include:

- Aircraft earth station (AES) avionics, comprised of existing airline specific equipments, that provide inputs from ACARS to a satellite data unit.
- Interim ground earth stations (IGES) that implement a subset of the INMARSAT System Definition Manual (SDM).
- ATC experimental centers provided by the participating countries.
- Terrestrial communications that utilize existing ARINC, SITA, and AVICOM networks.

The objective of the trials is to collect data for an end-to-end evaluation of an ADS-based air traffic control system for use as a basis in developing and implementing an operational system. The trials began in late September, 1990, when United Airlines flew a SATCOM-equipped aircraft on a regular scheduled flight from Hong Kong to San Francisco. Current plans call for the trials to continue until an operational ADS system becomes available.

In addition to the three multi-national cooperative efforts just described, each country included in Table 4 also has individual ADS efforts that it is pursuing (more or less) independently of the other countries. These individual efforts (See Table 4) are summarized below.

AUSTRALIA

In addition to being a principal participant in the Pacific Engineering Trials (PET) program, Australia is in the process of developing and evaluating an experimental air traffic controller display system. This system will display both ADS and radar position reports

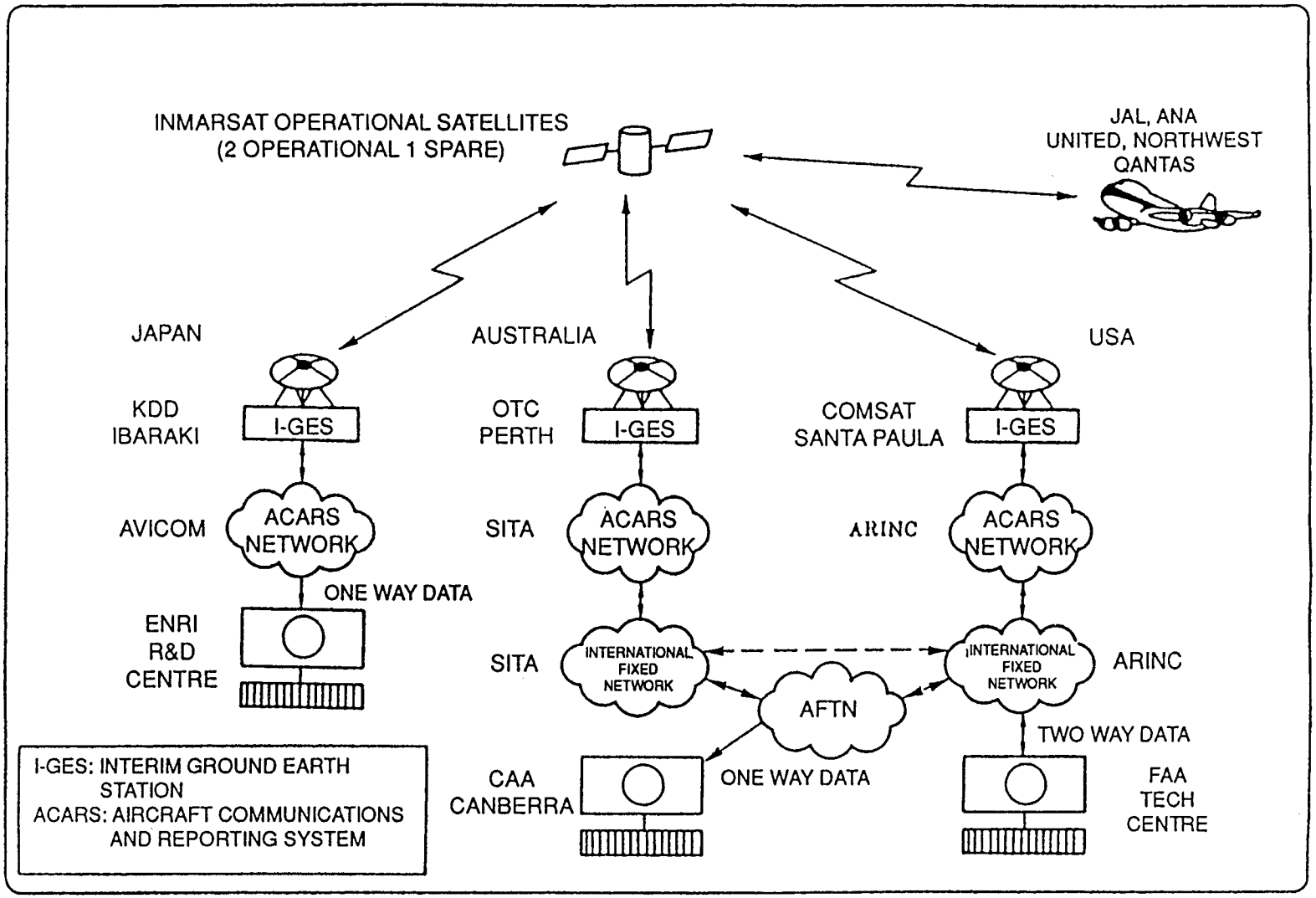


Figure 2. Automatic Dependent Surveillance (ADS)
Pacific Engineering Trials (PET)

using different colors and symbols for each. Additional information characterizing the system, to be installed in Sidney and Adelaide in 1991, is included in Table 4.

CANADA

Canada's ADS program is somewhat unique among those summarized in Table 4 in that the initial emphasis, starting in 1988, has been on ADS experiments using ground-based relayed-VHF rather than satellite communications. Aircraft ADS position reports and messages are sent as normal message text data, using existing ACARS/AIRCOM protocols, to the Transport Canada Technical Systems Center for real time processing and display.

Successful VHF-based ADS experiments were conducted on both continental and intercontinental (from Canada to France) flights using SITA, ARINC, and AIR CANADA communications services.

Satellite based ADS experiments are planned and will be initiated when equipped aircraft and a satellite GES become available.

FRANCE

As indicated in Table 4 France, like Australia, is developing an experimental air traffic controller work station for use in conducting satellite communications experiments including ADS.

ICELAND

The focus of ICELAND's ADS oriented Air-Ground Data Link Trials program (see Table 4) is a comparison of: a) HF, VHF, and satellite data links, and b) radar and ADS derived position reports (with various data link types) with initial emphasis on their use for the delivery of flight clearances. Iceland is procuring an ATC system with options for ADS.

JAPAN

Japan's ADS program has three major elements (See Table 4). In addition to participating in the Pacific Engineering Trials with Australia and the United States, Japan has also established a Satellite Data Link R&D Program that will run in parallel with the PET for the next five years. This R&D program will address: a) an experimental air traffic controller processing and display system (a subject, as Table 4 shows, that is also being addressed by Australia, France and Portugal); b) evaluation of data communications, and c) SARP verification. Japan's PET and Satellite Data Link R&D programs are follow-on efforts to earlier navigation experiments conducted using its ETS-5 satellite (see Table 4).

The Oceanic Data Processing system (ODP), which displays flight plan based aircraft position as radar (pseudo radar display), has been used in the oceanic sectors of the Tokyo Area Control Center since 1979. This system was upgraded in 1990. The upgrades included: 1) a high-resolution raster scan color display replaced the stroke type display and 2) a voice position report display and other functions were added. ADS processing will also be added to the system.

PORTUGAL

In addition to its efforts as a participant in the ESA PRODAT ATC Experiment with the United Kingdom and Spain, PORTUGAL is conducting a research program in concert with Lisbon University on both man-machine interface optimization and the application of artificial intelligence (AI) to conflict resolution.

Portugal is also replacing its existing ATC system with a new system with automation and traffic displays. Options include: ADS, Pilot/Controller communications and interfacility communications.

SPAIN

As a follow-on to its participation, with Portugal and the United Kingdom, in the ESA PRODAT ATC Experiment, SPAIN is in the process of initiating an Air Mobile Satellite Service (AMSS) Evaluation Program that includes development of a satellite communications test facility for use in evaluating the ICAO Satellite System and SARPS (See Table 4).

UNITED KINGDOM

As a follow-on to its participation (with Portugal and Spain) in the ESA PRODAT ATC Experiment, the United Kingdom has, in the planning stage, a SATCOM Development Program.

UNION OF SOVIET SOCIALISTIC REPUBLICS

A three phase ADS program was initiated in 1988. The first phase will emphasize simulation studies of air traffic management based on ADS, including pilot and air traffic controller display, and the use of GLONASS/GPS derived position data. The second phase will extend the first by employing experimental implementation and testing. The third and final phase will then result in a prototype ATC center that will be used to complete the development of ADS control procedures evaluated in the earlier simulation and experimental testing phases.

SUMMARY

The development and implementation of ADS on a global basis has required, and continues to require a cooperative and coordinated effort among governments, government civil aviation organizations, international and national standards organizations, international and national trade associations, airlines, providers of aeronautical mobile communications, communications satellite service providers, and manufacturers.

The ADS effort was initiated in the early to mid 1980's with individual country R&D efforts, and long range study and planning efforts sponsored and carried out within the international civil aviation and space satellite communities. These efforts led, in turn, to national and international experimental and engineering trials programs, initiated in the late 1980's and early 1990's, aimed at obtaining operational experience. The experimental and engineering trials programs were/are implemented using existing and, in some cases, modified equipment and software for each of the six ADS functions: pilot interface, avionics, data link, communications interface, ATC automation, and controller interface.

For ADS to become operational world-wide, a high degree of standardization of the implementation of the six ADS functions must be introduced. This standardization effort is now in progress world wide, and will soon undergo operational evaluation using next generation prototype systems that are being developed to satisfy the standards.

APPENDIX A

CHRONOLOGY OF EVENTS

Table A-1 provides a chronology of some thirty five (35) international events, spanning twenty three (23) years from 1968 to the present 1991, that are either directly or indirectly, related to the international development of ADS.

Table A-1. A Chronology of Some World-Wide ADS and ADS Related Events

	1960s
1968	The U.S. Department of Transportation (DOT) formed the Air Traffic Central Advisory Committee (ATCAC) for the purpose of recommending an ATC system for the 1980s and beyond.
1968	The ICAO formed the Application of Space Techniques Related to Aviation (ASTRA) panel consisting of leading satellite specialists from a number of ICAO Contracting states.
	1970s
1971	The ICAO ASTRA panel presented a paper entitled "Functional Aeronautical Applications of Space Techniques" at ICAO's Seventh Air Navigation Conference, calling for an international program of research, development, and system evaluation.
1975	The AEROSAT Council and the AEROSAT Coordinating Office was established, by a consortium of Canada, the United States FAA (with COMSAT as its operating agency) and the European Space Agency (ESA), to develop an aeronautical satellite system in response to the 1971 ASTRA panel report.
1977	The AEROSAT program was canceled, and the AEROSAT Coordinating Office was closed as a result of airlines, (and subsequently U.S. government) withdrawn support to the program due to increased fuel costs brought on by the oil crisis of the late 1970s. However, the AEROSAT Council remained in existence.
1978	The Aviation Review Committee (ARC) initially established by the Aerosat Council, and consisting of 18 ICAO nations and 7 organizations, initiated a reappraisal of the future use of satellites for civil aviation.
1979	The International Maritime Satellite (INMARSAT) organization was formed to offer satellite communication services to civil shipping on a world-wide basis.
	1980s
1981	The Ocean Area System Improvement Study (OASIS), completed in support of the ICAO ARC, initially developed the ADS technique and considered its implementation using both HF and satellite data link communications.
1981	The first issue of the annually updated U.S. National Airspace System (NAS) Plan for Facilities, Equipment, and Associated Development was completed by the Federal Aviation Administration (FAA).
1981	The ICAO Secondary Surveillance Radar (SSR) Improvements and Collision Avoidance Panel (SICASP) was established to develop SARPs and suitable guidance material concerning SSR enhancements, related data links and collision avoidance systems.
1982	MITRE began development of an experimental low data rate aeronautical satellite data link (ASDL) terminal and related demonstration based on the shared usage of an existing commercially available mobile satellite space segment, the International Maritime Satellite (INMARSAT) system. Development work leading to the ASDL design was based on the 1981 OASIS report, and FAA sponsored experimentation with the NASA ATS-6 satellite.

Table A-1. A Chronology of Some World-Wide ADS and ADS Related Events (continued)

1983	The ICAO ARC conclusions and recommendations were presented to the AEROSAT Council and soon thereafter to the ICAO Council.
1984	The first meeting of the Radio Technical Commission for Aeronautics (RTCA) Special Committee 155 (SC-155) titled "User Requirements for Future Communications, Navigation and Surveillance Systems, Including Space Technology Applications" was held; the objective of RTCA SC-155 was to provide a consolidated view of user inputs for consideration by the FANS Committee.
1985	The MITRE Corporation ASDL program, initiated in 1982, culminated in a successful flight test north of Iceland. An air/ground digital data link via satellite was used for transmission of aircraft position data and two-way transmission of messages.
1985	The FAA established an operational requirement for ADS, with broad application potential, and decided to complement the U.S. Oceanic Display and Planning Systems (ODAPS) with the ADS function utilizing a satellite-based air/ground communications data link with a goal of achieving initial operational capability in 1990.
1986	The RTCA SC-155, formed in 1984, issued its Final Report to the ICAO FANS Committee.
1986	ARINC initiated efforts to create AvSat, an air transport industry owned and operated aeronautical satellite system, to provide integrated air-ground voice and data communications throughout the world.
1987	Air traffic control (including ADS) and other experiments, using the European Space Agency (ESA) developed PRODAT experimental satellite based, low-date rate, data only communications system, were initiated by a consortium consisting of ESA, Eurocontrol, British Civil Aviation Authority (CAA), Spanish Direccion General de Aviacion Civil (DGAC), Societe Internationale de Telecommunication Aeronautique (SITA), and French CENA.
1987	Japan launched its Engineering Test Satellite (ETS) Model 5 and began air traffic control surveillance experiments employing satellite based automatic dependent surveillance (ADS), satellite based cooperative independent surveillance (CIS), and ground based search and secondary radar surveillance in the Japanese domestic, and Northern Pacific airspace that lasted into early 1990.
1987	The ICAO aeronautical mobile satellite services panel (AMSSP) was established to undertake specific studies approved by the Air Navigation Commission with a view to developing, on an urgent basis, using the Open System Interconnection (OSI) model, Standards and Recommended Practices (SARPs) and procedures and, where appropriate, suitable guidance material related to air-ground digital data links and ground air traffic services communications network giving due consideration to ADS requirements; the AMSSP is concerned with standardizing the satellite communication sub-system.
1987	The ICAO SICASP was given the task of developing protocols to permit commonality and interoperability between Mode S and other air traffic service (ATS) data links, including satellite data links; upper layer OSI protocols are being developed to support the ADS periodic reporting requirement such that the AMSSP can define the lower layer OSI protocols including the interface between ADS and the aeronautical telecommunication network (ATN).

Table A-1. A Chronology of Some World-Wide ADS and ADS Related Events (continued)

1987	Several airlines including Air France (France), Sabena (Belgium), Saudi (Saudi Arabia), TAP Air Portugal (Portugal), and Varig (Brazil) initiated service trials of aeronautical mobile satellite communications in an experimental program proposed by SITA as part of PRODAT satellite program.
1988	In May, the Fourth and final Meeting of the full ICAO FANS Committee (referred to as FANS/4), formed in 1984, was held in Montreal. It initiated an ADS Working Group to continue the development and refinement of ADS based on the ADS concept and message format definitions developed by the FANS Committee. FANS continued to advise the ICAO Council until a new committee could be established.
1988	AvSat project closed down due to technical, financial, and other problems.
1987	In December, the ICAO Air Navigation Commission established on Automatic Dependent Surveillance (ADS) Study Group to assist the Secretariat in conducting urgent tasks related to ADS.
1989	In March, the ADS Study Group held its first meeting in Montreal and developed operational communication requirements as requested by AMSSP/1 Recommendation 2.1/1
1989	In July, the ICAO Council established a new FANS Phase II Committee (referred to as FANS II) for monitoring, coordination of development and transition planning for the future air navigation system.
1989	In December, the ADS Study Group held its second meeting in Montreal to develop guidance material for the ICAO Circular on ADS (Circular 226-AN/135).
	1990s
1990	In March, the first International ADS Symposium was held in Atlantic City, New Jersey.
1990	In April, the ICAO Air Navigation Commission established the Automatic Dependent Surveillance (ADS) Panel (ADSP) to undertake specific studies with a view to developing SARPS, procedures and guidance material on ADS and to provide timely exchange with other ICAO bodies.
1990	In September, the ADS Trilateral Pacific Engineering Trials (PET) were initiated as a cooperative program between the United States, Japan, and Australia.
1991	In January, the ADS Panel (ADSP) held its first Meeting in Montreal.
1991	The International Satellite Communications and ADS Symposium is scheduled for September in Atlantic City, New Jersey.
1991	The Fourth meeting of the AMSS Panel (AMSSP) is scheduled for November. The objective is to finalize AMSS SARPS. The Panel name has been changed to the Aeronautical Mobile Communications Panel (AMCP).

CO-AUTHOR

William J. Budurka
Senior Systems Engineer
Mitech, Incorporated

William J. Budurka is a Senior Systems Engineer at MiTech, Incorporated. His responsibilities include systems engineering and technical management analysis of various aspects of satellite based air traffic control surveillance systems in support of the FAA's Automatic Dependent Surveillance Program.

Prior to joining MiTech, Mr. Budurka held positions as systems engineer, systems engineering manager, and program manager in the areas of aircraft navigation, satellite, surveillance, surface ship, submarine and advanced signal processor systems in IBM's Federal Systems Division. He has Bachelor and Master of Science degrees in Electrical Engineering from Lehigh University.

OPENING SESSION

Raymond J. Hilton
Director, Air Traffic Management
Air Transport Association of America

Raymond J. Hilton as been with the Air Transport Association since 1981. He is responsible for monitoring the FAA modernization program to assure the interests of the ATA member airlines are served. He does this by maintaining close liaison with the engineering and operating services of FAA and by maintaining current knowledge of the FAA national airspace system modernization program, its budget requirements, and other government agency and industry influences affecting the modernization program. He coordinates and cooperates as necessary with corporate and government representatives interested in FAA program development and implementation, and participates in national and international committees and technical conferences to influence airspace development and modernization to the benefit of the airlines.

Prior to joining ATA, Mr. Hilton spent twenty nine years in government service as an air traffic controller for nine years in the Air Force and FAA, and 20 years in engineering and development at FAA. He worked as an air traffic controller at various military control towers and at New York air route traffic control center, and for those who remember, the Pittsburgh air route traffic control center as an air traffic controller/computer programmer. He spent six and a half years at the FAA technical center at Atlantic City in experimentation and evaluation of air traffic control hardware and software systems. The remaining 14 years of his FAA career was spent at Washington headquarters planning, designing , developing and implementing air traffic control hardware and software systems. Two and a half years of that time was spent assigned to the AEROSAT Coordination Office at the European Space Agency in Holland where he was responsible for managing the development of an internationally coordinated test and evaluation plan for the application of satellite technology for air traffic control.

OPENING REMARKS

BY

RAYMOND J. HILTON
DIRECTOR, AIR TRAFFIC MANAGEMENT
AIR TRANSPORT ASSOCIATION OF AMERICA

Although this meeting is identified as the First International Satellite Surveillance and Communication Symposium, many of you will recall the Automatic Dependent Surveillance (ADS) symposium held here in March 1990. At the opening of that symposium I made the following points:

- FAA established an ADS program and has been focusing attention on refining the ADS technology and beginning to make the transition to applications of ADS.

- FAA arranged to cooperate internationally in the various ADS Memoranda of Agreement in both the Pacific and Atlantic ocean areas.

- We commended the efforts of FAA for establishing the system requirements team to assure the air traffic operations organization of FAA was part of the beginning and continued development of ADS.

- ICAO upgraded the ADS study group to a panel and called for membership by operational representatives familiar with procedures and airspace management. They too were aware of the importance of making the transition to applying to ADS technology.

- The ICAO FANS Phase 2 committee recognized the need to make the necessary transition from studying the new technology to application of the new technology.

- The airlines established an Air Space Systems Task Force to assure the technology to application of the new technology.

- The airline industry was expanding internationally and continues to do so and the new technology is needed to accommodate the needed expansion in the air transportation system.

- What was important then was to make the transition from ADS development to application of the technology in oceanic ATC.

At this symposium we must recognize that nearly all the organization needed to bring the satellite technology forward is in place, that demonstration trials proving the concept of oceanic airspace management using ADS has been demonstrated, that the benefit of satellite technology for air traffic service and the airlines is no longer doubtful, that internationally airlines have already begun to equip their aircraft with satellite communications equipment and are expected to continue to do so at an even more rapid rate, and finally, what is now needed is to find ways to expedite the mechanisms already in place to assure the technology is available for oceanic and domestic use to support the international civil aviation service providers, the international airlines and ultimately, the international air transportation system.

SESSION ONE: TRIALS AND DEMONSTRATIONS

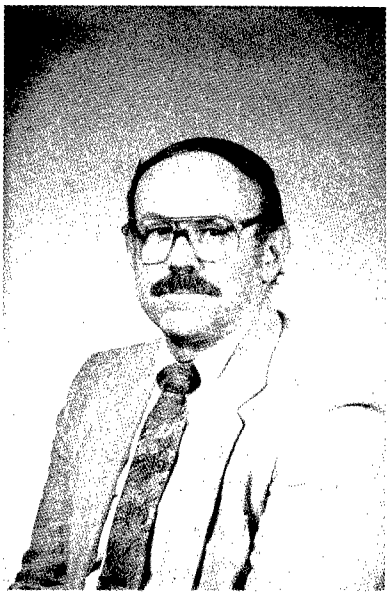
Tuesday, September 24, 1991

Session Chairperson - Ronald E. Morgan, Air Traffic Manager, Advanced Systems and Facilities, Division, Federal Aviation Administration

2:00	**Automatic Dependent Surveillance (ADS) Pacific Engineering Trials** - Frank L. Lorge, Electronics Engineer, Federal Aviation Administration Technical Center
2:20	**Japanese Trials** - Hiroki Takeda, Special Assistant to the Director, Radio Engineering Division, Air Traffic Services Department, Japanese Civil Aviation Bureau
2:50	**Australian Experiments in Automatic Dependent Surveillance (ADS) including the Pacific Engineering Trials (PET)** - H. Brian O'Keefe, Acting General Manager, Civil Aviation Authority, Australia (Co-author - Graeme Challinor, Manager, Analysis Research and Development, Civil Aviation Authority, Australia)
3:10	**French SATCOM Program and Related International Activities** - Pascal Senard, SATCOM Project Manager, French Direction Generale de l'Aviation Civile, Service Technique de la Navigation Aerienne (Co-author - P. Gautier, Satellite Communication Engineer, French DGAC)
3:30	**BREAK** sponsored by **SITA**
4:00	**Digitized Voice Trials** - Teresa A. Anderson, Air/Ground Service Planner, Engineering/Services Management, Aeronautical Radio, Inc. (ARINC)
4:20	**ADS Development in Canada** - Norman F. Dimock, Applications Development Engineer, Technical Services, Transport Canada Aviation (Co-author Donald F. McLean, Supervisor, Flight Data Processing, Air Traffic Services, Transport Canada Aviation)
4:50	**ADS Communications: A Cornerstone** - George A. Cobley, P.E., Technical Director, Communications Systems, Rockwell International
5:10	**Aeronautical Mobile Satellite Services ESA/SITA Aircom Service Trials Programme** - Graham C. Lake, Assistant Director, International Relations, Societe Internationale de Telecommunications Aeronautiques (SITA) (Co-author - A. Jongejans and P. Nguyen, ESA/SITA)
5:30	**Closing Remarks** - Peter L. Massoglia, Master of Ceremonies

SESSION ONE: TRIALS AND DEMONSTRATIONS

SESSION CHAIRPERSON



Ronald E. Morgan
Air Traffic Manager
Advanced Systems and Facilities Division
Federal Aviation Administration

Ronald E. Morgan is the Manager of the Advanced Systems and Facilities Division, ATR-300. Ron left the Western-Pacific Region in 1988 to join the Air Traffic Plans and Requirements Service as the Manager of the ACF Implementation Branch. He was the Assistant Manager and then Acting Manager of the System Plans and Programs Division before becoming the Acting Assistant Manager of ATR-300.

Ron has a background in both terminal and en route air traffic control facilities, both as controller and manager. He also holds a commercial pilot certificate and is a certified flight instructor. In the Western-Pacific Region he worked in the Planning, Requirements, and Automation Branch, both as a specialist and as manager, and served as Special Assistant to the Regional Director.

SESSION ONE: TRIALS AND DEMONSTRATIONS

Frank L. Lorge
Electronics Engineer
Federal Aviation Administration
Technical Center

Frank L. Lorge received his Bachelor of Science degree from Drexel University in Philadelphia in 1979. Since then he has worked in flight test of helicopter and fixed-wing navigation systems, and development of integrated avionics systems for military aircraft. He has worked on Automatic Dependent Surveillance since 1986, including the Loran Offshore Flight Following and ADS programs.

Mr. Lorge was responsible for developing the requirements and technical approach for the PET within the FAA, and wrote the original ADS PET agreement with the airlines. He helped develop the ADS specification for Step 1, and was the prime evaluator and technical negotiator of the contract. He also participates in ADS and SatCom standardization activities within ICAO, RTCA adn AEEC.

AUTOMATIC DEPENDENT SURVEILLANCE PACIFIC ENGINEERING TRIALS

Frank L. Lorge
Federal Aviation Administration Technical Center

Background

In 1988, the Federal Aviation Administration (FAA) initiated a cooperative program, called the Pacific Engineering Trials (PET), to evaluate the operational use of Automatic Dependent Surveillance (ADS) and the data link used to support it. The PET incorporates available equipment into a functional ADS prototype for the evaluation of the operational aspects of ADS. This program will ease the transition from the current, manual system, to the fully automatic system of the future. Results will be used in developing the specifications for ADS components, and identifying operational and technical issues which must be resolved before the ADS system can become fully functional. These issues will be addressed in the development stage, to insure that the fielded system meets all operational requirements in an efficient manner.

The trials are one element of the FAA's plan to modernize its oceanic air traffic control system. FAA programs are currently underway which will result in the introduction of data link, ADS, and improved controller automation tools to oceanic ATC. The programs include Flight Data Input-Output (FDIO) Replacement, data link workstation development, and modification of the Oceanic Display and Planning System (ODAPS) to include ADS. Additional programs will provide improved communications through the use of interfaces which conform to the Open Systems Interconnect (OSI) standards and the implementation of the Aeronautical Telecommunications Network (ATN), using the FAA's Data Link Processor.

In addition, the results of these tests will be used to support a variety of other applications. These include the development of International Civil Aviation Organization (ICAO) Standards and Recommended Practices (SARPS), specification development, procedures development, validation of the work conducted by the FAA's Oceanic System Requirements Team (OSRT), and certification activities.

Work on some these initiatives has already begun. United Airlines has applied for certification of avionics to use satellite data link for oceanic ATC communications. The equipment used in the trials will be used to address certification issues. Continuing efforts by the FAA's Aircraft Certification Office in Long Beach California, the Air Traffic Services, Flight Standards Service, and the FAA Technical Center, as well as ARINC and United, are expected to result in certification in the near future.

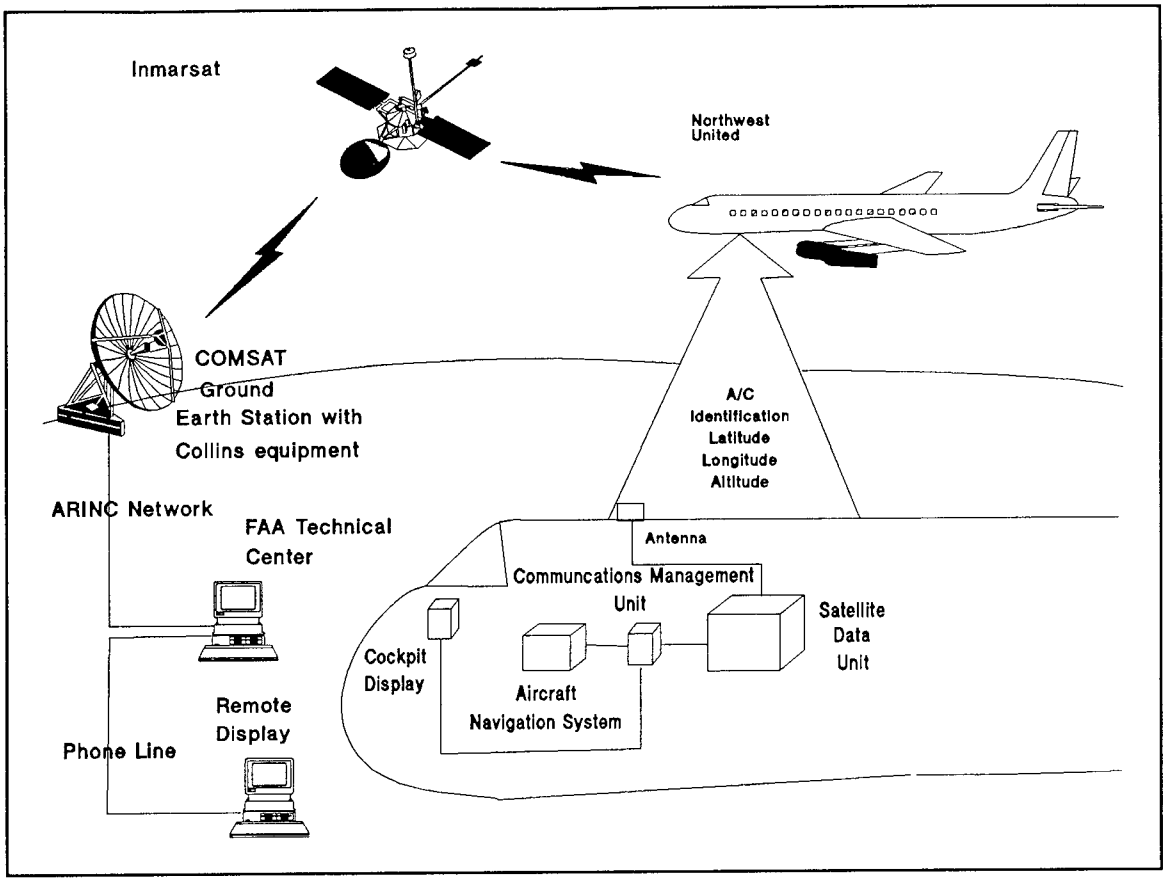


Figure 1
Pacific Engineering Trials System

Participants

The PET is sponsored by the governments of the United States, Japan, and Australia. Each of these participants is responsible for coordinating airline participation within their countries, and sharing results with the other governments. In addition, each is free to make unilateral agreements with other nations and present the results of those efforts. The additional countries participating through these unilateral agreements include New Zealand, Fiji, France, the Soviet Union, and Singapore.

In the U.S., the FAA has formed agreements with Northwest and United Airlines to participate in the trials. These airlines have agreed to install satellite communications and prototype ADS avionics on several of their aircraft. During normal oceanic flight operations over the Pacific, these aircraft will send ADS-type position reports and ATC communications messages to the ground, and receive data link messages from FAA workstations as part of the tests.

In addition to airlines, a large group of government and industry participants is involved in the PET program. Manufacturers of

avionics and aircraft, and data communications service providers have joined the FAA, its contractors and the airlines in order to conduct the trials. Participation by all these organizations is recognized as essential to the success of the program.

Equipment

The system is configured using prototype elements which provide the basic ADS functionality. This equipment will be upgraded or replaced, as the system evolves, with components which meet the required standards. The end state, which is expected to be realized in 1995, will conform to the international standards for ATN and ADS which are currently in development. Figure 1 shows the configuration of the initial system. Each major element of the system is discussed briefly below.
The avionics equipment used in the PET is comprised of existing airline equipment which has been slightly modified for these tests. Communications will be based on the Aircraft Communications Addressing and Reporting System (ACARS), which provides for the exchange of character-oriented messages between aircraft and the ground. A set of messages has been defined for use during the tests which contains information similar to that which is expected in ADS reports in the future. Text messages have also been defined which may be used, during an interim period only, to send operational ATC requests and clearances. As test results are obtained, message sets will be refined in order to produce a complete set of ATC messages. Once the fully operational ATC automation equipment is fielded, the avionics will be upgraded to conform to the avionics and certification standards which will then be in place.

Each aircraft carries a Teledyne Aircraft Condition Monitoring System (ACMS), which is used to assemble the ADS-type message, and a Collins ACARS Management Unit, which formats and addresses the message. A Collins Satellite Data Unit (SDU) is used to transmit the messages over the satellite link, using a Ball antenna. The installation has been certified in several configurations by Boeing on several of their aircraft.

The satellite system uses the existing space segment operated by Inmarsat and interim ground earth stations (IGES's), manufactured by Collins and operated in the U.S. by COMSAT. This link provides for bit-oriented communications with several aircraft at a time. Two IGES's, one on each U.S. coast, provide coverage of the Atlantic and Pacific oceans and the entire continental U.S.

The terrestrial connection is provided through the existing ADNS network, operated by ARINC, which is used by many airlines for company communications. This character-oriented network is used primarily for the transmission of ACARS messages. Connectivity is provided among many users, including airline offices, aircraft, and government agencies.

Data collection is performed by an engineering workstation computer, which is located at the FAA Technical Center, running special data recording

and presentation software. The software, developed by the MITRE Corporation, accepts messages from the ADNS communications line, records and displays them, and converts position reports for presentation on the situation display. It also provides the capability to uplink messages to any participating aircraft, and receive replies.

FAA Aircraft

The FAA Technical Center has also equipped an aircraft in order to evaluate satellite data link and ADS. This aircraft, a Boeing 727, will fly primarily along the east coast in order to conduct data link and ADS experiments.

The aircraft carries a Collins ACARS Management Unit and SDU, and has extensive data collection capability which will enable it to conduct experiments which would be impractical in airline aircraft. The data collection system records aircraft state information once per second, including heading, altitude, pitch and roll attitude, airspeed, wind speed and direction, ground speed, mach speed, navigational and steering data. The aircraft currently has INS available to provide positioning information, and a GPS receiver will be instrumented in the near future. The system also records satellite link information not normally available, such as satellite signal strength and error rates. The data system records all message traffic to and from the ACARS and the SDU, and can send and receive messages over the satellite link.

Plans for this aircraft include upgrading the SDU to a high data rate system using a high gain antenna. A GPS receiver will be installed early next year, and the aircraft will be outfitted with extended range fuel tanks in order to improve its performance on oceanic flights. Sometime next year a communications management unit will be integrated into the avionics to enable testing of the ATN, using satellite, VHF and Mode-S data links.

Data Analysis

Examples of some of the data collected to date are presented in the figures. While still at an early stage, several characteristics of the system are evident. Figure 2 shows the latitude/longitude plotted for a typical flight, along with the pilot-composed satellite progress reports. It can be seen that the satellite reports lie directly on the line of ADS reports (with one exception). The steady string of ADS reports is uninterrupted by gaps, which would result from missing reports. This demonstrates the reliability of the system, which is expected to improve as the fully standardized system components become available.

The plot also shows that automating position reports has the potential to eliminate some of the errors that can occur in the existing system. The error depicted in this plot is the result of an incorrect entry of position into the position report. This type of error occurs frequently in the current, manual system. Use of the automatic position report provided by ADS will virtually

Figure 2

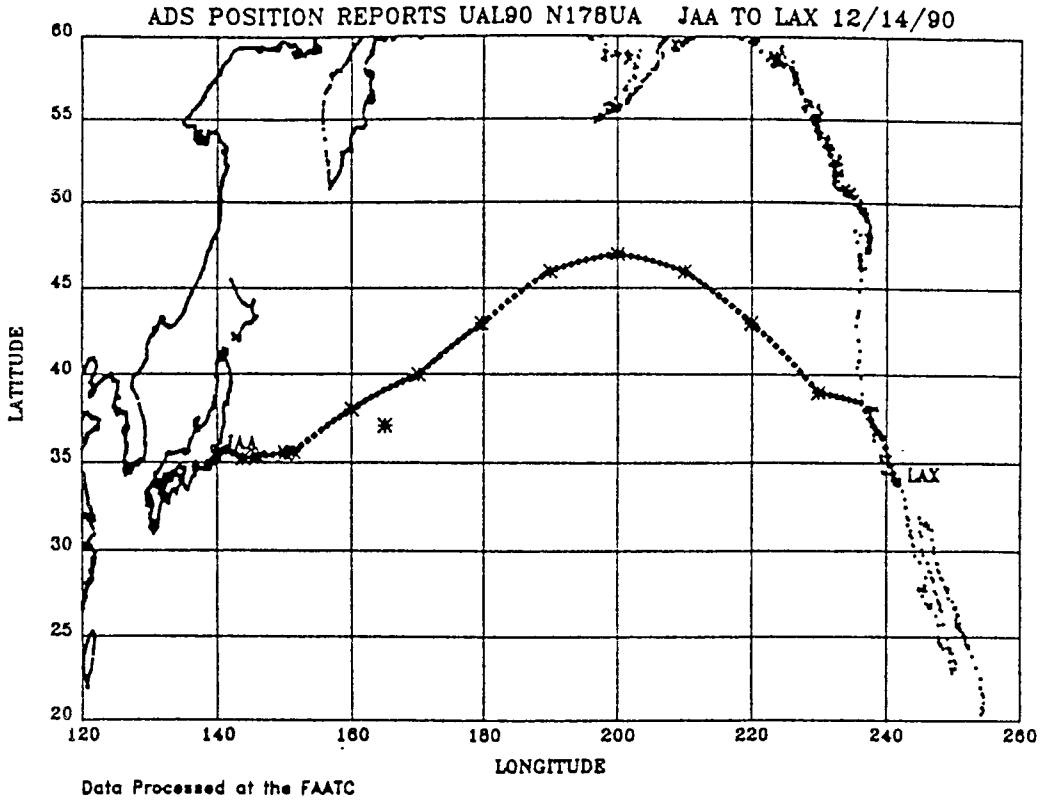
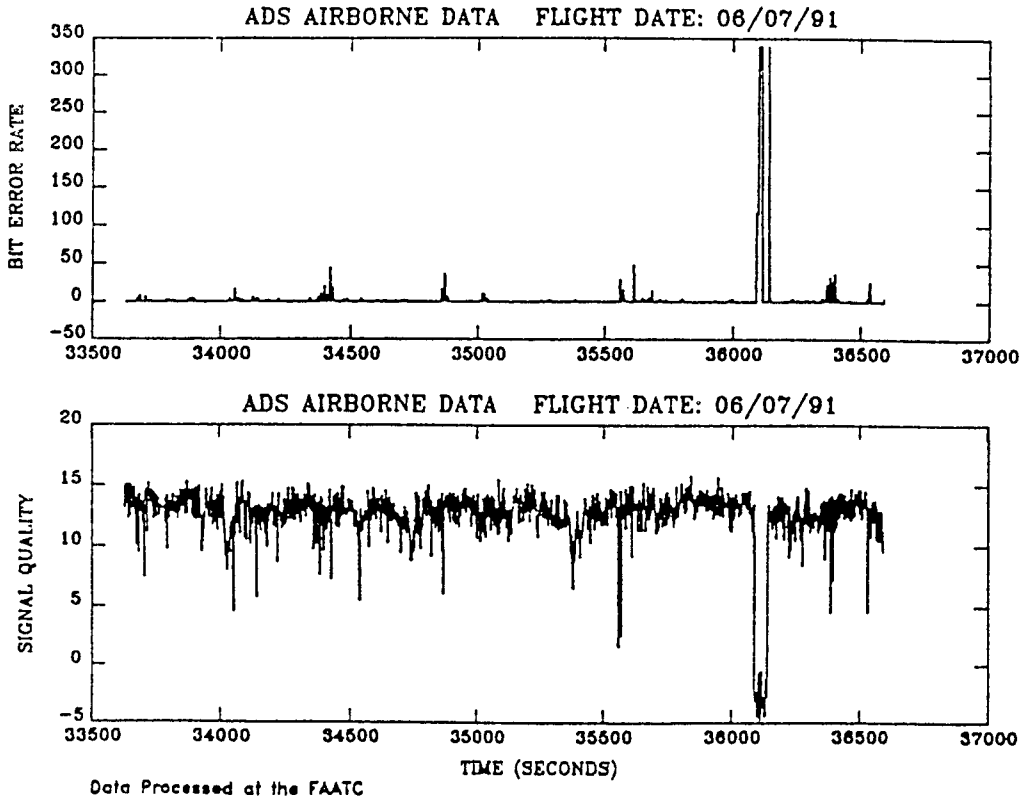


Figure 3



eliminate this problem. The implementation of ADS is intended to greatly reduce the amount of human error in oceanic flight operations.

Figure 3 shows the relationship between signal quality and bit error rate. These data, collected on the FAA aircraft, show that performance of the link, based on BER, is excellent when sufficient signal strength is available. When the signal level decreases, the BER increases rapidly and results in total loss of communications. Data of this type will be collected and analyzed to help determine under what conditions the link meets the requirements for ATC use.

Conclusion

The Pacific Engineering Trials program is still in its early stages, but results are already being applied to the development of ADS and data link. PET is one part of the overall FAA implementation strategy to improve the efficiency of oceanic air traffic control. The first step, certification of the avionics and limited use of the data link for sending ATC messages, is nearing completion.

The Pacific Engineering Trials are helping smooth the transition to the oceanic system of the future. This transition has already begun, and will result in changes to the way oceanic air traffic control is performed. This in turn will provide benefits in terms of airspace and operational efficiency while maintaining the excellent safety record of oceanic air travel.

SESSION ONE: TRIALS AND DEMONSTRATIONS

Hiroki Takeda
Special Assistant to the Director
Radio Engineering Division
Air Traffic Services Department
The Japan Civil Aviation Bureau
Ministry of Transport

Hiroki Takeda graduated from the Keio University in 1975 with a Bachelor of Science in Electrical Engineering. He then worked with the Japan Civil Aviation Bureau, Ministry of Transport charging with the development of the Radar Data Processing System (RDP). In 1977 he was transferred to the International Affairs Division, Secretariat to the Minister charging with the international technical cooperations to developing countries in transport fields. In 1979 he was sent to the Stanford University, CA., where he studied infrastructure planning and management, and graduated in 1981 with a Master of Science degree in Civil Engineering.

Following his study abroad, he worked in the Noise Abatement Division, Aerodrome Department, Civil Aviation Bureau to forecast the noise contour around the airport. He then worked in the Radio Engineering Division, Tokyo Regional Civil Aviation Bureau to implement the ATC as well as navigational facilities such as ASR/SSR, RCAG, VOR/DME and ILS.

Mr. Takeda was then transferred to the Business Administration Office, Corporate Planning Department, Kansai International Airport Co. Ltd. charging with the preparation of the business plan and budget.

He has been working for the radio engineering division, Civil Aviation Bureau since 1988 in charge with the new technologies in the aeronautical communications fields. He is now involved in the development of data link systems (VHF data link, SSR mode S and AMSS) also covering the international activities like ICAO. He is a Japanese nominated member of ICAO SICASP (SSR Improvement and Collision Avoidance System Panel) as well as AMSSP (Aeronautical Mobile Satellite Services Panel).

ADS (AUTOMATIC DEPENDENT SURVEILLANCE) PET (PACIFIC ENGINEERING TRIAL) PROGRAM IN JAPAN

Hiroki Takeda, Special Assistant, Radio Engineering Division, Air Traffic Services Department, The Japan Civil Aviation Bureau

1. INTRODUCTION

Australia, the United States and Japan have agreed to initiate a cooperative Automatic Dependent Surveillance (ADS) Pacific Engineering Trial (PET) program. The participating agencies are the Australian Civil Aviation Authority (CAA), the United States Federal Aviation Administration (FAA) and the Japan Civil Aviation Bureau (JCAB).

The commercial airlines such as Quantas, United, Northwest and Japan Air Lines are going to participate in this ADS PET program. Although the international standard for AMSS and ADS has not been finalized by ICAO yet, this ADS PET program is expected to provide the opportunities concerning pre-operational experiences as well as various technical expertise for the development of these standards.

2. OBJECTIVE

The goals of this ADS PET program are to resolve technical issues to gain operational experiences and to identify key issues related to the use of ADS. ADS is a function for use of air traffic services (ATS) in which aircraft automatically transmit, via a satellite data link, the position data derived from on-board navigation systems. As a minimum, the data includes aircraft identification and three dimensional aircraft position (Latitude, Longitude and Altitude). Additional data such as aircraft speed, way point etc. may be provided as appropriate.

ADS is the first application of direct aircraft-satellite technology for ATC. Therefore, it is important to gain as much experiences as possible with the ADS system in the development phase. The ADS PET is expected to be conducted at an early date using available equipments and prototype systems, to obtain experiences before an operational ADS system becomes available. As much data as possible will be collected and analyzed and the results will be shared among the interested parties.

3. SYSTEM CONFIGURATION

Australia, the United States and Japan utilize different aircraft, Ground Earth Stations (GES), ground data networks and ADS data processing systems respectively. The various system components to be used in this ADS PET program in Japan are shown in Figure 1. and their details are explained below.

(1) Avionics

The aircraft participating in this ADS PET program is a newly released B747-400 aircraft with the satellite communications capability. The Japan Air Lines' new B747-400s with the satellite

communications capability were delivered last December and this May. These aircraft are fitted with a low gain antenna by which a low speed data transmission (600 BPS) can be performed. The avionics conforms to a subset of ARINC characteristics of 741 which uses an ACARS (Aircraft Communications and Reporting System) type interface only and does not provide the ISO's (International Standard Organization) OSI (Open System Interconnection) based protocol.

Since the international standards for AMSS communications as well as ADS format have not been developed and finalized yet by ICAO, the specific airline's position report format (ACARS messages) will temporarily be used for this ADS PET program. Thus, ADS position report from aircraft varies from one airline to another. The format of Japan Air Lines' ADS position report is shown in Figure 2.

(2) Satellite

In this ADS PET program, the International Maritime Satellite Organization (INMARSAT) Pacific Ocean Region (POR) satellite will be used. Though the INMARSAT is preparing to launch the second generation satellite which carries a 3 Mhz band of AMSS transponder from last autumn, a maritime band of the existing satellite (POR) will be used because of its unavailability. If a second generation satellite becomes available during this ADS PET program, then the AMSS band will be utilized.

(3) Ground Earth Station (GES)

Since the INMARSAT satellite is to be used, the Ground Earth Station (GES) owned and operated by Kokusai Densin Denwa (KDD) company which is an INMARSAT signatory in Japan will be used. As the formal GES is still under development, the Interim-GES (I-GES) manufactured by Collins, which is a subset of INMARSAT SDM (System Definition Manual), will be used at the KDD GES site.

(4) Ground data networks

The KDD's I-GES will be connected to a data link computer system owned and operated by the AVICOM JAPAN which is a newly established VHF data link service company in Japan. The AVICOM JAPAN was established in September,1989 and has started VHF data link services over Japanese airspace since April, 1990, and also commenced satellite data link services (I-ACARS) over Pacific Ocean since December, 1990. The interface of Collin's I-GES matches perfectly with AVICOM's data link computer (DLC) system namely ACARS protocol.

In this ADS PET program, the software modification of AVICOM's DLC is involved. Whenever AVICOM's DLC accepts the ACARS messages, it will automatically send the messages to airline' host computer system by referring to the airline's address. Thus the AVICOM's software had to be changed so that whenever the DLC receives the ADS position reports, they would be directed to the Electronic Navigation Research Institute (ENRI), Ministry of Transport (MOT), where the ADS data processing and display system is located.

(5) ADS data processing and display system

The ADS position reports will be processed by computer systems located at ENRI, MOT. This computer system accepts the ADS data to display aircraft positions on a screen in realtime and to record them on Magnetic Tapes. This

computer system can not accept and process ADS data from UAL's, NWA's and QFA's aircraft for the time being, since each airline has different ADS message format.

This computer system was originally developed for evaluating the Cooperative Independent Surveillance (CIS) and ADS performances in the Engineering Test Satellite (ETS-V) experiments. It was modified to allow reception of ADS data sent from the AVICOM's DLC. The system uses NEC's MS135 mini-computer with a 20-inch high resolution color display. Aircraft position derived from ADS data will be indicated with a certain symbol on the display along with air routes, latitude/longitude lines and coastal lines, etc..

4. DATA ACQUISITION FLOW

The data acquisition flow is shown in Figure 1 and Figure 3. In order to derive the ADS position report from aircraft, the Japan Air Line's host computer has to initiate the polling messages (ADS position request uplink), which are automatically generated every 5 minutes by computer. This polling messages will be transmitted to AVICOM's DLC, then they will be relayed to KDD's I-GES. The KDD's I-GES will transmit this polling messages to Japan Air Line's B747-400 through INMARSAT POR satellite according to the subset of INMARSAT SDM format.

Whenever Japan Air Lines's AES receives these polling messages, the airborne computer (ACARS) generates ADS position reports by referring to its INS position and send them back to I-GES through INMARSAT POR satellite. Then ADS position reports from I-GES will be relayed to AVICOM's data link computer. When AVICOM's data link computer receives ADS position reports, it will deliver them not only to Japan Air Line's host computer but also to ENRI's ADS data processing and display system.

This is a basic ADS data acquisition flow to be adopted in the ADS PET program when the aircraft is over Pacific Ocean, namely outside VHF data link coverage. However, there is an exception in this ADS PET program. In order to avoid pilot involvement as well as modification cost on airborne equipments, no modification will be made to airborne equipments such as ACARS management system, satellite data unit.

According to Japan Air Line's avionics specifications, when both VHF data link and satellite data link are available (over land area), the ACARS unit will automatically select the VHF data link channel for economic reasons. Thus, the ADS position reports will be sent via VHF data link channel when the aircraft is over land area or near the coastal area. This situation is shown in Figure 3. At the beginning phase (take off, transition to oceanic route and level flight) and the final phase (level flight, transition to domestic route and landing) of the flight, the satellite data link, therefore, will not be used and no performance evaluation can be realized in terms of satellite data link path during those phases.

5. DATA ANALYSIS METHOD

Potential evaluation items are as follows. Analysis of the collected data will be done on an off-line basis.

(1) ADS positions

(a) Comparison with SSR data

This would be possible over and near the land area where SSR data is available. Since SSR data could be provided on an off-line basis, comparison would be made later. In this case, it would be desirable that clocks for ADS and for SSR are synchronized or calibrated at least.

(b) Comparison with flight plan data

This would be possible along the entire oceanic route if flight plan data is available. It only checks possible discrepancy between ADS based position and position in flight plan. It would not give quantitative analysis data.

(2) Transmission errors

Transmission errors will be evaluated in terms of characters. They will be measured by comparing the content of transmitted ADS reports with that received at the ENRI. The transmitted data will be recorded in the ACMS (Aircraft Condition Monitoring System). After the flight, this data will be distracted from the ACMS.

The C/N_0 will not be measured because of the lack of appropriate measuring devices at the GES. The aircraft attitude during the flight will be recorded nearly every 5 seconds by the ACMS.

(3) Transit delays

Transit delays will be estimated by using an on board recorder and computer timer at the GES as well as at the ENRI. It will give rough estimates of time delays on such path as AES to GES and AES to ENRI, etc. Measurement accuracy is limited by the time reference accuracy at each measuring point, typically on the order of a second.

6. PROGRAM SCHEDULE

Airborne equipment, AVICOM's DLC and ENRI's ADS data processing & display system has been modified to establish the air-to-ground link for the ADS PET program by the end of May and the ground to ground test was completed with the use of pseudo aircraft terminal at the beginning of June. The first initial flight test was conducted in July, 1991 to evaluate the end to end performance, and it was successfully completed. It is now expected that the actual flight test with the use of Japan Air Lines' revenue flights for the ADS PET program starts from this August.

The destination of the flight and the number of flight tests to be conducted in FY1991 as ADS PET program are as follows.

(1) Narita to New York (JFK)
(About 20 flights)
(2) Narita to Singapore (Changi)
(About 10 flights)
(3) Narita to Saipan
(About 10 flights)
(4) Narita to Europe
(About 10 flights)

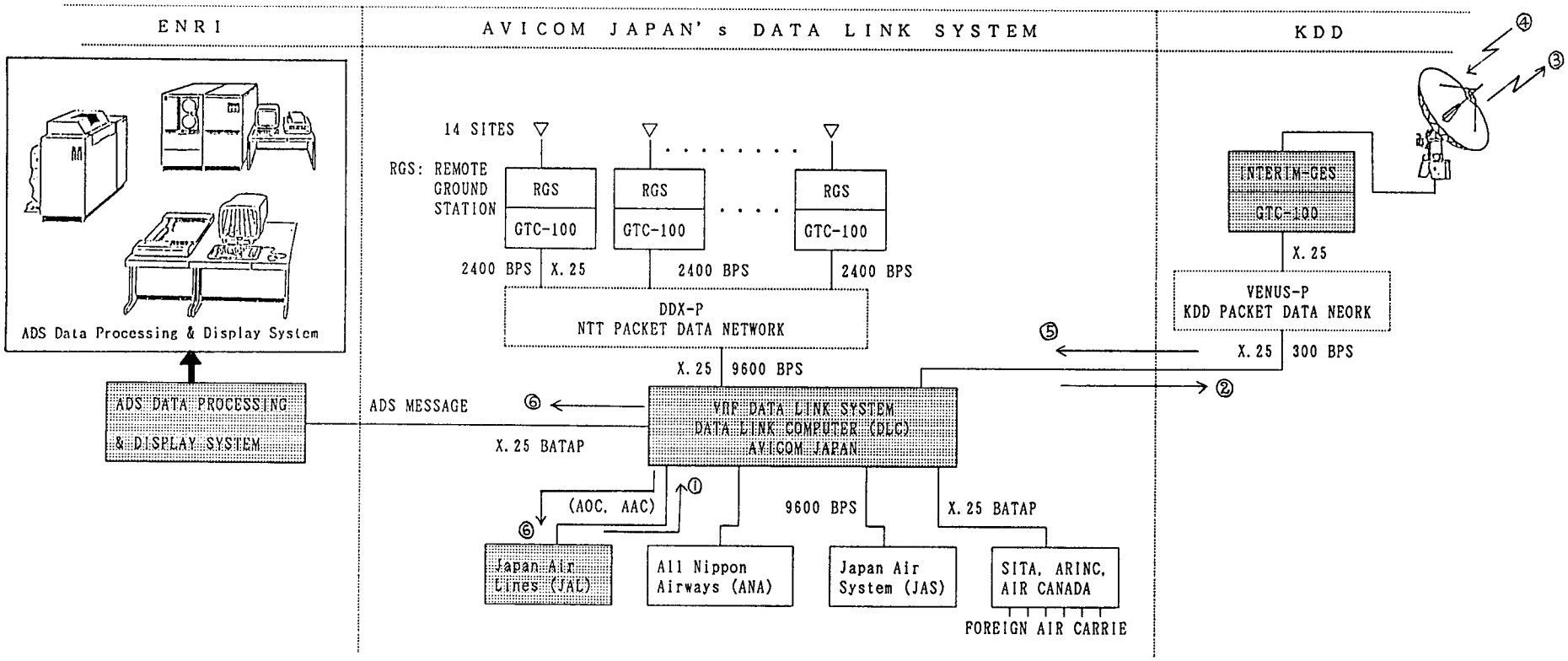
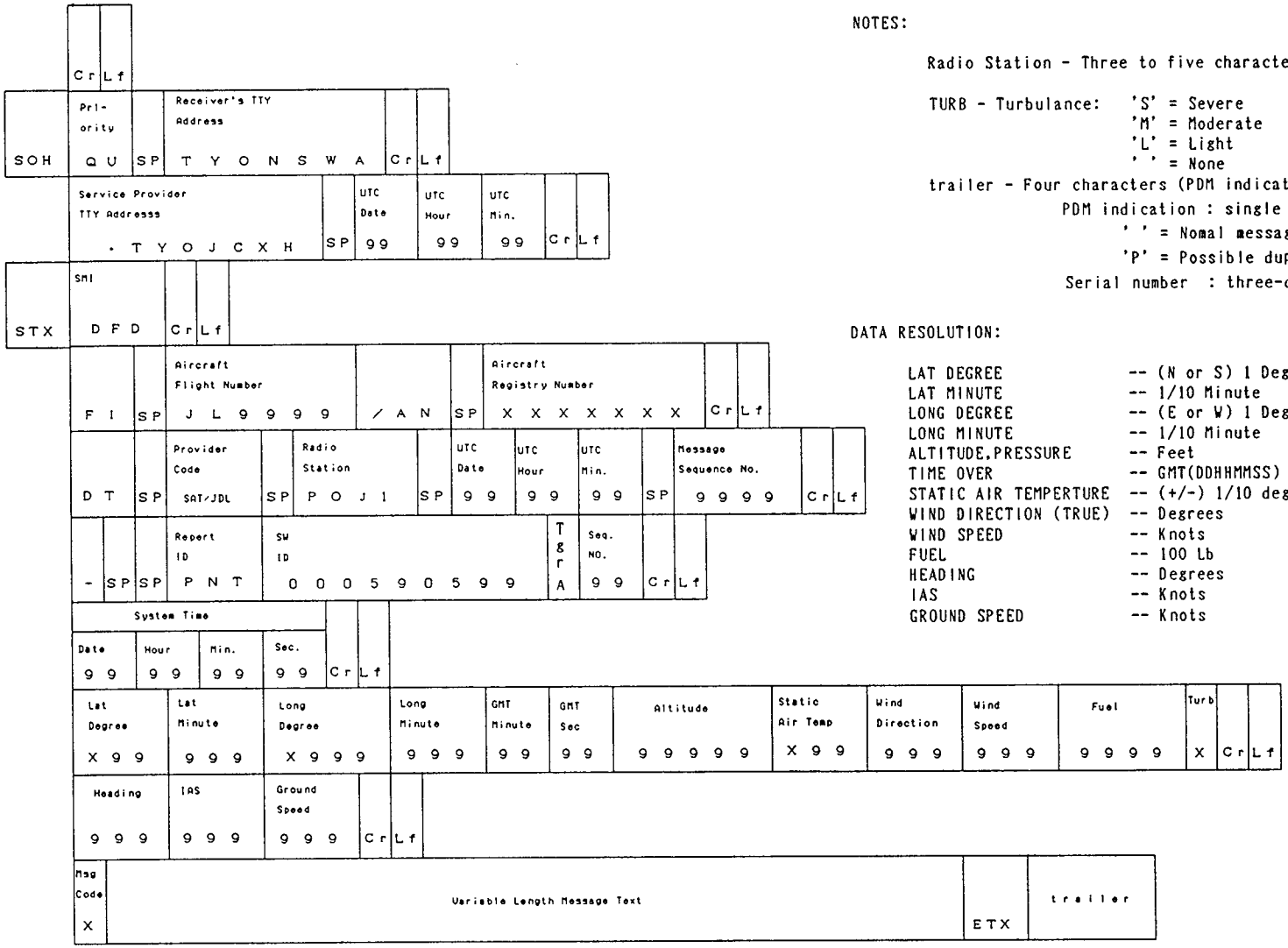


FIGURE 1. ADS PET PROGRAM IN JAPAN



NOTES:

Radio Station - Three to five characters (four shown)

TURB - Turbulance: 'S' = Severe
'M' = Moderate
'L' = Light
' ' = None

trailer - Four characters (PDM indication and serial number)
PDM indication : single character
' ' = Nomal message
'P' = Possible duplicated message
Serial number : three-digit decimal number

DATA RESOLUTION:

LAT DEGREE	-- (N or S) 1 Degree
LAT MINUTE	-- 1/10 Minute
LONG DEGREE	-- (E or W) 1 Degree
LONG MINUTE	-- 1/10 Minute
ALTITUDE,PRESSURE	-- Feet
TIME OVER	-- GMT(DDHHMMSS)
STATIC AIR TEMPERTURE	-- (+/-) 1/10 deg.Cent
WIND DIRECTION (TRUE)	-- Degrees
WIND SPEED	-- Knots
FUEL	-- 100 Lb
HEADING	-- Degrees
IAS	-- Knots
GROUND SPEED	-- Knots

Fig 2. ADS Position Format by JAL

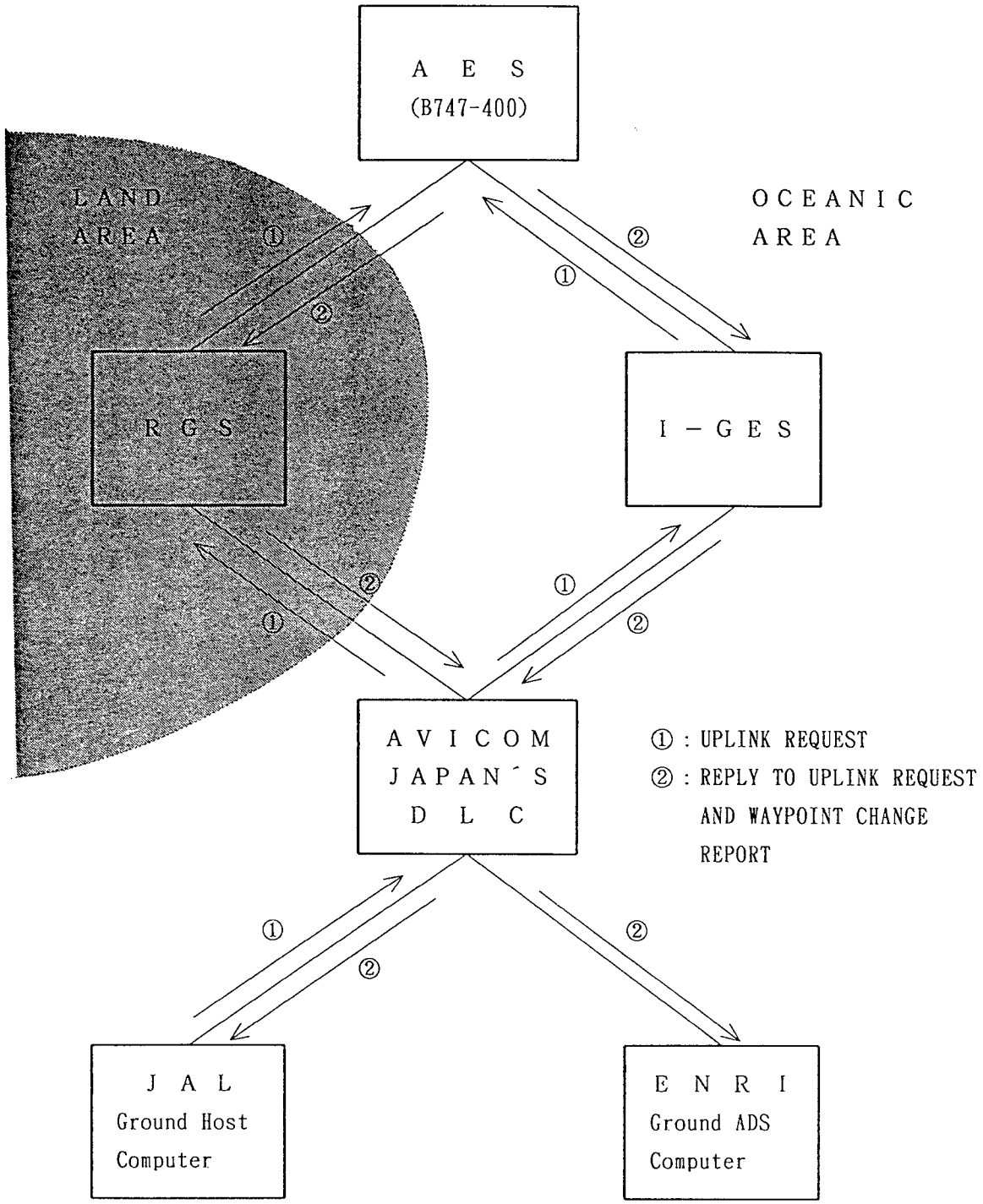


Fig.3 DATA ACQUISITION FLOW

SESSION ONE: TRIALS AND DEMONSTRATIONS

H. Brian O'Keeffe
Acting General Manager
Research and Development
and ICAO Division
Civil Aviation Authority, Australia
Chairman - ICAO FANS Committee

H. Brian O'Keeffe is Acting General Manager-Research and Development and ICAO Division, Civil Aviation Authority (CAA), Australia. In this role he provides advice to the CAA Executive on the impact of international technological developments on civil aviation. He is also Chairman of the ICAO Special Committee on the Monitoring and Coordination of Development and Transition Planning for the Future Air Navigation Systems (FANS) System (FANS Phase II).

Mr. O'Keeffe joined the Department of Civil Aviation in 1956. He carried out navigation aids research at the University of Adelaide from 1957 to 1959 and then joined the Department's Airways Engineering Branch in Central Office in Melbourne, advancing to the position of Senior Assistant Secretary - Planning Research and Development in 1975.

In 1982, he was appointed head of the Airways Division, which involved the planning, design, provision, and operation of air traffic control, flight service, operational control, and rescue and fire fighting services, as well as navigation, communication, and radar surveillance facilities and services.

He has been the Australian member of the ICAO FANS Committee since its formation, and once served as its Vice-Chairman. In mid-1988 he was elected as Chairman of the FANS Phase II Committee. In May 1990 he was elected Chairman of the FANS Phase II Committee that is associated with the global implementation of the FANS concept.

Following the establishment of the Civil Aviation Authority, he was appointed General Manager - Advanced Systems Development, responsible for the planning, research, design, and development of technologically advanced airways systems to meet the needs of aviation over the next 20 years in a cost-effective manner.

He graduated with a bachelor's degree in Engineering (Electrical) from the University of Queensland in 1956.

AUSTRALIAN EXPERIMENTS IN AUTOMATIC DEPENDENT SURVEILLANCE (ADS) INCLUDING THE PACIFIC ENGINEERING TRIALS (PET)

Brian O'Keeffe
Civil Aviation Authority, Australia

INTRODUCTION

Japan, Australia and the United States have agreed to a co-operative Automatic Dependent Surveillance (ADS) Trilateral Pacific Engineering Trials (PET) test program.

The participating agencies are the Australian Civil Aviation Authority (CAA), the Japanese Civil Aviation Bureau (JCAB), and the United States Federal Aviation Administration (FAA). National carriers of the three countries are also involved.

Two meetings have been held to devise and agree on details of the test program.

The latest meeting was held in Tokyo from 4 to 8 February 1991. Besides representatives from Australia, Japan and USA, observers were present from USSR, France, Fiji, New Zealand, Japanese airlines and other institutions. The next meeting will be held in Australia from 9 to 12 December 1991.

ADS data are being received in Australia from some transpacific flights and exchanged between the agencies. Increasing amounts of data are expected as more aircraft with ADS capability are placed in service.

Australia is also receiving ADS data from two domestic carriers via VHF ACARS.

The development of a general purpose display system is continuing. The displays can be driven by flight plans/pilot

position reports, ADS data or radar data. Prototypes are being placed in ATC centres for evaluation.

OBJECTIVES

The objectives of the ADS program are to

a) resolve technical issues;

b) to gain operational experience in the compilation, transmission and reception of ADS data messages;

c) to identify key issues relating to the use of ADS and pilot-controller data communications;

d) to gain experience in the development of display systems suitable for ATC;

e) to gather and correlate data from ADS, voice position reports, and radar for eventual input to the ICAO RGCS Panel to assist in their deliberations on separation minima in ADS airspace and in airspace with both ADS and non-ADS equipped aircraft.

The operational implementation of ADS and direct pilot-controller data communications will result in benefits to the airlines and air traffic services in the form of reduced separation minima, reduced ATC workload and the more efficient use of aircraft and airspace outside radar coverage.

ADS reports may also contain additional information on aircraft velocity vectors, weather details and the future intention of the aircraft in terms of the current flight plan. These data will allow the rapid detection of waypoint-insertion and other errors navigational errors and thus enhance the safety of operations.

The ADS program is being actively implemented using available equipment and prototype systems. Experience gained will enable an operational system to be implemented as soon as practicable.

CURRENT STATUS OF THE AUSTRALIAN DOMESTIC PROGRAM

Domestic ADS

In many parts of the world, including Australia, ADS will be beneficial in continental as well as oceanic areas.

In areas where VHF air-ground communications are possible, it is likely that ADS could be achieved at lower cost via VHF than via satellite. In addition, in the medium term there will be many more aircraft (particularly those used by domestic carriers) capable of VHF/ADS than satellite/ADS.

Australia is therefore experimenting with VHF/ADS as well as with satellite/ADS in the PET trials.

In a joint effort with SITA and our domestic airlines, some 1000 ACARS aircraft messages per day are received in the CAA's Head Office in Canberra. They are interfaced to our general purpose aircraft display system. It is proposed that technical evaluations including correlation with radar data will be performed.

ACARS messages and their transmission rate are not suitable, as they stand, for an operational ADS system. However the transition to specific ADS messages by VHF is not difficult.

Display systems

The benefits of ADS cannot be fully realised without adequate display systems. The traditional flight progress board is quite unsuitable for displaying frequent position updates.

The Australian CAA is therefore developing, and has progressed to a prototype phase, a low-cost hardware/software package implemented on commercially available workstations. Evaluation displays have been installed at Adelaide and will shortly be installed in the Sydney ATC centre.

Other experimental projects

The CAA is also experimenting with ADS through the use of a suitably equipped vehicle. The vehicle has been fitted with a GPS receiver, INMARSAT standard C earth station, computer, ACARS unit, antennae, power supplies and ancillary equipment.

The vehicle will be used to test and validate the proposed ADS and communications systems for FANS including the following:

a) simulation of an aircraft by generating time tagged position reports and transmitting these via satellite back to the CAA;

b) checking data integrity and bit error rates;

c) assessing transmission delays via alternative routing;

d) analysing protocols and procedures;

e) development and testing of a small ground earth station for the direct reception of ADS messages at the ATC centre and investigating the direct reception and decoding of a simulated aircraft signal by a ground station in Australia.

CURRENT STATUS OF THE PET

Pre-operational trials over the Pacific are being held in collaboration with the Japanese Civil Aviation Bureau and with the FAA under a Memorandum of Co-operation. Participating airlines are Qantas, JAL, ANA, North-West and United.

ADS data are being received in Australia from some transpacific flights. Increasing amounts of data are expected as more aircraft with ADS capability are placed in service.

At the meeting in Tokyo, Australia reported that it was developing low-cost general purpose display systems for ADS. As noted above, the displays will also be able to show aircraft positional data derived from radar and from flight plans/voice position reports.

Experimental displays are being installed at Sydney and Adelaide.

Qantas have taken delivery of their first SATCOM equipped B747-400 aircraft. CAA has an agreement with them to capture ADS data and share these with other Pacific aviation administrations.

Reports were also received at the Tokyo meeting from the Japan, USA, France and USSR representatives.

FUTURE PET CO-OPERATION

The participants and observers at the Tokyo meeting resolved to freely exchange data and information relating to ADS.

The USA offered to document a generic work plan of the PET program which would be a consolidated statement of individual projects and experiments being conducted by the PET participants and observers.

It was seen as highly desirable that a program of ADS data analysis and reduction be agreed so that useful input could be made to the RGCS and ADS Panels. The objective of allowing operating credits to ADS equipped operators is dependent on a reduction in separation minima and thus PET data on ADS performance and accuracy must be made available to RGCS Panel as soon as practicable and on an on-going basis.

The next PET meeting will be held in Australia from 9 to 12 December 1991.

CONCLUSION

ADS will bring significant benefits to the aviation industry and service providers.

The PET program and the experiments with Australian domestic carriers and new display systems are demonstrating the practical feasibility of ADS.

CO-AUTHOR

Graeme Challinor
Manager
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Graeme Challinor is Manager, Analysis Research and Development, Civil Aviation Authority, Australia. He manages a technical and operational group carrying out R&D projects related to FANS. He is also the Australian member of the ICAO ADS Panel.

He graduated from Oxford University in Natural Sciences (Chemistry). He carried out research work in nuclear magnetic resonance spectroscopy at Oxford and then joined the Atomic Energy Research Establishment, Harwell in 1964.

He worked as Senior Chemist for the Pyrethrum Board of Kenya. He is a private pilot. During this period he obtained Membership of the UK Institute of Statisticians by examination. He was subsequently elected to Fellowship in recognition of his work in operational simulation techniques.

In 1972 he joined the Australian Department of Civil Aviation and trained as an air traffic controller. He headed the operations research section. With the formation of the Civil Aviation Authority he took charge of an R&D group with interests in simulation modelling, airport capacities and delays, air traffic management, and artificial intelligence techniques and their application to air traffic services. The group is also managing the Australian Automatic Dependent Surveillance program including the development of new display systems for ATC.

SESSION ONE: TRIALS AND DEMONSTRATIONS

Pascal Senard
SATCOM Project Manager
Air Navigation Technical Center
French DGAC

Pascal Senard is Project Manager within the Advanced Systems Division for the french Air Navigation Technical Center (STNA), a position he has held since 1988. He is in charge of the evaluation of the satellite communications systems impact in the ATC services.

Mr. Senard is actively involved in the ICAO AMC and ADS Panels as assistant to the french nominees. He is currently directing the SATCOM experiment in the South Pacific.

He joined the STNA from the french Flight Test Center where he served as Microwave Landing System (MLS) flight test engineer, after having held a position in A-320 avionics development programs.

Mr. Senard holds a "Ingenieur" degree in Civil Aviation and Air Transport from the Ecole Nationale de l'Aviation Civile, Toulouse, France.

FRENCH SATCOM PROGRAM AND RELATED INTERNATIONAL ACTIVITIES

P.Senard / P.Gauthier

French DGAC-STNA, Paris, France

1 - ABSTRACT

This paper describes the work that the French Administration wishes to undertake, or is currently performing, in the field of satellite communications used for ATC purposes.

The aim of this work program is to prepare the possible integration of a future Satcom-based ATC system, in consistency with the needs specific to the French Civil Aviation and in harmony with the approach adopted at an international level.

Therefore, the paper will start with a short introduction recalling the context in which French ATC authorities have to deal with the emerging concept of satellite communications.

This will be followed by a general presentation of the intended work program and of its successive steps.

2 - INTRODUCTION

2.1 - International context

For some time now, the French DGAC, as most of its colleagues, has been showing a growing interest for satellite communications. This interest is driven by two major events, that have occured recently inside the civil aviation community:

The first event is the availability of the first Aeronautical Satcom system. This system is provided by Inmarsat and has been primarily designed to be used by airlines for passenger communications or for their own purposes. Initial versions of avionics and ground facilities supporting this system are now available and may be used by ATC for preliminary trials and experiments.

The second event, related to the first one, is the effort carried on by international organisations such as ICAO and RTCA to ensure at an early stage a sufficient level of standardisation of future AMSS systems. These efforts are reflected in the documents issued by these organisations: SARPs for ICAO, with the main objective of ensuring interoperability between systems; and MOPS for RTCA, which define minimum performance requirements.

According to the current international context, it is now probable that the use of satellite communications for ATC will develop rapidly. However, this development is likely to take place mainly in those countries where the need for a Satcom-based ATC system is particularly clear,that is: countries which control wide oceanic areas with a high density of traffic, or where the satellite is the only identified means to overcome the shortcomings of classical communication media.

2.2 - Specificity of French situation

France, as a number of other countries, is responsible for several airspaces with widely differing characteristics. If we consider, for example, the metropolitan territory and the South Pacific region, it is obvious that the situation concerning air traffic control and the needs in air-ground communications is completely different.

In the first case, we are talking of a continental airspace with a high density of traffic and extensive infrastructure, a strong need for operational coordination with European neighbouring countries, and where the Mode-S Secondary Radar - as in most other European countries - is seen as an efficient way of providing the required air-ground communication and surveillance capacity.

On the opposite, the South Pacific region is a wide oceanic airspace with relatively low traffic density. Control procedures relying mostly upon HF communications have been successfully used up to now. The situation is the same for the other states involved in the control of South Pacific airspaces, ensuring a satisfactory coordination between the various participants.

Whereas the need for satellite communications, as far as the metropolitan territory is concerned, is for the moment rather unclear, the use of a Satcom system could confer to ATC in the South Pacific and in the Brest ACC which is interfacing oceanic airspaces some improvements which need now to be assessed.

This example underlines the diversity of situations and of needs that must be accounted for, when we consider the possibility of integrating a Satcom system to support ATC.

3 - TENTATIVE OVERALL PROGRAM

3.1 - Main steps overview

The main objective of the program is, as mentioned above, to prepare the possible integration of a future Satcom system to be used by French ATC.

First step: preliminary study and demonstration trials

It is then necessary, before anything else, to have a clear idea of the benefits that we can expect from such a system. In other terms, the first step of the program consists in a preliminary study to express our need for a Satcom-based ATC system. The most appropriate way to formalise this work is to issue a document called functional definition of requirements (and user needs), which summarizes, in terms of functions, the services that the system is expected to provide. Demonstrations trials are committed for that purpose.

Second step: predefinition study

The functions of service that can be found in the functional definition of requirements remain at a strictly qualitative level (in particular, any reference to technical solutions must be banished from this document). The next step of the program is then an attempt to express the requirements in a quantitative way. This is achieved by defining, for the various functions, some criteria, with a target level and a possible flexibility. Technical orientations may also be proposed at this stage. The outcome of this task will be another document, called functional and performance specification, which is supposed to be a faithfull reflection of the user expectancies. This second step may be considered as a predefinition phase. It must take advantage of the experience and expertise gained at an international level through the work performed by the different working groups.

Third step: evaluation of proposals

The interest of the functional and performance specification is to serve as an objective basis for the selection of a system configuration, with the associated service provider(s).

Suppliers will be able to propose a system design based on this document, and their offers, together with the ones concerning already existing systems, will be compared by evaluating their degree of conformance to the aforementioned specification. This evaluation of proposals is the third step of the program. A decision must be taken at this stage on a "go" or "no go" basis, that is: whether to continue the program with the most suitable configuration and supplier (and in that case the level of uncertainty must be evaluated); or to stop it if the requirements expressed in the specification cannot be satisfactorily fulfilled.

Preoperational phase and operational deployment

If the third step has led to the selection of a service provider, the next step will consist in a preoperational phase, where the new services will be integrated to the current ones and validated. This preoperational phase, which finalizes the system definition, will be followed by the final step of the program which is the operational deployment.

This overall approach is summarized in figure 1, which shows the succession of the different phases of the program.

The following paragraphs present the work plan envisaged by the French Administration about the first two steps: the expression of the needs and the predefinition study, which are considered as short-term tasks.

3.2 - Preliminary study and South Pacific Trial

3.2.1 - Expressing the needs

The objective of this first step of the program is the issue of the functional definition of requirements, which is aimed at expressing the needs for a Satcom-based system.

In this preliminary study, emphasis will be put on the oceanic areas under French responsibility, where a potential need for satellite communications has been identified. Potential users of the system (i.e pilots and controllers) will be questionned by engineers involved in Satcom development are to be set in order to define what should be expected from the satellite communications service. The South Pacific trials are dedicated for helping the operational people to operate such a system and return pertinant comments.

Two important points must be kept in mind during this study: first, consistency must be maintained with the developments implemented in neighbouring flight control areas, in order to ensure a uniform level of service all along the regional routes; second, the possibilities offered by the satellite must be considered in relation with the development of ADS in the region of concern.

According to these points, the South Pacific Trial is an important element of this preliminary study. This experiment is described with more detail in the next paragraph. Although it uses early versions of avionics and protocols, which are not SARPs-compliant, it will provide an operational background to the study and will help to clarify the kind of benefits that can be expected from the satellite. Furthermore, the trial is coordinated the PET (Pacific Engineering Trial) program, and as such will contribute to harmonised ATC developments in the Pacific region.

Although this preliminary study will mainly focus on the use of satellite in oceanic areas, it will also consider the possibility of Satcom implementation in the metropolitan area, in the frame of a coordinated management of European airspace. Studies in this field should be performed in close cooperation with Eurocontrol.

3.2.2 - The South Pacific Trial

The South Pacific Trial should start by the end of September 1991. It will use a Boeing 747-400 of the UTA airline equipped with Collins "data 1" avionics, a Canadian Marconi high gain antenna and a Ball low-gain antenna. When flying over the Oceanic Control Area of Noumea (which should happen once a week during regular scheduled operational flights), the plane will transmit ADS messages to the Control Center. These ADS messages will be automatically assembled by an ACARS unit on-board the aircraft and will be routed to the controller via the Pacific Ocean Inmarsat satellite, an Satellite Aircom consortium Ground Earth Station (most likely Perth's), and the SITA network.

The controller will be able to visualise, on a graphic display, the movement of the plane according to the ADS position reports. Provision has been taken for an additional data-processing facility.

Due to the use of data 1 avionics, the ADS reporting messages will be embedded in the ACARS format, and simplified protocols (non SARPs-compliant) will be used over the satellite link.

In addition to the transmission of ADS messages, both pilot and controller will have the possibility to exchange free-text, manually typed, ACARS messages. Furthermore, voice communications, using a 9.6 kilobit per second codec, will be available for crew and passengers.

Naturally, the system described here is purely experimental and, for safety reasons, will not interfere with the classical control procedures. However, the possibility to replay flight records will allow the simulation of a number of scenarios. This should be a major help in defining what could be the role of the satellite in the diverse aeronautical services of: search and rescue, flight information, surveillance and strategic planning, and tactical control.

3.3 - Predefinition study

As mentioned above, the predefinition phase is based on the results of the preliminary study, which are contained in the document functional definition of requirements. The role of the predefinition study

is to define the criteria by which the degree of satisfaction given by the system can be quantified. For each criterium identified, a target level must be established, together with the flexibility allowed (if any) with respect to the target value.

It is essential at this stage of the program to maintain a strong coordination at international level. This will allow to identify, among the various standardization, simulation and experimentation programs undertaken in the different countries involved, the results which may help to express the requirements in a quantitative way.

The scope of the study is illustrated in Figure 2, which gives an example of typical criteria which can be applied to the Satcom-based ATC services. The relationship between the criteria and the services, as well as the target levels and flexibility values, must be determined in accordance with the work performed by the relevant international bodies. In particular, it is important to note that the results of the on-going SARPs and MOPs finalization, and validation, will be major inputs to the study.

Eventually, the results of the study should be synthetized in the document functional and performance specification, which could serve as a negotiation basis for a potential onfiguration proposed by service providers to French Civil Aviation.

3.4 - Schedule

As far as the schedule of the program is concerned, only tentative dates can be given for the time being. The preliminary study is foreseen to last until end 1992. The predefinition study should start approximately at mid-1993 and extend over an estimated one-year period.

The continuation of the program is dependent upon the outcome of the first phases, and no forecast is made yet concerning schedule. However, it is likely that a Satcom-based ATC system will not be operational in a French-controlled airspace before the end of the decade.

4 - CONCLUSION

By undertaking this program, the French Civil Aviation wishes to play a role in the general plan set up by the FANS II Comittee. The objective of this genral plan is to take the best advantage of the new concepts in air-navigation.

concepts, and in particular of the possibilities offered by satellite communications. In accordance with this overall direction pointed out by the FANS II Comittee, France and is developping an approach to allow the integration of a future Satcom-based system.

This approach has been presented in this paper and is characterized by a program breakdown in successive phases, starting from the expression of the user needs to end up with the operational deployment of the system. For the time being, provisions in the workplan of French Civil Aviation are made for the first two phases, which consist in a preliminary study (expression of needs) and a predefinition study (definition of satisfaction criteria).

Whereas the will to respond in an optimal way to French-specific ATC needs is a major aspect of this program, another prioritary objective is to maximize the benefits at a more global scale: a regional-scale could be considered initially (in the North Atlantic, the Pacific or in Europe), the final aim being a worlwide harmonized use of satellite communications for ATC purposes.

For this reason, a tight cooordination and a stimulating cooperation between all the entities involved in these developments are felt to be a major condition for general success.

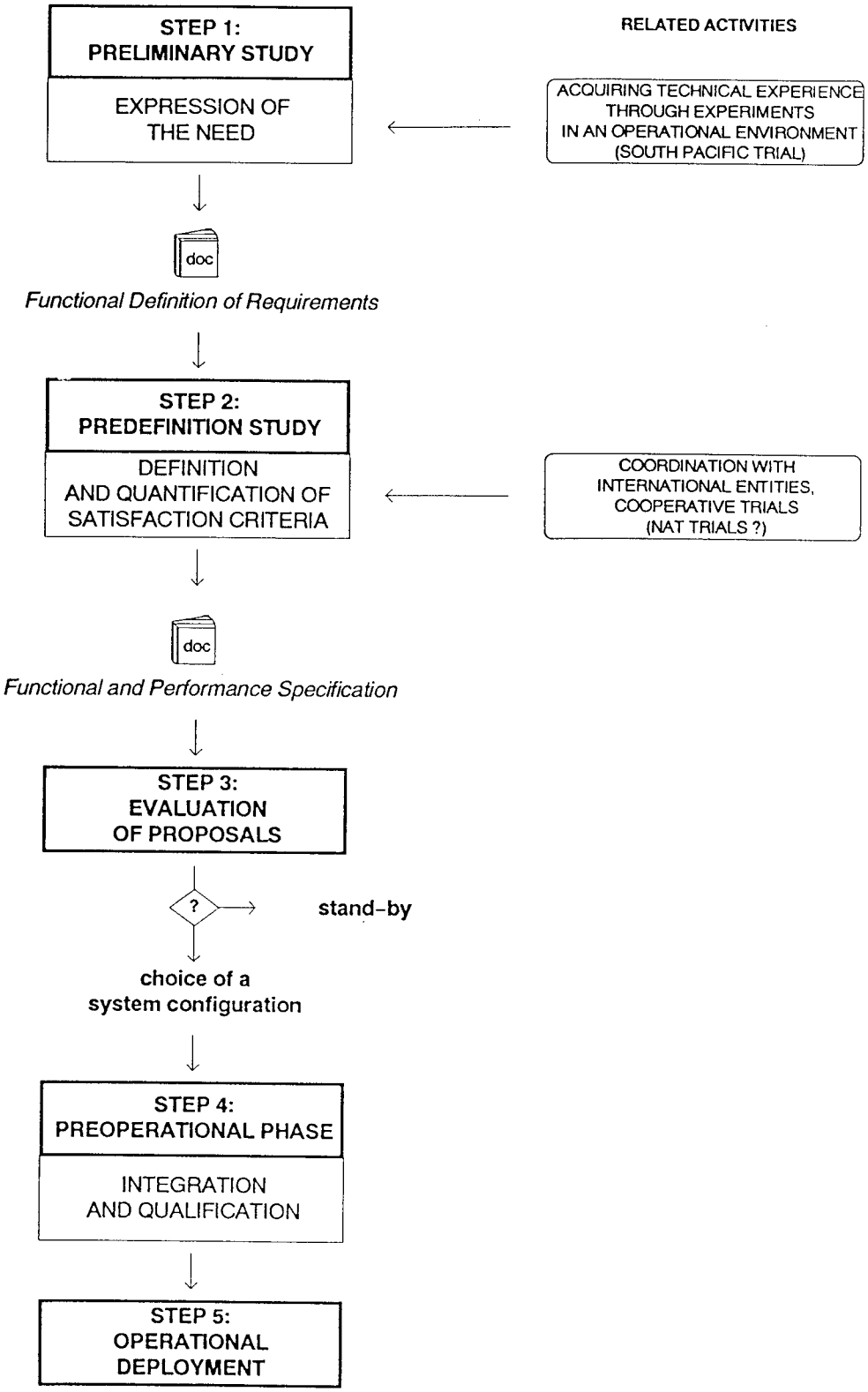

FIGURE 1 - OVERALL PROGRAM PHASING

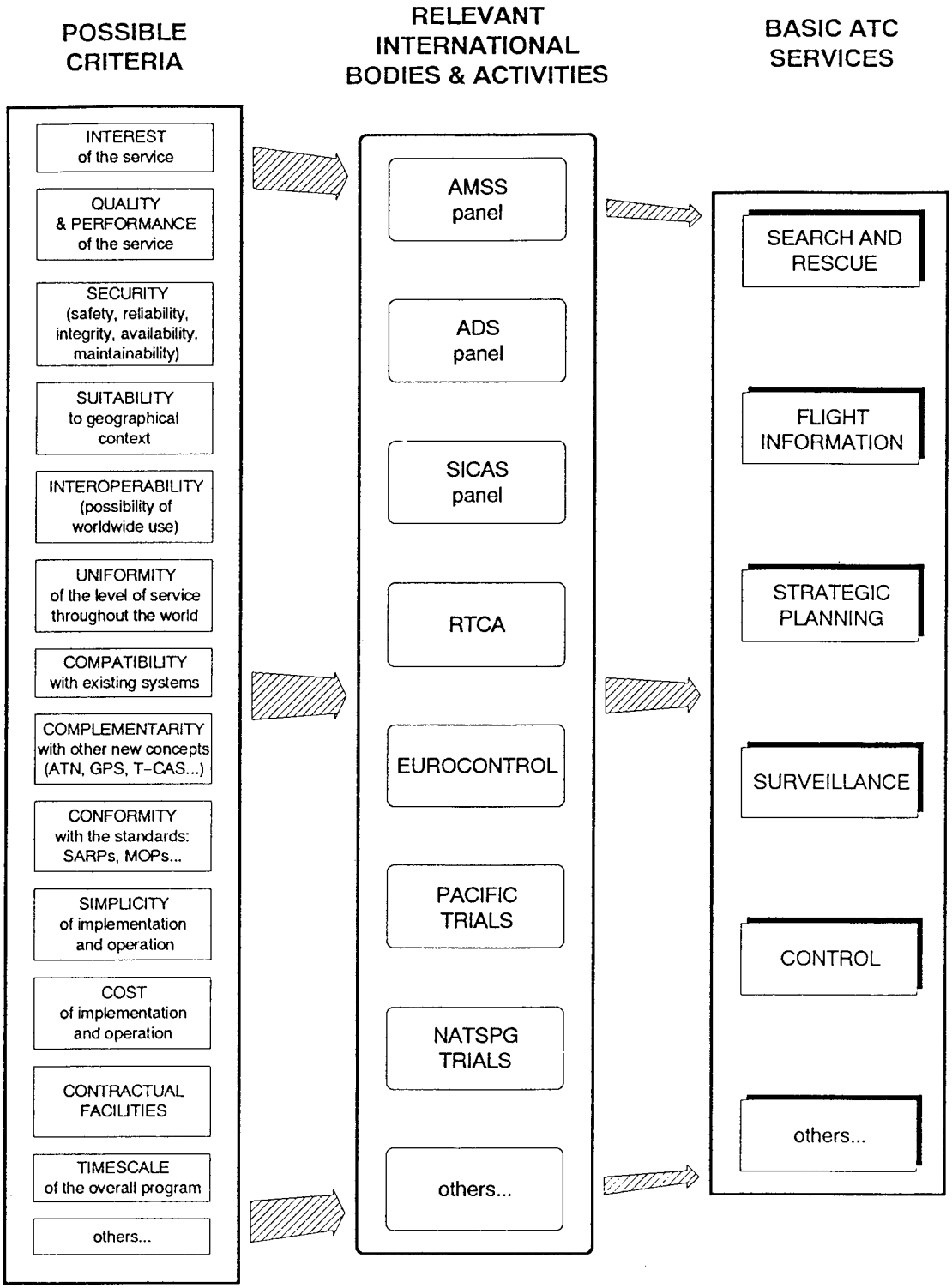

FIGURE 2 - SCOPE OF THE PREDEFINITION STUDY

CO-AUTHOR

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Patrice Gauthier graduated in 1987 from the Ecole Superieure d'Electricite, with a specialization in Radio Communications.

He then joined Altran Technologies, a consultant group specializing in advanced technologies, particularly in space and aeronautical fields.

After a three year mission for Matra Space Systems, where he participated to the definition of commercial communication payloads, he was assigned by the technical services of French DGAC to study the possibility offered by mobile satellite communications for Air Traffic Control applications.

As such, he has been involved in the development of standards (SARPs) for an Aeronautical Mobile Communications Service.

SESSION ONE: TRIALS AND DEMONSTRATIONS

Teresa A. Anderson
Air/Ground Services Planner
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ARINC

Teresa A. Anderson is the Services Planner for ARINC's International HF and Satellite Air/Ground communications services. Teresa is responsible for the business management and development of these services. She received a B.S. in Aviation Management from Embry-Riddle Aeronautical University. Prior to joining ARINC, Teresa was responsible for market planning at Presidential Airways.

DIGITIZED VOICE TRIALS

Teresa A. Anderson

Aeronautical Radio, Inc., Annapolis, MD

BACKGROUND

In September 1990, the airline industry inaugurated satellite service with the commissioning of the first aircraft for commercial Aeronautical Mobile Satellite Service (AMSS). The aircraft, operated by an ARINC customer, was equipped with data communications capability only.

Shortly thereafter, corporate aircraft began installations of passenger telephony equipment. Now, the next step in satellite communication is about to be taken as the industry prepares to adopt flight deck voice communications service.

Although ICAO has stated that data link will be the primary mode for routine communications, voice will be used as a back-up and for non-routine communications.

ARINC is preparing to support the introduction of digitized voice for Air Traffic Control (ATC) and Airline Operational Communications (AOC), through service provision and participation in joint trials. The FAA will be conducting an engineering evaluation of digitized voice communications.

TRIAL PARTICIPANTS

The participants of the digitized voice trials include the airlines, the FAA and ARINC. All airlines that operate aircraft equipped with satellite voice avionics are eligible to participate. The FAA Technical Center will be conducting engineering evaluations and the US Air Route Traffic Control Centers (ARTCC) will be participating in the direct pilot-controller communications.

ARINC will bring satellite communication services and engineering support to these trials. Through ARINC's existing Air/Ground Communications Centers, ARINC will provide call routing and telephone patching. Also, ARINC will collect and analyze test data in support of the FAA's efforts as well as individual airline test programs.

SERVICE AVAILABILITY

The initial satellite voice service became available in December 1990 and worldwide satellite voice communications has been in place since early 1991. Inmarsat has plans to offer the next generation of voice service, known as Voice 2, by the first quarter of 1992. ARINC has in place the architecture to support satellite air/ground voice communications.

Today, each of the ARINC Ground Earth Stations (GES) is equipped with special equipment for dial-access to the ARINC Communications Centers. As voice communications volume increase, dedicated circuits will be installed as well.

Several manufacturers are developing flight deck voice avionics. The Voice 2 avionics availability will coincide with the Voice 2 GES capability in early 1992. Several airlines are looking at new and retrofit installations of voice avionics. The types of airframes include B747-400, B767-300, MD-11, A-340 as well as corporate aircraft such as the Gulfstream G-IV.

The FAA digitized voice trials will last approximately six months, beginning in early 1992.

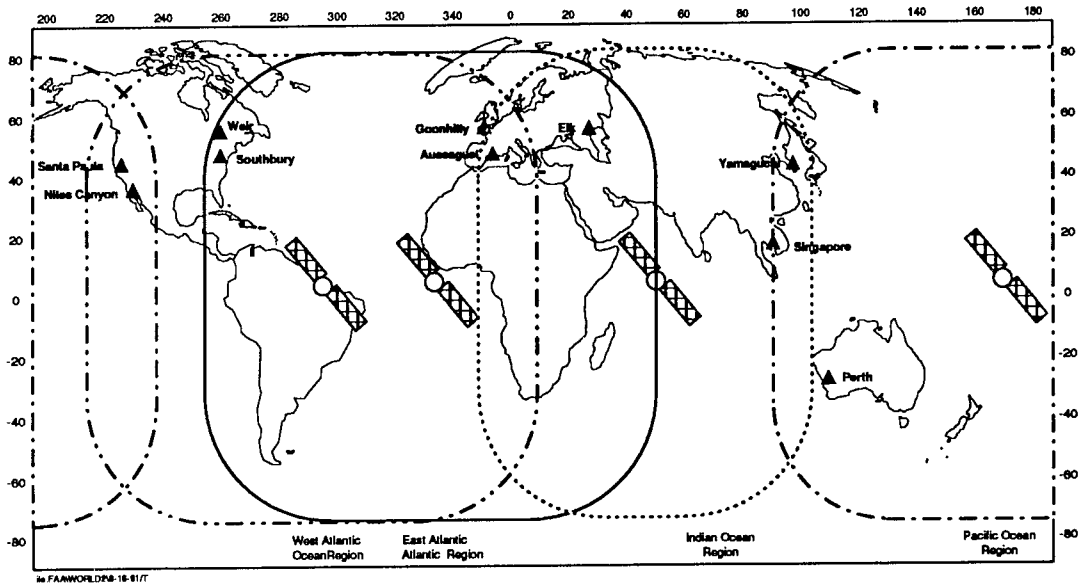

Figure 1: Inmarsat AMSS Coverage Map

SATELLITE SYSTEM

Inmarsat has four satellites that together provide worldwide coverage for aeronautical satellite communications. In addition, each satellite is backed up with operational spares to ensure satellite availability. ARINC has contracted with several Inmarsat signatories for redundant GES coverage for each satellite region. In addition, ARINC has entered into a Joint Venture with SITA for added redundancy to assure communications service availability.

VOICE CONNECTIVITY

Each GES is connected to ARINC Air/Ground Communications Centers via the Public Switched Telephone Network (PSTN) which provides connectivity to any phone number in the world. Initially, ARINC has installed special equipment at each GES to automatically receive and place calls to the ARINC Communications Centers in San Francisco and New York. As voice traffic increases, ARINC will be installing dedicated circuits at each GES to assure line availability. PSTN connections will remain in place as back-up to dedicated circuits.

ARINC COMMUNICATIONS CENTER ARCHITECTURE

ARINC utilizes a specialized voice interconnect system at each of its Communications Centers. Through this system, ARINC Radio Operators are able to create phone patches in addition to placing and receiving phone calls. The voice interconnect system is configured to accept digitized voice calls from satellite equipped aircraft either through the PSTN or via dedicated circuits.

The voice interconnect system also provides connectivity to dedicated circuits that ARINC has in place linking the Communications Centers and the applicable Air Route Traffic Control Centers (ARTCC). Dial access capability also provides back-up in event of non-availability of the dedicated circuits.

Through the voice interconnect system, the Radio Operators are also capable of contacting an airline's dispatch office, maintenance center or other point to create phone patches or relay information.

As part of the Radio Operator's duties, Air Traffic Control (ATC) voice communications are transcribed into ARINC's Air/Ground System (AGS).

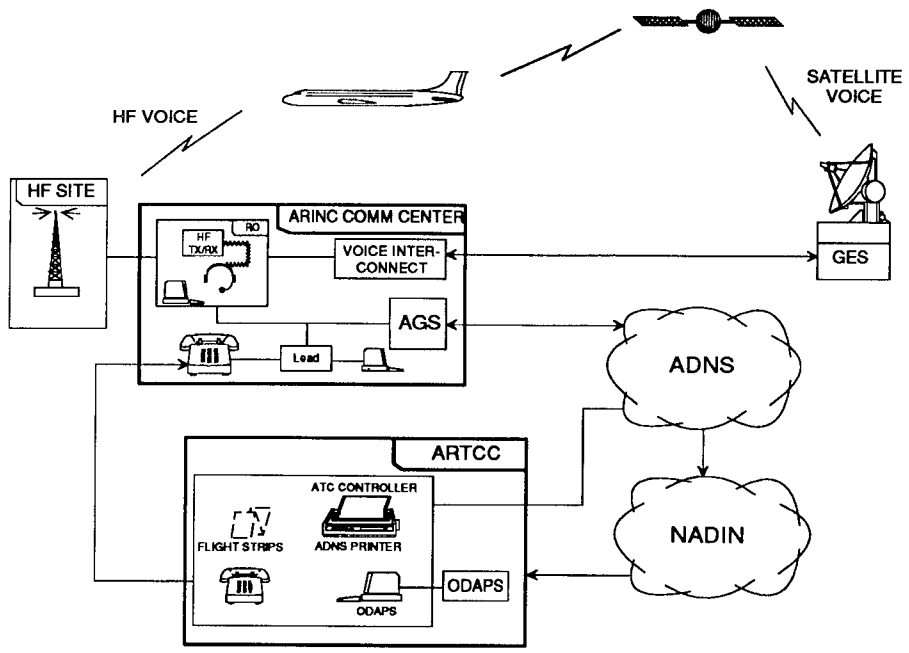

Figure 2: Oceanic ATC Communications Delivery

AGS sends messages through the ARINC Data Network Service (ADNS) to the responsible sector controller as well as airline dispatch destinations. ARINC Radio Operators also provide transcription services for operational communications.

NEAR-TERM VOICE CAPABILITIES

The ARINC Communications Centers and networks are operated to meet the air/ground voice requirements of the air transport industry. This voice network supports both High Frequency (HF) and Very High Frequency (VHF) radio communications. ARINC also acts as the voice of the FAA by providing ATC communications via HF in the US controlled Flight Information Regions (FIR).

In today's oceanic environment, in order to deliver a clearance, first a controller contacts an ARINC Communications Center. The Lead Radio Operator, who receives the call, transcribes the ATC message. The Radio Operator handling the communications for that particular flight will then contact the flight crew and deliver the message via HF radio.

Flight deck originated radio messages are placed to the ARINC Radio Operator who transcribes the message. The Radio Operator then contacts the appropriate controller and delivers a copy of the transcribed message.

ARINC has further enhanced its voice network architecture by introducing the capability of handling satellite voice communications. By using ARINC's existing Air/Ground voice communications architecture, aviation is able to realize digitized voice applications immediately.

For aircraft equipped with satellite voice, there are no changes to the existing communications procedures except that the flight crew is contacted using digital voice.

However, faster, more flexible and more accurate communications are expected. From the controller's perspective, there will be no difference in procedures. ARINC will support an aircraft operator's transition into digitized voice communications with no adverse impact for ATC, minimizing the implementation time.

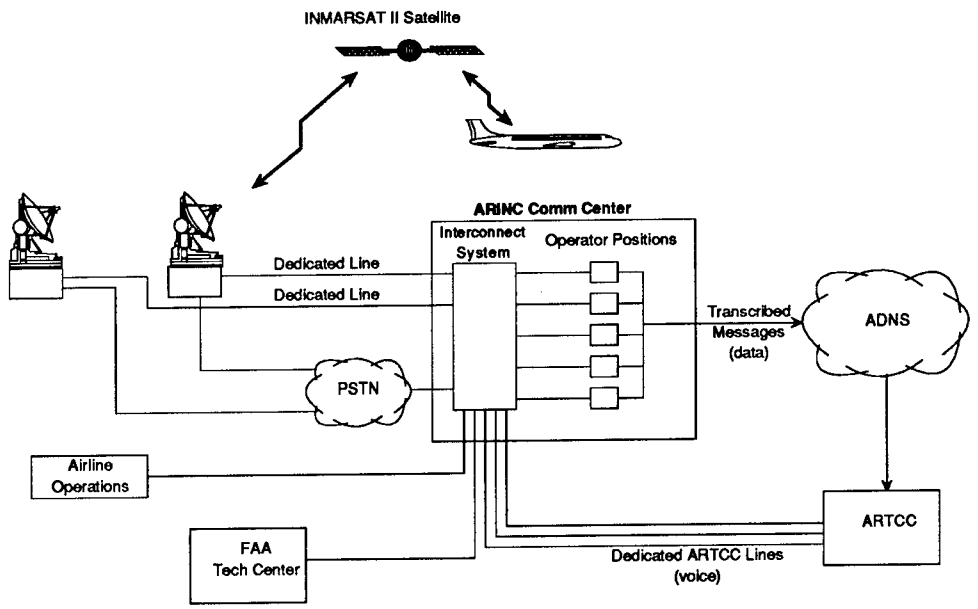

Figure 3: Architecture for FAA Digitized Voice Trials

THE FANS CONCEPT

Through the ICAO Future Air Navigation System (FANS) committee, aviation is planning for improvements in communication, navigation and surveillance (CNS) to take air transportation into the next century. The basic elements of the FANS concept identify data link as the primary means of air/ground communications. Voice communications will be reserved for non-routine or emergency communications and as a back-up in the event of data link failure. Other elements of the FANS concept call for improved performance capabilities of navigation equipment and enhanced surveillance of aircraft operating in non-radar environments.

FUTURE OCEANIC COMMUNICATIONS

ARINC's system evolution is synchronized with the FAA's development plans. Consistent with the FANS concept, the FAA is migrating all routine communications to data link messages. Only emergency or non-routine communications will be conducted via voice. The future oceanic voice system will enable direct pilot-to-controller communications as in today's domestic airspace.

The FAA has developed a five phase plan to migrate to the future ATC communications environment. ARINC supports that plan and is developing the system evolution in lock-step with the FAA's efforts.

DIGITIZED VOICE TEST PLANS

There are three things that the FAA will be evaluating during its digitized voice trials period. The tests consist of:

- ATC communications evaluation
- Edge of coverage definition
- Long duration call validation

ATC COMMUNICATIONS EVALUATION

Through the procedures developed for the ATC communications tests, the FAA will validate the use of digitized satellite voice for non-routine, emergency and back-up communications.

In addition, the FAA will verify that no procedural change is needed for ATC and minimal or no change is required for the flight crew. The FAA will conduct an appraisal of digitized voice com-

munication quality by compiling feedback from all participants of the digitized voice calls.

Call set-up times will be recorded and analyzed for both air-to-ground and ground-to-air calls. Call set-up is defined as the period of time between the last digit is dialed and the first ring is heard. In the air-to-ground direction, pilots will record the call set-up time and for ground-to-air calls, ARINC Radio Operators will record call set-up time.

Digitized voice quality will be measured on a scale of 1 to 5, with 1 being unacceptable and 5 being excellent. Each participant in a phone conversation will grade the call's quality immediately after the call's completion. Call participants are the flight crew, Radio Operator, controller and may include others.

A series of scripts have been developed for these tests. By having a specific dialogue to follow, more objective comparisons can be conducted of the various voice calls. The scripts are based on non-routine communications such as medical emergencies or fuel leaks.

EDGE OF COVERAGE DEFINITION

The digitized voice trials will verify the boundaries of voice coverage by empirically determining the footprint of the satellite. In addition, an appraisal of digitized voice communications intelligibility at edges of coverage will be conducted.

For these tests, the aircraft's position will be recorded at the set-up of each call. Again, the voice conversations will follow a script of non-routine communications and the call quality evaluated on a scale of 1 to 5. In addition, the aircraft's position will be logged at the point of loss of communication.

LONG-DURATION CALL VALIDATION

The final parameter the digitized voice trials will evaluate is the satellite system's ability to sustain long duration call connection. Unlike HF, satellite voice communications create an actual circuit, much like a home telephone. It is likely that during emergency situations, the voice link will be in place for an extended period of time.

The long duration call validation will test the capabilities of AMSS to sustain lengthy calls. In addition, a determination will be made of the ratio of calls disconnected by the system to those terminated by one of the call parties. Also, the average length of a call terminated by the system will be measured.

The ARINC Radio Operators will establish voice communications with the flight deck for one of four different lengths. Calls will last 15 minutes, 30 minutes, one hour and three hours. Due to the length of these calls, the communication link will be checked periodically rather than having continuous conversations. The call length is measured as the period of time between the called party answering and the termination of the call.

SUMMARY

ARINC has the voice network architecture in place to support satellite voice communications today. By utilizing existing facilities and procedures, ARINC is able to facilitate rapid implementation of this new technology without adverse impact on system users.

ARINC is working closely with the FAA to coordinate the oceanic communication evolution towards direct pilot-controller communications, whether by data or voice.

The Digitized Voice Trials will evaluate ATC communication capabilities, define edge of satellite coverage and validate the performance of long duration calls. ARINC supports these efforts by providing the communication service, both in the satellite link and in the establishment of calls. ARINC also provides quality evaluation and assists in data collection.

SESSION ONE: TRIALS AND DEMONSTRATIONS

Norman Dimock
Applications Development Engineer
Technical Services
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Norman Dimock graduated from the Technical University of Nova Scotia in 1972 with a BEng-Elect. He then worked with Transport Canada in Winnipeg, designing electronics and selecting and testing sites for communications and navigational aid radio facilities in the central and far north. In 1980 he transferred to the Advanced Communications group in Ottawa and there developed methods for aircraft antenna calibration, communications radio transmitter flight checking, speech intelligibility measurement, and digital audio processing.

Mr. Dimock is presently the project manager for ADS Investigations, mainly concerned with technical development in support of ADS flight trials and simulations. He is also the Canadian advisor to Working Group B of the ICAO Automatic Dependent Surveillance Panel.

AUTOMATIC DEPENDENT SURVEILLANCE (ADS) DEVELOPMENT IN CANADA

Norman F. Dimock, and Donald F. MacLean

Transport Canada, Ottawa, Canada

ABSTRACT

This paper presents Canadian work in progress to investigate operational and technical requirements for using ADS and datalink in Air Traffic Control (ATC). Ongoing tests and experiments are described. North Atlantic ADS trials preparations are reported and some related operational and technical issues are discussed. ADS-ATC Simulation plans are outlined. The notable features of ADS Development System workstations, to be used by controllers participating in ADS trials and simulations, are detailed.

INTRODUCTION

Transport Canada provides Air Traffic Services for vast non-RADAR airspaces over the North Atlantic and northern Canada, and so has an acute interest in expediting the implementation of ADS. To support international guidance of ADS development we provide a member on the ICAO ADS Panel and representatives on the associated Working Groups. Meaningful participation depends greatly on accumulating relevant experience.

We have built up some operational and technical experience through several years work in various datalink experiments and tests. This paper presents information and observations from those efforts which may be helpful to others engaged in the work. By sharing it we hope to further encourage the spirit of openness and co-operation already prevalent. Also presented here is a statement of our approach to institutional and technical arrangements for North Atlantic ADS trials which we are preparing to initiate in co-operation with other authorities.

DATALINK/ADS TESTS AND EXPERIMENTS

Oceanic Clearance Delivery (OCD)

Transport Canada was alerted to the capabilities of VHF based air/ground datalink for ATC purposes in 1986, when Captain David Walker, of Air Canada, proposed investigating the concept of delivering oceanic clearances directly onto the flight deck, in "hard-copy". This was in recognition of the fact that, with the introduction of two man crews, the task of copying and verifying clearances had become onerous and, potentially, hazardous to safety. Company regulations stated the need for two pairs of ears to monitor the delivery of such clearance messages, to ensure correct reception, and subsequent "read-back". Even with a clearance on one of the organized North Atlantic (NAT) tracks, the reception of the clearance entailed a potentially lengthy "listening out" on a congested clearance delivery frequency, followed by a coordinate by coordinate readback to the Gander Clearance Delivery Officer. During this time, the aircraft could be effectively "deaf" on the tactical control frequency.

Since 1986 Transport Canada has incorporated several refinements to the initial, basic concept, where the Oceanic Planner was tasked with manual entry of the clearance, through automatic generation by the Gander Automated Air Traffic System (GAATS) - with full voice readback, to the current status, where an electronic readback is provided from the flight deck, and is compared against the GAATS generated message. Use of datalink for delivery of the clearance message necessitates a final, short voice contact between the aircraft and the ground to validate the clearance, but misinterpretations because of language or dialect difficulties are now alleviated.

Transport Canada has learned many valuable technical and operational lessons as a result of this evolving project in the areas of addressing aircraft uplinks; message integrity checking; electronic readback; service provider interfaces; ATC procedures; and message identification methods (sequence numbering, etc.). It is noteworthy that even for this narrow use of datalink it was necessary to apply the available technology in minimal steps, checking results and allowing procedures and expectations to adjust before the taking next step. Otherwise the stability and safety of the system would have been jeopardized.

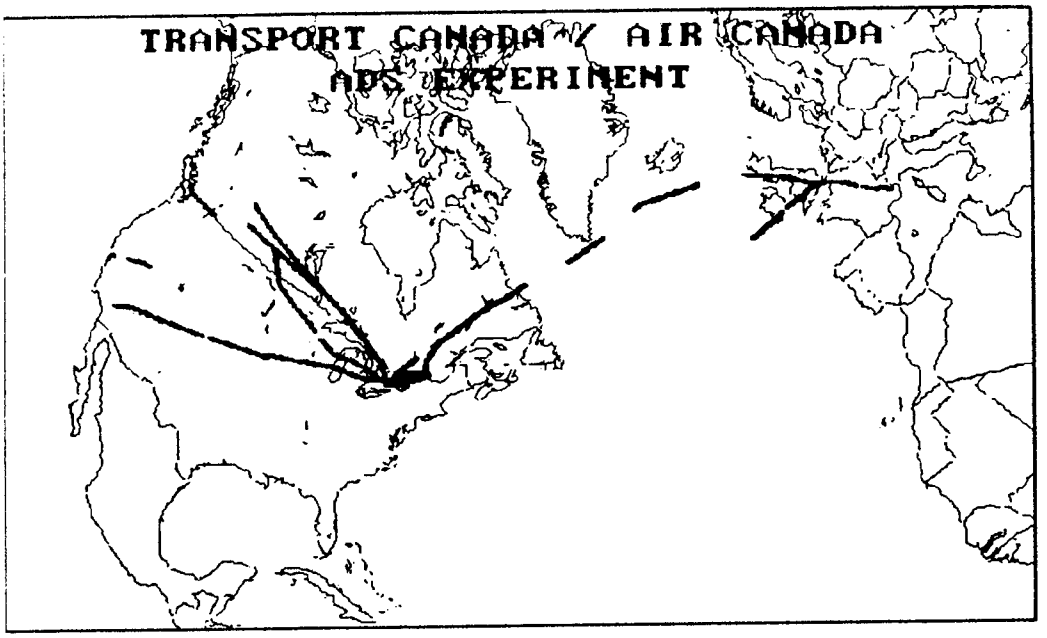

Fig. 1--VHF ADS Tracking

VHF ADS Position Reporting

In 1988 VHF datalink was recognized as being able to provide empirical data in support of the work being carried out by the Aeronautical Mobile Satellite Service Panel in relation to Automatic Dependent Surveillance (ADS). As a result in that year Transport Canada and Air Canada began downlinking automatic position reports from Boeing 767 aircraft. Twenty aircraft are now outfitted with upgraded avionics software, and real-time tracking over Canada, the United States, Europe, Greenland, and Iceland has been demonstrated (Figure 1).

A related ADS Data Collection and Statistical Analysis study [1] was contracted to correlate VHF-reported positions with RADAR returns and to use the results to analyze the statistical behaviour of Inertial Reference System (IRS) errors. The objective was to gain information about the tails of IRS in-flight error distributions beyond the domain of the manufacturer's specifications. The information was to be used in evaluating the suitability of automatically reported IRS data as a basis for surveillance in oceanic airspace.

It was discovered during the study that the available RADAR data, although being accurate as to the **relative** positions of aircraft - as required by ATC for ensuring separation, did not provide sufficient accuracy as to the **absolute** position of each aircraft - to serve as the required reference for measuring IRS errors. This finding will have to be addressed when schemes for reconciling ADS and RADAR data at airspace transition boundaries are being evaluated. However, the RADAR Modernization Project (RAMP) is presently upgrading Canada's systems so the problem may be solved coincidentally. The IRS accuracy study has been suspended until blended navigation data is available on aircraft data buses. Then VOR/DME data can also be downlinked to be used as the absolute position reference.

Another area of investigation, of general concern when dealing with store-and-forward data networks, has been the measurement of message transit delay. Delay is especially critical during real-time ADS plotting of aircraft positions. A closely associated issue is the accuracy of an aircraft's time stamping of position reports. Because aircraft clocks are typically set within an accuracy of 20 seconds, measurement of transit delays is not entirely straightforward. However useful information can be obtained by examining the **range** of transit times of messages from single flights.

Each curve plotted on Figure 2 relates to the messages received from a particular flight. The curves indicate the percentage of messages which apparently (comparing time stamp to arrival time) experienced less than the ordinate transit delay. Note that aircraft clock error resulted in some apparently negative delays. The plots show that transit delay surpassed 10 seconds in about 80 percent of cases.

Transit delays of such magnitude would make the network generally unusable for operational ADS. However with planned improvements in the interface to the datalink service provider the delays will be reduced and oceanic trials can be supported.

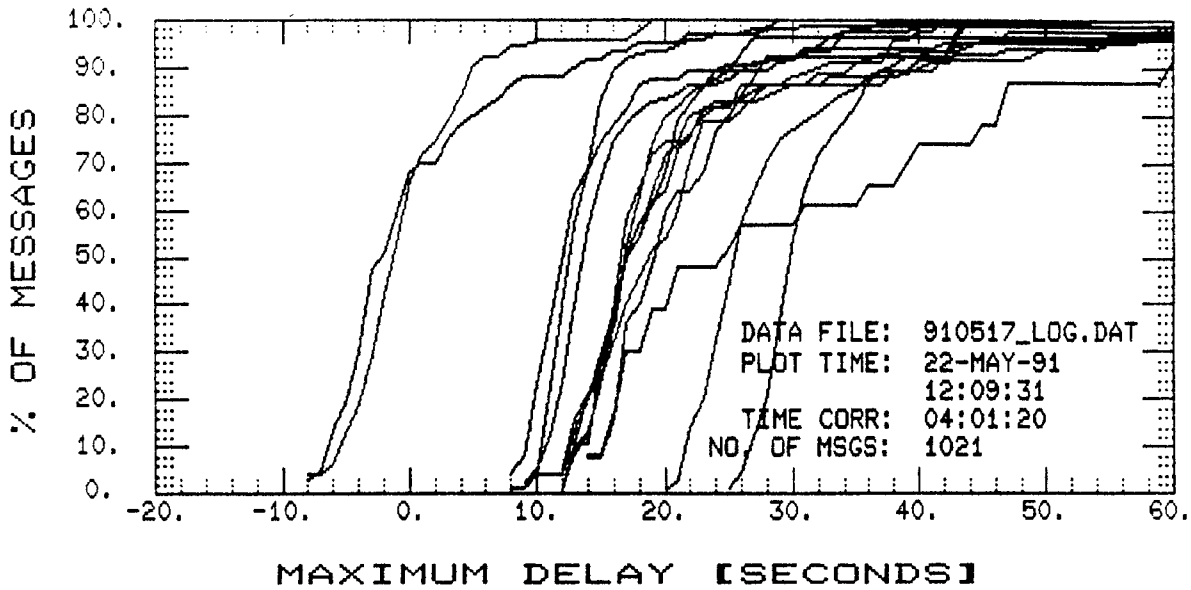

Fig. 2--Apparent Transit Delays of VHF ADS Reports

The following are general observations and questions prompted by situations encountered during the VHF ADS experiments:

1) It is necessary for a network user to have a reliable means of metering the exchange of messages for purposes of verification of billings from the service provider. How and by whom (an independent third party?) will message traffic be metered? In our trials we have kept a loose count automatically of messages received for rough verification of invoices but that would not suffice for an operational arrangement.

2) An off-line playback, demonstration, or documentation facility is required in order to convince a service provider or aircraft operator that problems exist when they arise. Examples from our experience include late position reports, frequent position report drops-outs during aircraft approach, erroneous position reports just after initialization, and incorrect translation of data from air-ground link format to ground-ground datalink format. If a third party is providing a network service connecting aircraft to ATC, where will responsibility for verification of reliable message delivery lie?

3) When ATC finds that certain position report delays appear to be unacceptable, how is ATC to know whether the delay is in the network and not in the aircraft? This problem does not arise in RADAR surveillance, but it will in ADS. ADS position reports should be given priority just below that of emergency messages both within avionics and within any delivery sub-networks, and maximum tolerable message delays must be specified and continuously or periodically checked for **each independent** intermediate system. Should each prime contract service provider be required to routinely meter, in an auditable manner, message losses and delays and to report whenever criteria are failed? Where a prime contractor cannot manage such internal metering, external time-stamping of inputs and outputs may be a necessity.

PRE-OPERATIONAL TRIALS

Canada is actively promoting establishment of North Atlantic ADS Pre-Operational trials which are needed so that international standards for ADS can be properly developed. Requirements for operational ADS-ATC cannot be validated or even fully imagined without a period of ADS trials involving controllers interacting with pilots and with other ATC units to take advantage of the availability of aircraft equipped with some form of interim ADS capability.

International Coordination, and Time Frame

As this paper is being prepared exploratory discussions regarding North Atlantic ADS trials have taken place with representatives of civil aviation authorities (CAAs), user organizations, and service providers whose clients fly the North Atlantic. A willingness and readiness to collaborate within the earliest possible time frame prevails. IATA is canvassing its member airlines, several of which will be at least minimally equipped to participate by late 1991 or early 1992. Service providers have offered to contribute data communications capacity.

Canada, in cooperation with the United Kingdom, is proposing to the North Atlantic Systems Planning Group (NAT SPG) 27th meeting (Paris, 10-21 June 1991) to coordinate these initiatives and to monitor resulting trials commencing in late 1991. The desire is to enable and ensure cooperation between civil aviation authorities in the investigation and development of ADS-ATC practices for NAT airspace.

Objectives

The trials are to be loosely defined at the beginning, with additional specific goals to be developed in due course. The presently stated objectives are:

a) Validation of scenarios developed by such bodies as NAT SPG and ADSP.

b) Collection of empirical data on end-to-end system performance.

c) Experimentation in transfer of communication and transfer of control between ATC agencies.

d) Investigation of controller-machine interfaces, and familiarization of control staff with concepts of ADS.

Constraints

Trials procedures must not unduly affect the pilot: for instance, ATC control of ADS reporting must not require action by the aircraft crew.

Trials practices must conform to existing and anticipated ICAO SARPS to the extent practicable. In cases where the trials require the interim use of non-conforming practices, such use must not be taken as tacit endorsement. For instance aircraft identifiers in datalink messages should contain seven characters, to provide for the standard ICAO 3-letter airline code, rather than six characters as used in previous trials.

Some Questions

From the first meetings of the ADS Panel working groups in April 1991 it was evident that the various participants came with differing ideas as to some basic approaches in both the operational and technical areas. A few of the questions prompted there are presented here to encourage their further discussion with parties who have only an indirect connection with the international development of ADS but whose experience and requirements are very important - parties such as avionics manufacturers and airline technical associations and datalink service providers:

1) How should the data in pilot-controller messages be transmitted and presented to the receiving party - only in standard form, or as viewed by the sending party, or as suits the receiving party? This is of operational concern but must be considered in light of the technology available for message entry and presentation.

2) Should avionics be capable of periodically reporting merely a single set of data elements to each ground end system which has sent a simple request, or rather be capable of reporting different sets at different rates to each end system which has sent a complex request? Are there any operational benefits which are precluded by the former approach, and are there technical benefits to the latter approach which would outweigh technical complications? Aeronautical Radio, Inc. (ARINC) Characteristic 745, adopted by the Airlines Electronic Engineering Committee (AEEC) in November 1990 clearly supports the latter approach [2], but not all representatives to the ICAO ADS Panel are conversant with the details of AEEC decisions.

3) Should periodic ADS reporting always begin immediately after receipt of a request, or might it be necessary in some circumstances to have it deferred to begin at some time or location (which the request would somehow specify) afterward? What are the related operational requirements, and could the latter approach be implemented in a simple and efficient way? ARINC Characteristic 745 does not support deferred periodic reporting [2], but perhaps the AEEC is not aware of the related operational requirements.

(4) Would spontaneous ADS position reports initiated by an aircraft dependent upon its manoeuvring be a feasible augmentation to periodic ground-requested reports? Then provided that an aircraft did not deviate significantly from its current flight plan, the only reports required would be those at waypoints, to ensure that ATC loop errors are detected. Otherwise reporting rates would to a certain extent have to account for the maximum three-dimensional acceleration which an aircraft is capable of, to ensure that any non-conformance would be detected soon enough. That could mean that reporting would generally be required at rates equivalent to RADAR scan rates.

This area has not received much attention from the ADS Panel, but analyses could be performed to determine an optimal reporting strategy based on the probability of an aircraft diverging from its anticipated trajectory in excess of appropriate tolerances along track, across track, or vertically. Through collection of experimental-type ADS reports and through simulations and studies it should be possible to investigate:

- Spontaneous aircraft reporting of any alteration of the NEXT or NEXT + 1 waypoint.

- Spontaneous aircraft reporting of any out-of-tolerance deviation from anticipated great circle track from present position to NEXT waypoint.

- Message efficiency based on the premise that only spontaneous (i.e. unrequested) reports would require an acknowledgement.

- Reporting rate versus position error statistics for periodic and spontaneous reporting.

- Measured aircraft enroute manoeuvring under representative flight conditions.

ARINC Characteristic 745 defines ADS Event Contracts which require an aircraft to initiate reports when vertical rate change, turn rate change, or altitude exceed uplinked tolerances [2]. However to non-participants in AEEC business it is not obvious that such Event Contract provisions are the best approach taking account international operational requirements.

General Technical Approach

When planning for ADS trials was begun within Transport Canada two years ago it was anticipated that Air Canada would be one of the first airlines to equip with SATCOM and would continue the cooperation extended during our VHF ADS Experiments. Now because of the progress of satellite equipage across the industry we are presented with the opportunity of beginning trials in cooperation with several international carriers.

We recognize that the trials should therefore build on the experience which some of those carriers have gained in their work with the FAA in the Pacific Engineering Trial (PET). International agreements should establish an interim ADS and datalink message standard to be evolved from the character-oriented data message formats which were used in the PET. We would wish to negotiate with the FAA and the participating airlines for development and formalization of a detailed specification of such an interim standard.

In general our ATC Automation Systems (that is: ADS Development System workstations) will access VHF and SATCOM datalink by interfacing to the Host computer of an airline datalink service provider. That is the general arrangement employed in the PET and in our VHF ADS experiments and Oceanic Clearance Delivery tests. More specifically Transport Canada will use the data communications access arrangements and interface techniques which have been employed in its recent efforts toward ATIS delivery by datalink.

Technical Specifics

Discussions with Canadian carriers, and work being progressed by the FAA in conjunction with American Airlines, has prompted Transport Canada to begin investigating datalink delivery of Automatic Terminal Information Service (ATIS) and Pre-Departure Clearance messages. Work is progressing with Air Canada as a service provider on both these items, with concentration on ensuring that the sending systems can provide the required data elements in an appropriate format.

As an result of this work Transport Canada has decided to interface to the airline datalink service providers' Host computers via a single **Air Traffic Services to Datalink (ATS-D/L) Router**. For the present all ATS end systems will access datalink service only through that Router. The Router-Host link is a single X.25 Permanent Virtual Circuit (PVC) provided by the Packet Switched Data Network (PSDN) service known as DATAPAC. See Figure 3.

ATC end systems at regional Area Control Centres (ACCs) will be linked to the Router via X.25 Switched Virtual Circuits over the PSDN. The Router will use the destination teletype address contained in standard datalink messages to direct air-to-ground messages to the ATC end systems. The Host will use the aircraft's identifier and its location coordinates, provided in the message preamble as for Oceanic Clearances at present, to direct messages to VHF ground stations, or if an aircraft is reachable only by SATCOM, the Host will route messages to the provider of Aeronautical Mobile Satellite Service (AMSS) - INMARSAT. What system will be responsible for correlating Flight Identifiers with ICAO 24-bit Airframe Identifiers must be determined, but that is a technical issue which will not impact the controller or the operational aspects of the trials.

SIMULATIONS

Transport Canada is preparing to perform substantial simulations of ADS-ATC. The first essential of the simulation exercises will be to familiarize Oceanic and Northern airspace controllers and Supervisors with situation displays and with datalink, to enable them to make suggestions and to train them for participation in ADS trials. Airline pilots are already accustomed to datalink. Our controllers must also be well prepared.

The simulations are being supported by the existing facilities and staff at the Transport Canada

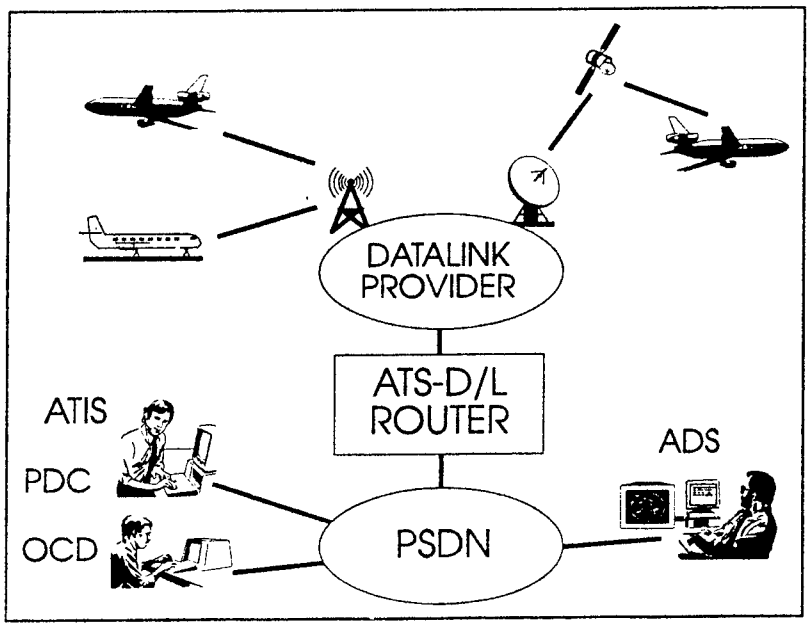

Fig. 3--Air Traffic Services Interface to Datalink

Research and Experimentation (R & E) Centre in Hull, Quebec. The computer system there which in the past has generated aircraft pseudo-RADAR returns is being enhanced to generate pseudo-ADS position reports and to provide pilot interfaces for simulated 2-way ATC datalink. For the controller's interface, including 2-way datalink and graphic situation display, ADS-DS workstations identical to those deployed to ACCs for ADS trials will be used.

The first simulation exercises are slated to take place in September 1991. During the simulation exercises data regarding controller actions and conflict occurrences will be automatically collected. Video taping will be used to assist analysis of controller-machine interface usage.

Objectives

a) Perform ADS Development System shakedown, and develop controller's menus for message types and data elements;

b) Develop ADS and datalink procedures for North Atlantic and Northern Domestic ATC;

c) Integrate those procedures in a mixed (10%, 50%, 90% - D/L versus non-D/L equipped traffic) environment;

d) Analyze impact on controller
1) workload;
2) traffic separation;
3) coordination - transitions and hand-off procedures;

e) Develop a non-Track sectorization scheme for the North Atlantic - using sectors similar to those of Domestic airspace;

f) Investigate random routing and tactical control for the North Atlantic.

g) Validate ADS-ATC Scenarios developed by the ICAO ADS Panel.

h) Investigate operational system performance requirements related to message transit delays.

Remote Simulations

Because ADS message exchange is intrinsically store-and-forward, X.25 Packet Assembler Dis-assemblers (PADs) will allow messages to be exchanged between the Simulator and normal ATC end systems via a PSDN, so we can present remotely simulated traffic to controllers at non-operational positions at ACCs. That will allow those controllers to take part in some restricted types of exercises without the expense and disruption of travel. It will be difficult to monitor and control an exercise where a supervisor cannot walk between the pilot positions and the controller positions, but this may be the only affordable way to provide working controllers with really interactive ADS simulation.

ADS DEVELOPMENT SYSTEM (ADS-DS)

To support ADS trials and simulations a stand-alone controller workstation has been developed. It is

called the ADS Development System and it is an enhancement of Transport Canada's Northern Airspace Display System (NADS) which controllers use operationally for planning, conflict-probing, tracking and progressing flights through non-RADAR northern domestic airspace.

The application runs under the OS/2 multitasking operating system on 33 MHz PC/AT 386 hardware. Peripheral hardware includes a multi-port communications adapter for asynchronous character-based data communication, an X.25 PAD for interface to a PSDN, a 19-inch 1280x1024 pixel 4-colour monitor with mouse pointing device for graphic situation display, and a 14-inch colour monitor and VGA for text display.

The following description of the ADS-DS, and observations regarding its development, are intended as a reference for implementors of similar systems.

Interfaces

Besides an interface to access datalink service, the system has an interface to the operational flight data processing system (FDPS) for input of flight plan data. As well at the Gander Oceanic ACC it has an interface to a message processing system for exchange of air-ground message text with HF voice radio operators.

During development the most difficult of all problem areas was the interface to the Gander FDPS. Because the ADS-DS is not operational it was not feasible to upgrade the operational FDPS to provide a special interface. So the ADS-DS must decode flight plan data which is formatted for flight strip printing. That form is simple for a controller to read but complicated for a machine to decode.

Activation of Flight Plan and Data Link

Flight plan data from the FDPS is automatically decoded. It is stored until the flight is activated or automatically expired. Activation of a flight enables surveillance and message exchange for that flight - via datalink or via the link to HF radio operators.

Winds Model

The ADS-DS and the Gander FDPS both have the capability of estimating wind components using Atmospheric Environment Service winds data as input. Rather than have each system independently calculate the winds, the ADS-DS uses the FDPS waypoint estimates directly to infer the wind components for each flight leg.

Graphic Situation Display (mixed equipage)

For D/L equipped aircraft, graphic display of position depends on ADS position reports. For non-equipped aircraft it depends on pilot position reports. Two distinct aircraft symbols are used.

For both equipped and non-equipped aircraft, the symbol on the graphic display moves according to the current flight plan. ADS history trail dots show reported position for comparison to planned position during visual conformance checking. For nil-flight-plan aircraft, symbol position is extrapolated from reported positions.

Pilot-Controller Message Exchange (mixed equipage)

Air-ground messages are sent and received by the controller via the same screen menus, queues, and display areas regardless of aircraft equipage. Messages are exchanged with equipped aircraft via datalink. Messages are exchanged with non-equipped aircraft via an electronic text data link to an HF voice radio Operator.

A deliberately simplified scheme has been implemented for the creation of menus for ground-to-air message composition. It is not 'smart' but rather is very flexible and easy to learn - two essentials in the ADS trials environment where user training must be minimal and where operational needs are yet to be discovered. The intent is to encourage controllers and their supervisors to define their own selectable message types, data fields, formats, and selectable data element values according to their operational needs. The simplifying principle is: what-you-see during menu editing is what-you-get during menu use. Each menu is a simple text file, and any text editor can be used.

Air-to-Ground messages are listed in a prioritized and time-ordered queue on the screen as they arrive, and the controller can action them in random order. There is a Received Messages status line visible in all screen modes, with associated annunciation tones, displaying the count of queued messages and new arrivals.

There is a Messages History facility to permit the controller to scroll back and forth among air-ground messages exchanged with a certain aircraft or with all aircraft during a session. This provides a way to quickly review messages in the sequence in which they were sent and received.

Conformance Checking

Conformance checking compares the ADS-reported aircraft position to the flight-planned position

for the same point in time. Three-dimensional tolerances are applied and an appropriate warning is issued as a message to the controller, queued ahead of normal-priority air-to-ground messages, whenever an aircraft enters a state of non-conformance.

The alternative to applying an along-track time or distance tolerance would be to automatically re-probe for conflicts, and to warn the controller only if a problem was found. However to keep the controller in the loop it is probably better to always issue a warning whenever an aircraft is significantly early or late and to re-probe only when the controller deliberately initiates such action.

NEXT and NEXT + 1 reported data are simply compared to next and next + 1 flight plan fixes. Small tolerances for round-off errors are applied.

The aircraft's navigation accuracy as represented by the reported Figure Of Merit (FOM) is not taken into account. Automated ATC systems could realize the capability of accounting for the FOM, and then separation minima could be established for worst-case aircraft positions as determined in real time rather than as determined statistically for the long term. That would mean a potential of higher airspace capacity, but the price would be greater complexity of SARPS and of automation to implement them.

CONCLUSION

The operational and technical questions touched on here, and many others, have been discussed within Transport Canada, within other CAAs, within the working groups of the ICAO ADS Panel, and elsewhere, but have not been resolved because internationally there has been no common base of ADS experience. Pre-operational ADS trials can provide much needed common experience to all participants - ATC authorities, aircraft operators, datalink service providers, and avionics manufacturers. Trials can also serve to test proposed ADS-ATC practices before ICAO recommendations are drafted. We urge that advantage be taken of any opportunity to contribute to and so benefit from trials efforts along with us.

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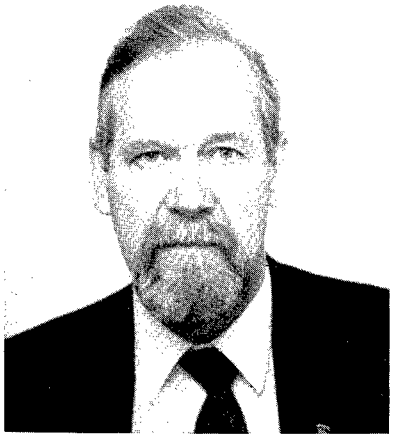
[1] ADS DATA COLLECTION AND STATISTICAL ANALYSIS, Phase 1 - Final Report, Transport Canada, Ottawa, 1991. pages 13-34

[2] PROJECT PAPER 745 AUTOMATIC DEPENDENT SURVEILLANCE (ADS), Draft 6, Aeronautical Radio Inc., Annapolis Md., 1990, pages 66-71

CO-AUTHOR



Donald F. MacLean
Supervisor - Flight Data Processing
Air Traffic Services
Transport Canada Aviation

Donald F. MacLean began his career in aviation as a Navigator in the U.K. Royal Air Force, gaining the rank of Flight Lieutenant before returning to civilian life in 1961. He then served eight years with the U.K. ATC service, as an Air Traffic Control Officer at Prestwick Airport in Tower and Approach Control. In 1968 he immigrated to Canada and spent the next eight years as an Enroute Controller with Transport Canada at the Dorval ACC, where he became involved with the development of current automated systems.

He spent two years in Winnipeg ACC, as a Data Systems Coordinator before moving to Transport Canada Headquarters, Ottawa, to join the Operational Requirements Division as a specialist, initially in communications requirements, and subsequently in flight data processing requirements. For the past several years he has been Supervisor of the FDP section.

He has been an operational advisor to the Canadian representatives on international panels and committees such as FANS and NATSPG; and is currently the Canadian Member on the Automatic Dependent Surveillance Panel (ADSP).

SESSION ONE: TRIALS AND DEMONSTRATIONS

George A. Cobley, P.E.
Technical Director
Communications Systems
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George A. Cobley graduated from Iowa State University in 1964 with a BSEE. While employed as a radio equipment designer at E.F. Johnson Company, he attended Graduate School at the University of Minnesota. In 1978, he joined Rockwell International as a Technical Staff Member to work in the Navigation Receiver Design Group. In 1980, he became manager of the Communications Group and was responsible for the design of HF and VHF Radio communications equipment used in commercial air transport aircraft. In 1984, he became manager of the Commercial Avionics Engineering Data Transmission Group. In 1986, he was appointed manager of the new Satellite and Data Communications group which supported the emerging satellite based aeronautical communications interests. In 1987, he was appointed Technical Director for Data Communications Systems.

Mr. Cobley has been involved with numerous AEEC and RTCA committees relating to data communications. He has served as chairman of RTCA SC-165, Working Group 1, Equipment Standards, which prepared draft material for the SATCOM MOPS. He has presented technical papers around the world, covering data communication topics such as SATCOM flight trials, ACARS, ADS, etc.

In addition to his holding of a Professional Engineer license, he holds FCC licenses as an amateur radio operator and as a commercial radio operator, and FAA licenses as a commercial pilot and flight instructor.

Outside of his professional work, he has served as a Special Deputy for Waseca County Minnesota Sheriff Department. He has been active in Civil Defense and served as Communications Chief, Damage Assessment Officer, and Radiological Officer and instructor. He is currently holding an elected office on the Linn Country Iowa State University Extension Council.

ADS COMMUNICATIONS — A CORNERSTONE

by

George A. Cobley, P.E.

Collins Commercial Avionics
Rockwell International Corp.

ABSTRACT

ADS Communications forms a cornerstone to the applications and communications networks of the 21st century. The need to communicate operational data between an aircraft and the Air Traffic Services is becoming focused and will lead to ever increasing applications. The obvious ones are the clearances and acknowledgements for oceanic operations, and the natural extension to domestic operations. This paper will present a brief review of the development, then examine the trial results. Data will be presented on the operational parameters that were collected at the Santa Paula Ground Earth Station operated by COMSAT. It will be shown that the operational signal parameters are statistically comparable to our early predictions. The data for this paper was collected by Collins, ARINC, United Airlines, and others as it became available.

ADS COMMUNICATIONS — A CORNERSTONE

On Friday, 28 September 1990, N176UA departed Hong Kong for San Francisco. The flight was routine to the extent of being boring as operation was flawless. Automatic position reports were generated by the ACMS every 5 minutes when the aircraft was above 10,000 feet. Interspersed with those reports were free text and dispatch messages, weather requests and reports, connecting flight information, and engine reports. At the ground station data was collected showing signal-to-noise, raw bits in error, and frequency errors.

Since that initial flight of N176UA, additional aircraft equipped with SATCOM/ACARS have been commissioned. Certifications of combined SATCOM and ACARS equipped aircraft have added to the capability to communicate worldwide such information as current aircraft position. These aircraft are routinely providing position reports and taking full advantage of the ACARS service available while thousands of miles from land based VHF radio sites.

On 11 September 1991, Boeing conducted an Engineering Flight Test of the integrated ACARS/SATCOM system that was certified on 13 September 1990. On that engineering flight, the aircraft was maneuvered to induce known conditions such as wing blockage and multipath. Operations were conducted near the edge of coverage to evaluate performance under unfavorable conditions, but the boundary was never crossed because of the aircraft schedule and fuel dictated a return to Seattle before the edge could be found. Two days later the integrated system successfully demonstrated to the Federal Aviation Administration that it could perform the intended function.

It was in late September 1990 that the first revenue flights carried active SATCOM systems integrated with ACARS and automatically reporting position. These flights used the first FAA certified integrated Satellite Communications System with ACARS to provide data link service to 747-400's operated by United Airlines. United inaugurated the Pacific Engineering Trials with the first flights. Since then, other inter-

national airlines, such as Qantas, have added similar systems to their fleets.

The ACARS MU has a choice of operating channels: VHF or SATCOM. The block diagram shown in Figure 1 shows the typical SATCOM/ACARS installation. Automatic position reports may be created in the ACMS (Aircraft Condition Monitoring System) that then forwards them to the ACARS MU where the message is prepared with the appropriate header and trailer. Error protection is provided across the reliable ARINC 429 link by incorporating a parity check. From this point to the terrestrial frontend processor, the message integrity is protected against corruption by the BCS check. Figure 2 shows where error protection is provided. The intermediate links across the ACARS MU to SATCOM SDU, and across the RF Links employ classical CRC

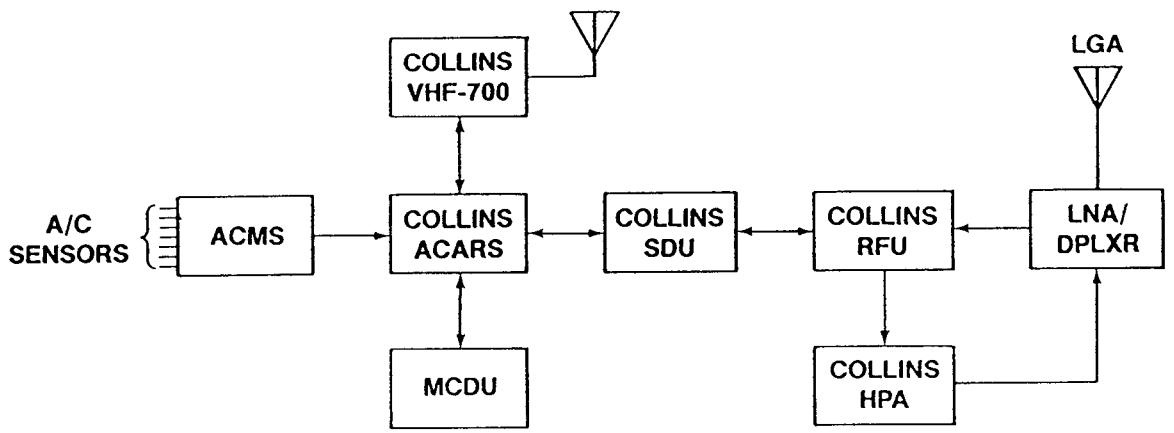


Figure 1. UAL 747-400 Configuration

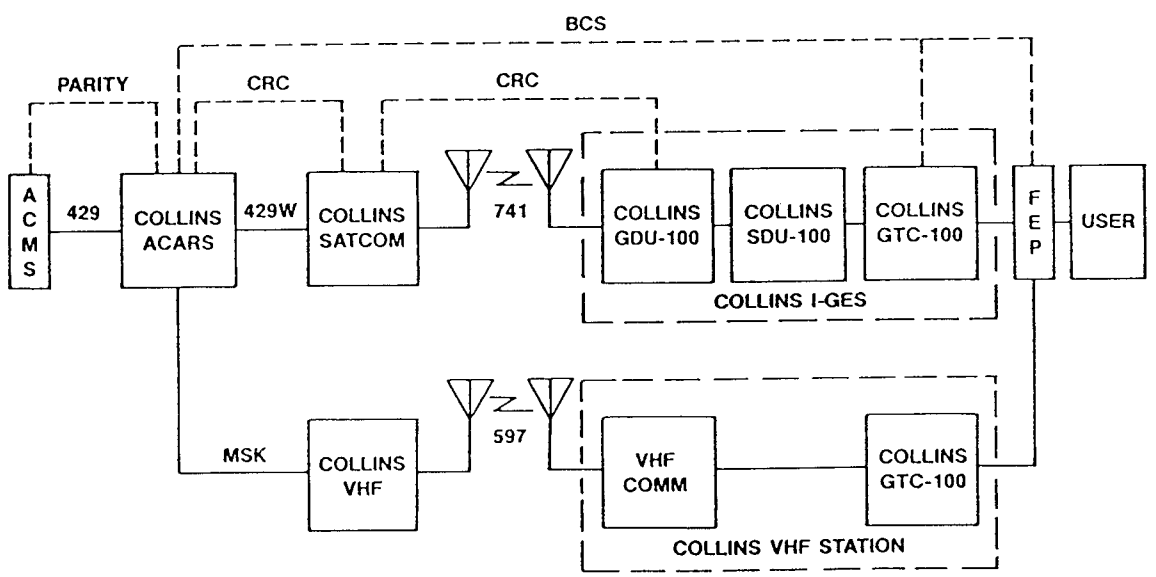


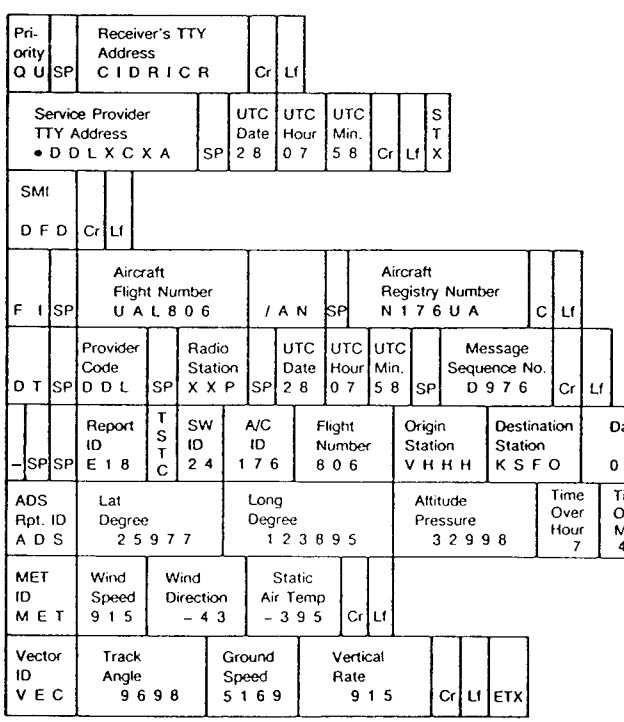
Figure 2. ADS Error Detection

error detection. Using these combinations of error protection, the accuracy of the delivery system between the ACMS source and the terrestrial frontend processor is assured.

On 27 September, United flew the first trip of N176UA from San Francisco to Hong Kong. On that flight, position reports were sent from the aircraft using an existing ACARS format. These reports were nearly as infrequent as HF voice reports. On the return trip, automatic position reports were sent every five minutes when the aircraft was above 10,000 feet. Each of those reports contained the data outlined in Figure 3.

The basic purpose of the UAL ADS Trials message is to convey the current position and altitude of the aircraft to the user; such as FAA, MITRE, the airline, and support organizations such as Collins and ARINC. But the ADS report may contain more than these basic parameters. It could contain flight dynamics, and/or weather data. Figure 4 depicts the future ADS report formats. While these will actually have to wait for end-to-end bit oriented protocol operation, they do serve as a guide to what earlier implementations should provide. The use of end-to-end bit oriented protocols is expected to be available next year at the earliest. It was with this in mind that United Airlines and others created their ADS report that functions over existing facilities. The United ADS format in Figure 3 parallels the ultimate plan.

Even in these early trials, the amount of data contained in the reports is significant to all users of the airspace. These initial ADS Trial reports contain three pieces of meteorological information. The winds aloft and temperature



Radio Station — Three To Five Characters (Three Shown)

FOM — Figure Of Merit (TBD) Will Be Provisioned With A Space Character.

DATA RESOLUTION:

LAT DEGREE	—	(N Or S) 1/1000 Degree (S = Minus)
LONG DEGREE	—	(E Or W) 1/1000 Degree (W = Minus)
Altitude, Pressure	—	1 Foot
Time Over (HHMMSS)	—	GMT
Wind Speed	—	1 Knot
Wind Direction (True*)	—	Degrees
Static Air Temperature	—	(Sign) 1/10 Deg. Cent.
Track Angle (True*)	—	1/10 Degree
Ground Speed	—	1/10 Knot
Vertical Rate	—	1 Foot/Minute

*Range = 180; Positive Sense — CW From North

Figure 3. UAL ADS Trials Report Format

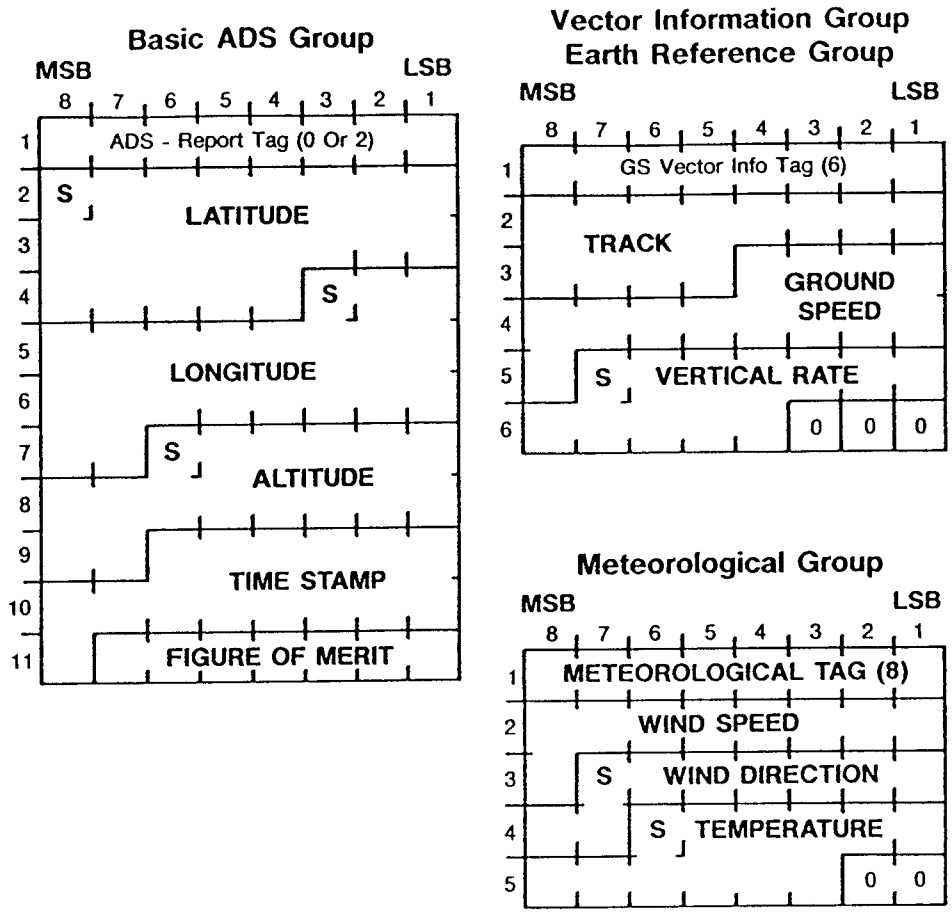


Figure 4. ADS Future Formats

that could be used now to supplement other sources of such data in the oceanic environment. When these data are plotted, the wide variability that occurs during a flight is readily apparent. For example, Wind Speed as shown in Figure 5. The United ADS Trial reports also included the "Earth Reference Group" of Vector Information. Included in this group are Track Angle, Ground Speed, and Vertical Rate.

With an operating data link to and from an aircraft, new uses start coming to mind. While the very beginning of the ADS Trials was to show the viability of ADS reporting, it didn't take long to include simulated ATC messaging. This is a natural growth path. But was that all? Not really. We observe air crews using the SATCOM Data Link for the routine messaging they enjoyed when in VHF data link coverage. A very popular set of messages are the weather and NOTAM uplinks to en route aircraft. In the early use of the SATCOM links, we have seen dispatchers issuing the re-dispatch messages to aircraft thousands of miles from home using SATCOM rather than VHF or landlines. Downlink messages have included aircraft performance data such as engine data, and maintenance needs that are required at the next destination. Of course, we shouldn't overlook the desperate needs of passengers, and crew, to keep up on the latest sports. A few messages have conveyed football, baseball, and basketball scores. To the users, information is just a keyboard away. So, once agreement was reached to do the ADS Trials, there was no stopping the other messaging that occurred.

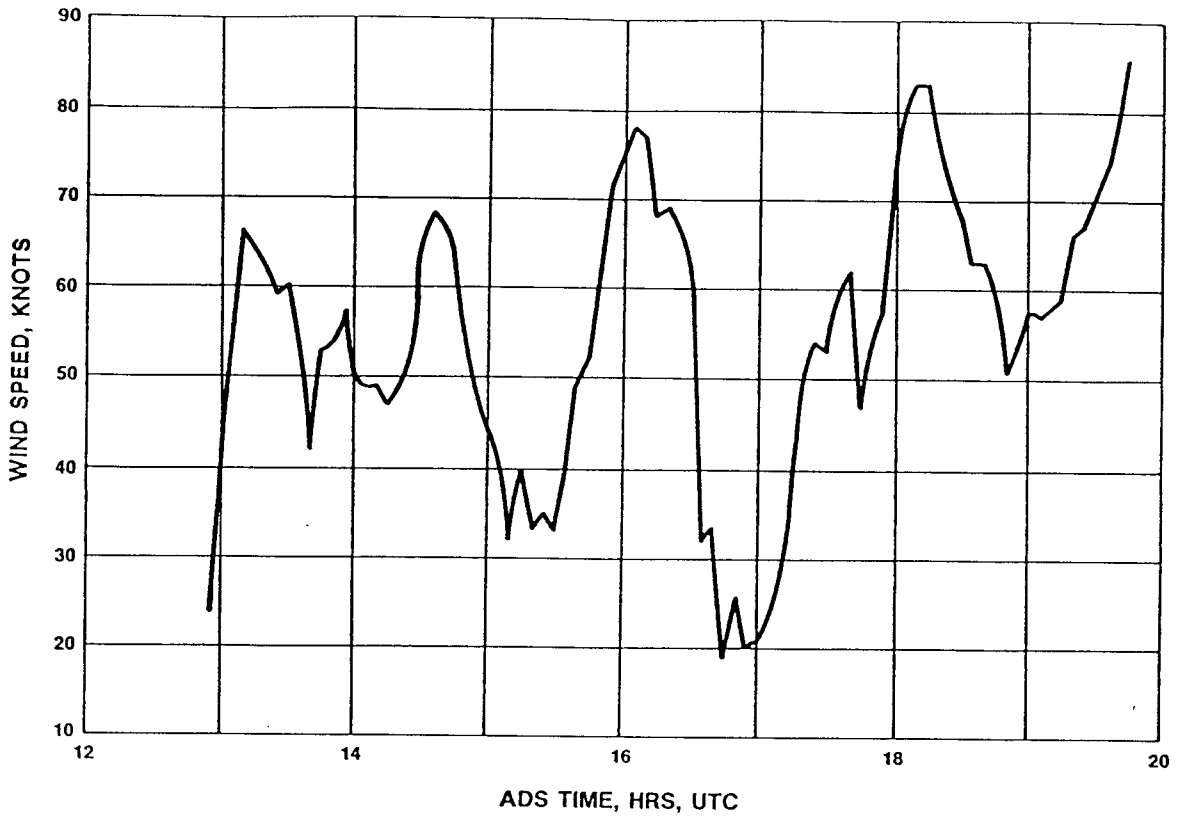


Figure 5. Wind Speed vs ADS Time

During the United flight from Hong Kong to San Francisco, data was collected at the Santa Paula Coast Earth Station. The Interim Ground Earth Station manufactured by Collins is capable of recording every signal unit sent and received along with various engineering parameters. One of those parameters is the Carrier-to-Noise ratio. Figure 6 plots the C/N as a function of time for the flight as measured at the ground station. These data have been filtered to make them easier to see the long term trends that would otherwise be masked. The aircraft was operating in a region of good satellite signals. Table 1 provides a listing of the theoretical link budget which is similar to the INMARSAT System Definition Manual. This table shows that the carrier to noise ratio should be about 37.9 dB. Taking into account the receiver bandwidth, the expected C/N at the ground station would be about 11.9 dB. As can be seen, there are two distinct periods when the data are essentially unchanging, from about 0830 to 1200 and from about 1200 to 1600 UTC. The apparent step function change in C/N at about 1200 correlates with a step altitude change from FL330 to FL350. No satisfactory explanation has yet come to mind.

ACKNOWLEDGEMENT

I wish to thank the participants in the Pacific Engineering Trials, and in particular, Mr. Scott Stahr, United Airlines. His information, insight, and cooperation are very much appreciated. I would also like to thank Mr. Eric Nelson of the Collins Data Communications Group. His participation on the early ADS trials flights and during postflight data reduction has been very helpful.

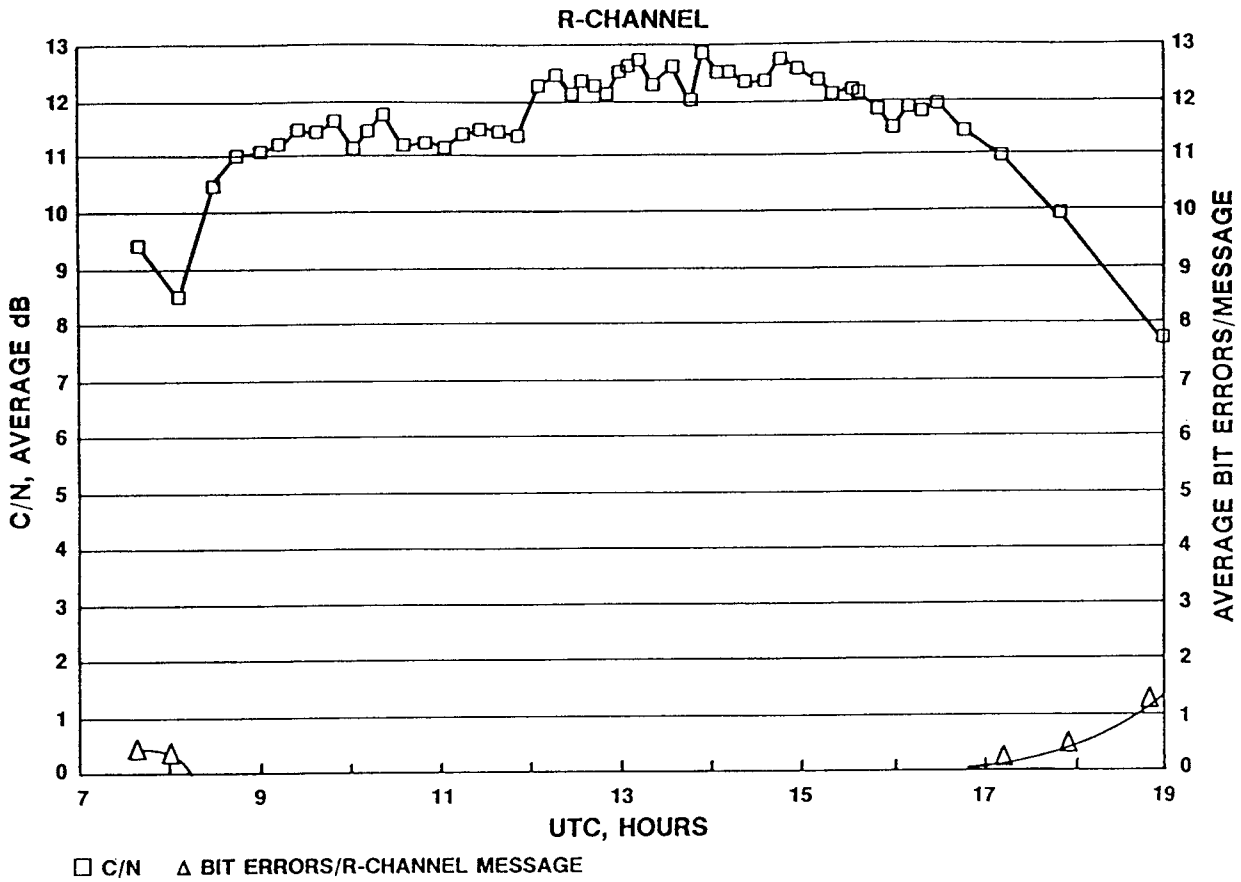


Figure 6. HGK-SFO, 28 Sept 90

Table 1. Return Link Budget For 600 b/s

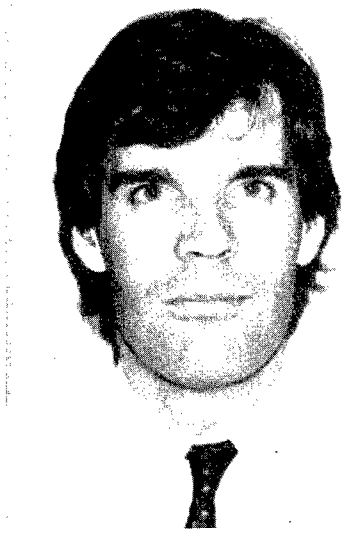
Uplink (AES To Satellite)

Frequency	1.64 GHz
AES Elevation	20 deg
Path Loss	188.8 dB
Satellite G/T	–10.3 dBk
AES EIRP	13.5 dBW
Uplink C/No	43.0 dBHz
Satellite Gain	152 dB
Satellite C/IMo	46.5 dBHz

Downlink (Satellite To GES)

Frequency	4.2 GHz
GES Elevation	20 deg
Path Loss	197.6 dB
GES G/T	32.0 dBk
Satellite EIRP	–23.3 dBW
Downlink C/No	39.7 dBHz

SESSION ONE: TRIALS AND DEMONSTRATIONS



Graham C. Lake
Deputy Director, International Relations
Societe International de Telecommunications
Aeronautiques (SITA)

Graham C. Lake is Deputy Director, International Relations responsible for directing all SITA relations with Civil Aviation Administration world-wide. He is responsible for SITA development and implementation of the Air Traffic Control data link trial programs in which SITA is involved.

Mr. Lake is a British national and graduated from the U.K. College of Air Traffic Control in 1976. He worked as an operational Air Traffic Controller in the British Isles until 1986 when he moved into ATC management and administration.

Mr. Lake joined SITA at the beginning of 1988 and is based at their Northern Europe regional office in London.

FEDERAL AVIATION ADMINISTRATION
TECHNICAL CENTRE

THE FIRST ANNUAL INTERNATIONAL
SATELLITE SURVEILLANCE AND COMMUNICATIONS SYMPOSIUM

AERONAUTICAL MOBILE SATELLITE SERVICES
ESA-PRODAT/SITA AIRCOM SERVICE TRIALS PROGRAMME

A JONGEJANS and P NGUYEN

E S A / S I T A

INTRODUCTION

In order to enhance its existing VHF AIRCOM service and in view of the potential development of satellite-based data communication services, SITA initiated, in 1986, plans for demonstrations and service trials of an Aeronautical Mobile Satellite Communications system for the benefit of its member airlines.

For this purpose the European Space Agency (ESA), the International Maritime Satellite Organisation (INMARSAT), and SITA reached an agreement to carry out service trials using the existing MARECS satellite and based upon the development of the ESA PRODAT project.

The PRODAT/AIRCOM Service Trials launched in late 1986 have been successful and were expected to be completed by July 1991.

The purpose of this paper is to describe briefly the experimental work being carried out by all involved participants.

PRODAT/AIRCOM SERVICE TRIALS OVERALL DESCRIPTION

Objectives

The objective of the PRODAT/AIRCOM Service Trials is twofold:

- to consolidate the concept of satellite-based communications between aircraft and ground facilities in a fully integrated AIRCOM/SITA ground network environment;

- to enable airline participants to evaluate the potential benefits of a satellite-based data link involving new applications related to three main areas of Aeronautical Mobile Communications i.e.:

. Air Traffic Service (ATS) providing the Automatic Data Reporting (ADR) including both Automatic Dependent Surveillance (ADS) and cockpit crew/ground air traffic controller communications capabilities,

. Company Communications including Airline Operational Communications (AOC) and Airline Administrative Communications (AAC),

. Aeronautical Passenger Communications (APC) enabling passengers to send and/or receive private telexes during the flight.

Project Organisation

The PRODAT/AIRCOM Service Trials were provided to the airlines free of charge, on the basis of the voluntary participation of each interested party.

The following participants have contributed to the project process:

■ ESA has defined and financed the procurement of the PRODAT Satellite Communications network, including:

. PRODAT aeronautical mobile terminals, including installation kits,

. Upgrading of the ground earth station located at Villafranca de Castillo, Spain, for supporting the PRODAT satellite communications system.

■ INMARSAT has made available, free of charge, space segment capacity for the service trial period;

■ SITA has provided the integration of the PRODAT satellite link into the existing SITA AIRCOM service and terrestrial tele-communication network. Moreover, overall project coordination with airlines, including end-to-end integration tests, has been carried out by SITA;

■ Three European Air Traffic Control (ATC) authorities have participated actively in the ATC experiments in order to evaluate the Automatic Dependent Surveillance (ADS) concept, i.e.:

. the UK Civil Aviation Authorities (UK CAA) with the Air Traffic Control Evaluation Unit (ATCEU), UK,

. the Spanish "Direccion General de Aviacion Civil" (DGAC), Madrid, Spain,

. the EUROCONTROL Experimental Centre (EEC) in Bretigny, France.

Three aircraft are equipped with PRODAT avionics for the purpose of the ATC experiments:

. one Jetstream from RACAL Avionics,

. one BAC1-11 from the Royal Aerospace Establishment in Bedford,

. one HS748 from the UK CAA.

■ The participating airlines have provided aircraft retrofitted with the PRODAT and ACARS/AIRCOM avionics, i.e.:

. TAP Air Portugal: one LOCKHEED Tristar,

. VARIG: one BOEING 767-200ER,

. SABENA: one AIRBUS A310-300,

. SAUDIA: one BOEING 747-300.

PRODAT SYSTEM ARCHITECTURE

The PRODAT system is an original low data rate system conceived and developed by ESA in the frame of a wider satellite telecommunications programme PROSAT aimed at defining and promoting mobile satellite communications in Europe.

Figure 1 illustrates the PRODAT/AIRCOM system architecture.

PRODAT Communications System

The satellite link was designed for using MARECS type L band which provides global coverage. The aircraft were equipped with terminals manufactured by RACAL (UK) and SNEC (France) under ESA specifications. The main parameters are given below:

■ link to aircraft: TDM at 1500 baud;

■ low gain omnidirectional antenna on aircraft (G/T=-24dbK);

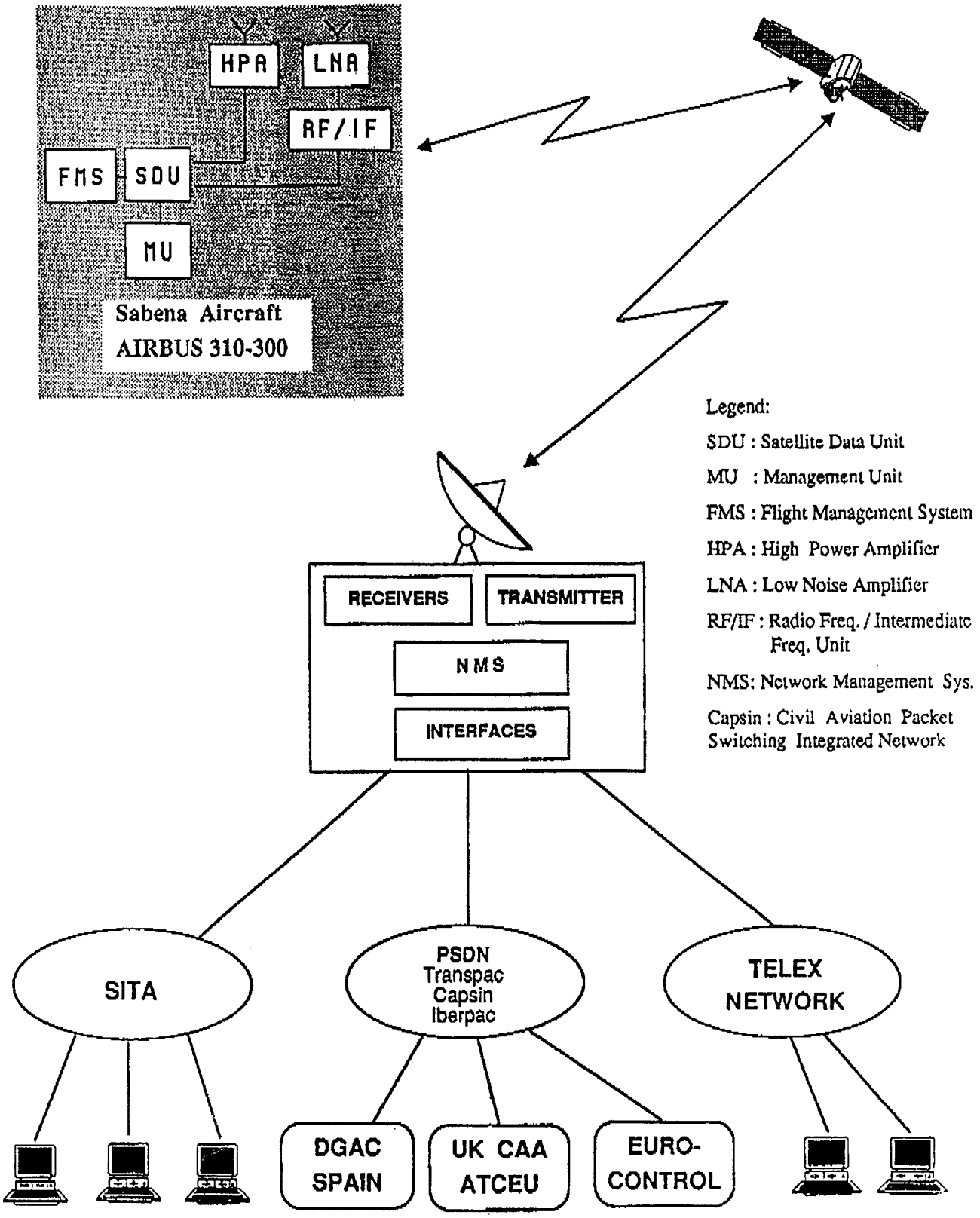


Figure 1 - PRODAT - Overall system architecture

- transmit power on aircraft: 10 watts;

- link from aircraft 300 baud spread to 266kchip/s;

- adaptive forward error correction and ARQ in both links.

PRODAT Avionics

The avionics is divided into three ARINC 600 line replaceable units to be installed in the electronics equipment bay of the aircrafts (see Fig. 2).

The satellite data unit (SDU) includes the digital processing modules and interfaces, the RF/IF unit includes the radio frequency circuits and the third unit contains the 10 watt high power amplifier (HPA). Two omnidirectional antennas (transmit and receive) are mounted about 80 cm apart on the top fore part of the fuselage.

For control and test purposes, as well as the manual entry of data (public telex, ATC messages, SITA Type B messages) a Husky Hunter handheld micro computer is connected to the SDU via an RS 422 interface.

In addition, the PRODAT avionics are interfaced through an ARINC 429 databus and a customised protocol to the AIRCOM/ACARS MU and to the aircraft navigation avionics whenever possible.

PRODAT Network Management System Centre

The Network Management System (NMS) installed at ESA's ground station of VILLAFRANCA near MADRID (Spain), also performs the satellite Tracking, Telemetry and Command (TTC) operations. A suitable bank of receivers and transmitters was developed and installed in the NMS centre, supported by a redundant HP1000 mini computer loaded with a dedicated software to drive the equipment and perform all the message handling tasks. In addition, the NMS controls the interfaces to the telex network, the X25 packet data network and the SITA AIRCOM network.

The following basic functions are supported by the system:

- end to end messages in both directions with delivery reports;

- request/reply for automatic collection of data on board;

- periodic polling down to 10 seconds according to a predefined list.

PRODAT/ATC EXPERIMENTS

As described earlier, the three experimental aircraft were equipped with PRODAT avionics in order to test the satellite data link for ATC applications for different flight configurations, satellite elevations and functions.

The following ATC functions were available:

- periodic polling according to a pre-established list at rates up to six polls per minute (position report on request);

- request/reply (for MET information, waypoint report, identity report);

- two-way ATC tactical messages (communication between pilot and ATC controller).

For this experiment carried out by the three participating ATC administrations, a special X25 link was established for each session between ATC centres and the PRODAT network management centre. In turn, each centre drove the experiment while the other two received the data.

In addition, a ground based Multi-Aircraft Simulator Terminal (MAST) produced by PESA/ETSIT in MADRID, accessed via the satellite link and fed with simulated flight data of up to 40 aircraft from the EUROCONTROL computer, was included in the experiment.

A series of flights was devoted to Automatic Dependent Surveillance (ADS) during which the "poll-reply" is used to track the aircraft in real time on a simulated radar display. The short (10 s) repetition period permits the tracking of very tight manoeuvres.

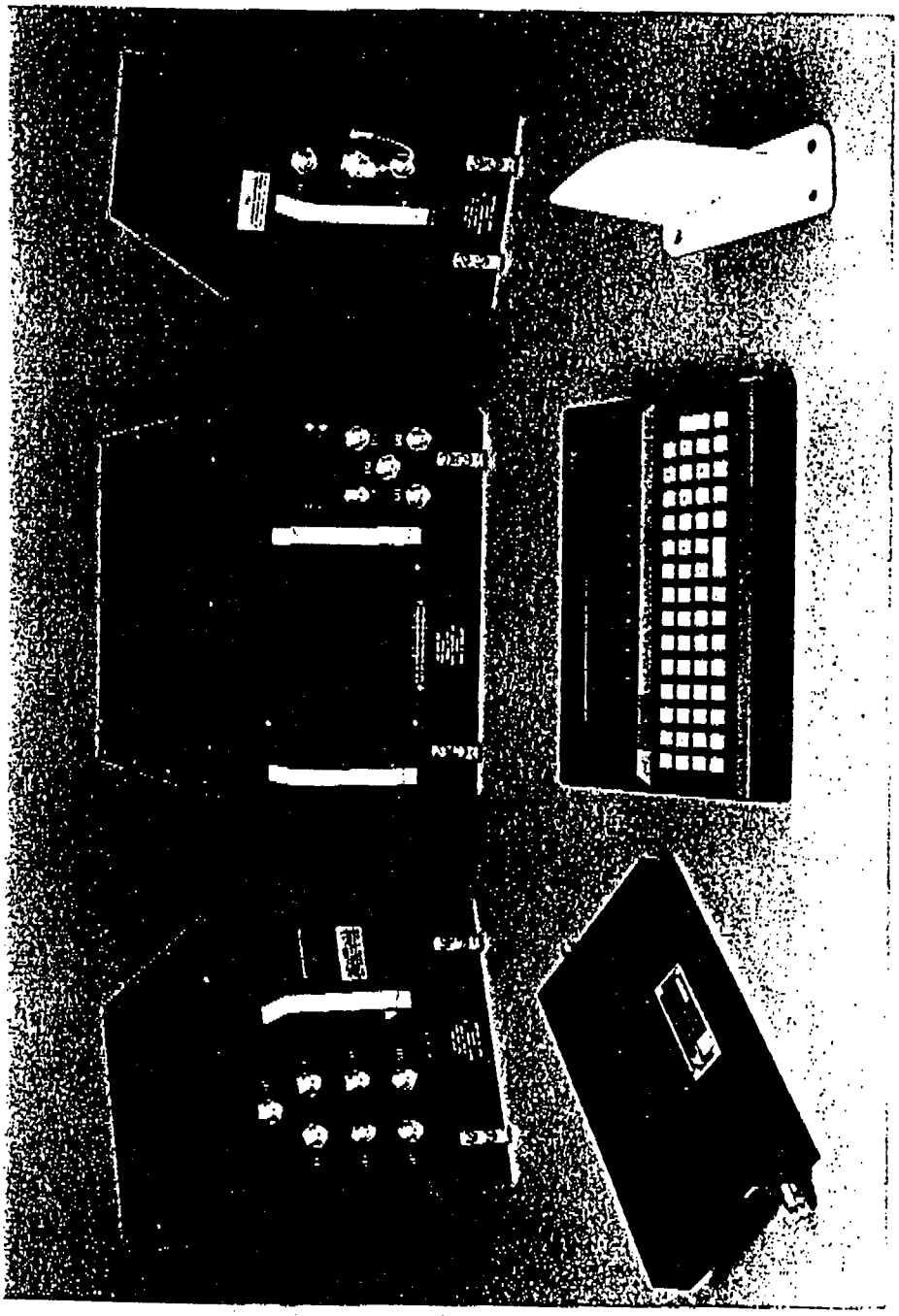


Figure 2 - RACAL - PRODAT Avionics

On 24th October, 1988 the RACAL's Jetstream aircraft was controlled entirely via the PRODAT data link and ADS functions on a flight from the UK to Madrid in Spain, under the responsibility of the Spanish Civil Aviation Authority (DGAC). This was a world first. Between 10th and 14th October, 1988, the BAC1-11 of the Royal Aircraft Establishment (UK) made dedicated evaluation flights at low satellite elevation angles. It departed from Bedford (UK) and flew to Thule (North Greenland 76° 20'N, 68° 30'W) via Iceland. (Fig. 3)

No significant degradation occurred down to a satellite elevation of 3°, apart from a sudden interruption at around 8° elevation caused by the high tail elevator surface on this particular type of aircraft.

At 0° elevation and below, the main limitations come from the antenna pattern which has a 5dB lower gain in longitudinal axis than in the transverse axis, owing to the cylindrical shape of the fuselage.

The carrier to multipath ratio (C/M) at elevations close to 0° was about 8dB, with 10dB fades lasting 1 to 2 s.

The link was still working at "negative" elevation angles, 150NM beyond the geometrical satellite horizon. It was not possible to carry the test further because of the range limitations of the aircraft.

Some of the results are given in Table 1. Test coordination during the flight was achieved with PRODAT itself.

	Elevation Range		
	Above 8°	7° to 3°	2° to -2°*
Satellite along aircraft axis	P = 90% E = 0.1%	P = 20-60% E = 8-15%	E = 20-40% E = 20-40%
Satellite perp. to aircraft axis	P = 90% E = 0.1%	P = 70% E = 5%	P - 60-70% E = 20%

P: polling success rate
E: vector erasure rate received on the aircraft, in stabilising flight altitude
*: HPA power increased by 2dB

PRODAT/AIRCOM EXPERIMENTS

Scope of the Trials

The PRODAT/AIRCOM experiment offered to the participating airlines a comprehensive set of means enabling both in-flight crew and associated ground staff to evaluate the benefits of Aeronautical Mobile Communications, including AOC, AAC, APC and ATC services.

AOC Services

The AOC applications are provided using the standard ACARS/AIRCOM equipment available on the market and fully compatible with the standard ARINC 597/724 Characteristics.

The AOC Service features which were able to be tested during the trials include:

- Movement Messages,
- Weather Messages,
- Free Text Messages.

AAC Services

Two facilities are provided :

- SITA Type B messaging,
- International telex.

APC Services

Passengers also have the possibility of sending or receiving a private telex to or from any ground based telex terminal.

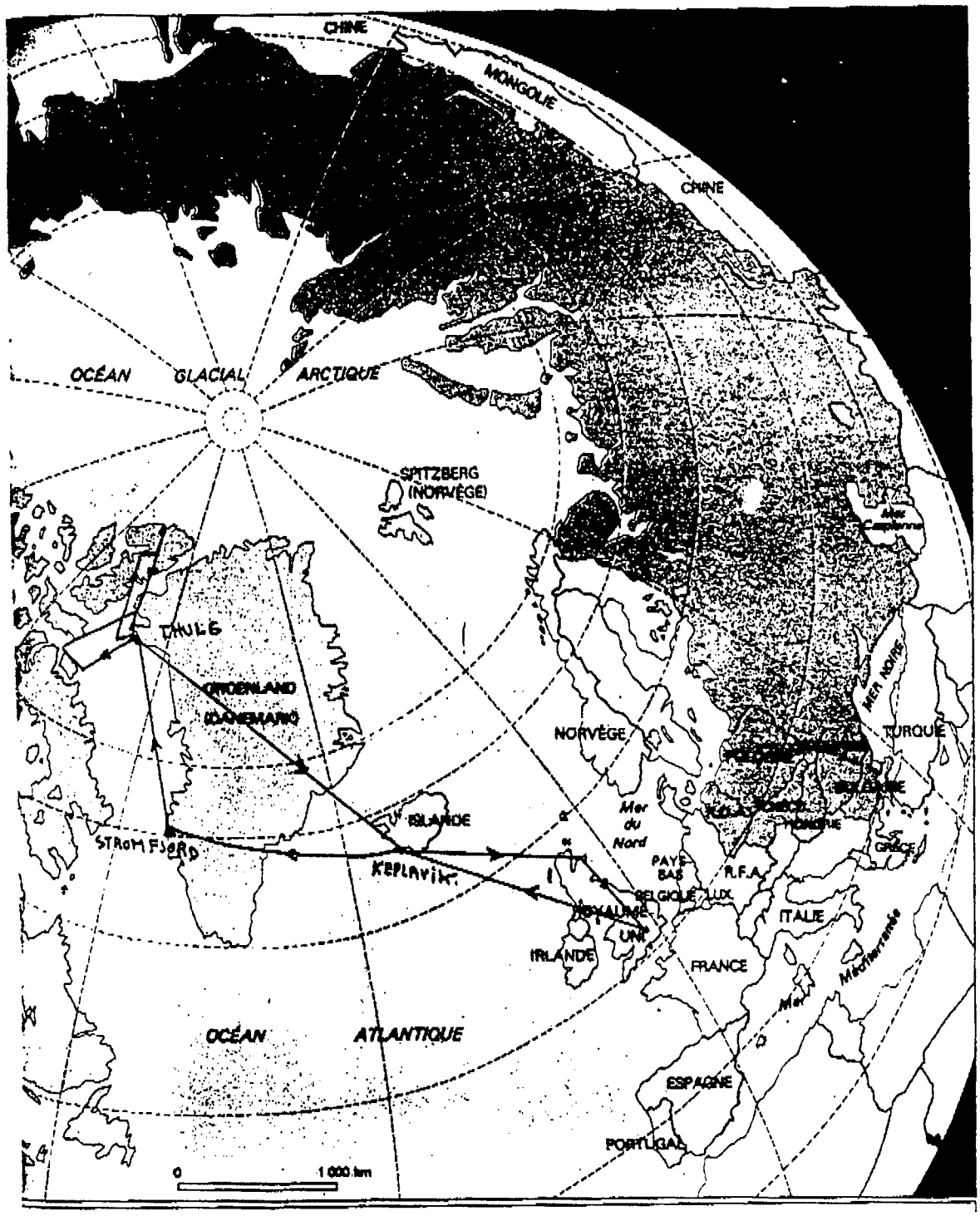


Figure 3 - Evaluation flight at low satellite elevation angles

ATC Services

As a complement of the PRODAT/ATC experiments, the airlines can also request the actual aircraft position from any ground based SITA terminal. Position data extracted from the on-board navigation equipment are then sent to the originator of the request through the SITA ground network.

The following requests can be made depending on the availability of navigation equipment fitted in the aircraft:

- Aircraft position and aircraft-id requests
- Waypoint requests
- Meteorological data requests
- Flight-id requests
- Waypoint and velocity requests

Project Step Breakdown

The PRODAT/AIRCOM Service trials have been implemented as follows on a step by step basis for each participating airline:

Aircraft Installation

This step includes all preparation required for the aircraft wiring and installation of the PRODAT and ACARS/AIRCOM avionics.

The workload and time schedule depend on the aircraft type and the airline ground maintenance facility.

Ground System Preparation

Ground system preparation covers activities required for connecting the ESA PRODAT system to the SITA AIRCOM. Additional software are also made available in order to allow the participants to evaluate new application fields during the trials.

Ground System Integration and Technical Flight Test

An overall system integration on the ground is performed, followed by a technical flight test to decide if the pre-operational trials can take place.

A training course is organised for the airline personnel providing them with the necessary information for the system operation.

Pre-operational flight tests

Flight tests can take place after the go-ahead signal from the technical flight test.

TAP AIR PORTUGAL SERVICE TRIALS

General information

Starting date	:	September 1986
End date	:	July 1991
Aircraft type	:	LOCKHEED Tristar L 1011-500
Aircraft tail no	:	CS-TED
ACARS/AIRCOM Avionics	:	TELEDINE CONTROLS
Routes	:	NORTH AMERICA (New York, Boston, Montreal, Toronto, etc.) SOUTH AMERICA (Rio de Janeiro, Sao Paulo, Porto Allegre etc.) WESTERN EUROPE (Paris, London, Amsterdam) AFRICAN ROUTES down to Johannesburg.

Scope of the Trials

TAP Air Portugal intended to evaluate the three main applications of Aeronautical Mobile Communications, i.e :

- AOC via TELEDYNE CONTROLS' avionics
- AAC via HUSKY handheld computer
- APC via HUSKY handheld computer

Project history

From a chronologic standpoint, TAP Air Portugal Service trials can be summarised in three main phases:

Phase one: Aircraft Installation

This phase extended from November 1986 until February 1988 and covered preparation work of the CS-TED aircraft and the associated ground infrastructure for TAP Air Portugal.

This phase ended with a ground check at the LISBON airport followed by a technical flight test from LISBON to NEW YORK (JFK) on February 11th, 1988. This was the first time an ACARS/AIRCOM message was exchanged via a satellite data link during a regular transatlantic flight.

Phase two: Pre-operational Flight test

This phase covered the period from March 1988 to December 1990, during which time TAP Air Portugal performed continuous pre-operational flight test campaigns with two main interruption periods due to hardware failures.

Numerous pre-operational flight tests have been carried out by TAP Air Portugal providing both on-board cockpit crew and ground based staff with valuable experience as regards the satellite-based data communications link. In addition, new applications such as in-flight revised flight plans and in-flight weather requests were also tested and highly appreciated by the crew.

Company communications (AAC) and Passenger telex (APC) were also tested successfully many times throughout these pre-operational flight tests.

Phase three : Follow-up and Maintenance period

This phase covered the last period of the Service Trials Programme from July 1990, with the migration of the ESA-ground earth station from Villafranca-Spain to Fucino-Italy. These continued until July 1991.

VARIG SERVICE TRIALS

General information

Starting date	:	17 February 1987
Ending date	:	29 December 1989
Aircraft type	:	BOEING 767-200 ER
Aircraft tail no	:	PP-VNN
Routes - Domestic	:	Brasilia, Porto Allegre, Sao Paulo etc
- International	:	North and South America (Asuncion, Buenos Aires Los Angeles etc.)

Scope of the Trials

The Varig Service Trials Programme concentrated on two aspects:

- AOC application via TELEDYNE CONTROLS' avionics;
- AAC application via the hand held HUSKY computer.

Project history

The VARIG Service trials can be also divided into three main phases:

Phase one : Aircraft Installation

Starting from mid 1987 and terminating in October 1988, this phase covered preparation work performed for the aircraft avionics installation.

Phase one was concluded by a successful technical flight test from Rio de Janeiro to Porto Allegre on October 28th, 1988.

Phase two : Pre-operational Flight Tests

This phase covered the period from November 1988 until March 1989 during which several pre-operational flight tests were successfully conducted.

The number of flight tests was limited by the occurrence of several hardware failures and periods of unavailability of the aircraft and/or space segment.

Phase three : Follow-up and Maintenance Period

The final phase covered the last six months of the project with several malfunctions discovered during test flights due to power supply problems related to the use of aircraft engine power.

The Varig Service Trials Programme was subsequently completed in late 1989.

SAUDIA SERVICE TRIALS

General Information

Starting date	:	August 1988
Ending date	:	July 1991
Aircraft type	:	BOEING 747-300
Aircraft tail number	:	HZ-AIT
ACARS/AIRCOM Avionics	:	BENDIX/ALLIED
Routes - Domestic	:	Riyadh, Dharan ...
- International	:	Western Europe, North America, South East Asia

Scope of the Trials

- The Saudia Service Trials mainly focussed on:

- AAC applications for company messages through the HUSKY hand held computer.

Project History

The Saudia Service Trials Programme can be summarised in two main phases:

- Phase One: Aircraft Installation

The installation phase began in August 1988 and lasted until February 1989 with the aircraft fully fitted with PRODAT/AIRCOM avionics.

A technical flight test took place on February 13th, 1989 during a flight from Jeddah to Riyadh. The first part of the flight test was successful while the latter was rather disturbed by fading conditions resulting from the aircraft's tail shadowing and very low elevation.

- Phase Two: Pre-operational Flight Tests

The Saudia Service Trials began after the technical flight test of September 1989, with some intermittent interruption periods due to hardware failures.

Several flight tests were recorded during this pre-operational service trials period. Analyses from the history file showed that flight control data and engineering maintenance data were the topics of most interest to the on-board crew. New features such as the in-flight weather request were highly appreciated by the crew.

An ultimate pre-operational flight test campaign has been agreed in order to allow Saudia to consolidate their Service Trials programme.

SABENA SERVICE TRIALS

General Information

Starting date	: April 1987
Ending date	: July 1991
Aircraft type	: AIRBUS A310-300
Aircraft tail no	: OO-SCC
ACARS/AIRCOM Avionics	: BENDIX/ALLIED
Route	: North America (New York, Montreal, Boston...) Africa (Conakry, Dakar, Lagos, Lome, Niamey...)

Scope of the Trials

The Sabena Service Trials concentrated on the AOC applications providing flight control data using BENDIX/ALLIED avionics and ATC applications providing actual data extracted from the on-board Flight Management System (FMS).

Project History

The Sabena Service Trials programme can be summarised in two main phases:

■ Phase One: Aircraft Installation

The installation phase for Sabena aircraft covered the period from May 1987 to February 1989 to provide the on-board avionics fully installed and operational.

This long period also included ground integration testing of PRODAT avionics with the ACARS/AIRCOM avionics and FMS equipment to provide flight data for the ATC experiments.

The aircraft installation phase was completed in February 1989 with a technical flight test from Brussels to Dakar. Various software upgrades in both PRODAT and ACARS/AIRCOM were performed from March 1989 to December 1989.

■ Phase Two: Pre-operational Flight Tests

Since the beginning of this service trials phase in March 1990, Sabena has successfully performed almost daily flight trials with regular transoceanic flights (Brussels-New York-Brussels or Brussels-Conakry-Brussels).

Departure and Arrival reports are also transmitted to ground ATC centres participating in PRODAT/ATC experiments allowing them to run the ADS experiments in conjunction with the airline flight trials.

Figure 4 illustrates a Sabena flight route traced by the ATCEU in Bournemouth, England.

Various demonstrations on flight tracking based on the PRODAT/ATC experiments have been successfully conducted using the Sabena daily flight test, most notably at the first meeting of Phase II of the Future Air Navigation System (FANS II) held in Montreal on May 25th, 1990.

CONCLUSIVE REMARKS

The ESA-PRODAT/SITA-AIRCOM Service Trials Programme has proved the viability of the satellite-based data link concept and its capability to provide the "missing link" between an aircraft flying over an oceanic region and its ground base.

New applications such as revised flight plan, in-flight meteo update bulletin have been highly appreciated by the crew, providing them efficient and reliable means to get instantly in touch with their home dispatch office at any phase of the flight.

Considerable efforts have been provided by all participants and valuable experience has been gained in the following areas, for the benefits of the aviation industry, i.e.:

■ From the airline standpoint:

. identification and evaluation of airline needs as regards the satellite based data link applications;

. aircraft wiring and installation aspects, including maintenance and logistic needs for SATCOM avionics;

. coordination between ground staff and onboard crew implying a coordinated and appropriate operational procedure.

■ From an ATC experimenter's viewpoint:

The Service trials, particularly with the Sabena aircraft, have confirmed that the satellite-based data link has a high potential for the Automatic Dependent Surveillance. Several flight records produced during regular transoceanic Sabena flights have provided ATC experimenters with the necessary ADS concept modelling data, in view of the potential use of satellite-based data links for international ATC.

PRODAT enabled the world's first civil ADS flight, and the first regular ADS messaging from a commercial airliner in revenue service during the fall of 1989 and throughout 1990.

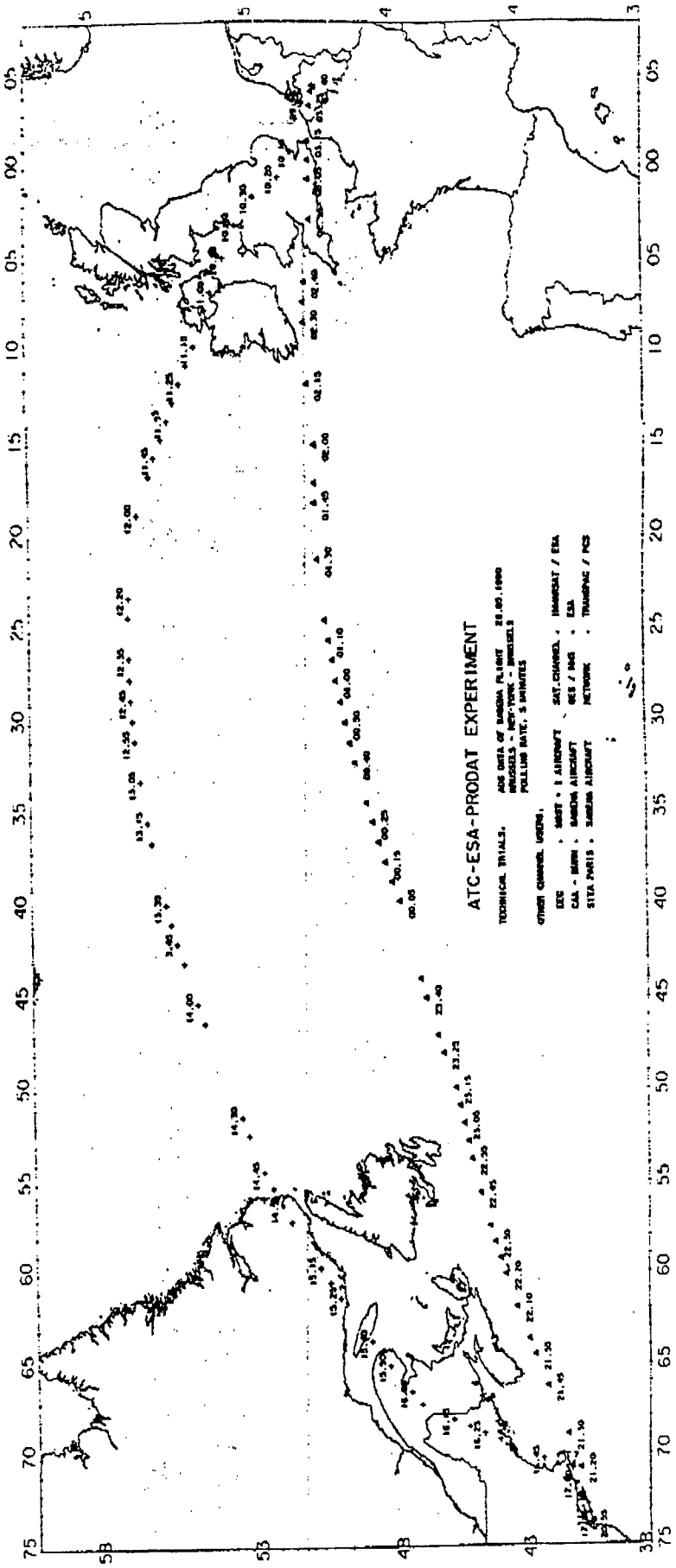


Figure 4 - Sabena aircraft tracking with PRODAT/ATC experiments

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SESSION TWO: PROGRAMS, STANDARDS AND INSTITUTIONAL ISSUES

Wednesday, September 25, 1991

Master of Ceremonies - Joseph J. Fee, Oceanic Systems Manager, Federal Aviation Administration

Session Chairperson - Yaroslav Kaminsky, Special Assistant, Satellite Program Office, Federal Aviation Administration

8:30 **Opening Remarks** - Joseph J. Fee, Master of Ceremonies

8:35 **FAA Aeronautical Satellite Communications Project Plan** - Yaroslav Kaminsky, Special Assistant, Satellite Program Office, Federal Aviation Administration (Co-authors - Joseph F. Dorfler, Satellite Program Manager, Federal Aviation Administration; Jim Nussbaum, Manager, SATCOM Program, CTA)

8:50 **Aeronautical Mobile Satellite Service (AMSS) Message & Voice Access Request Transit Delay** - Thomas F. Dehel, Group Engineer, CTA

9:10 **An Improved Periodic Reporting System by Satellite** - Dr. Keith Smith, Manager, Engineering, Aeronautical Services Division, INMARSAT

9:30 **Satellite Data Link Research and Development Program in Japan** - Hiroki Takeda, Special Assistant to the Director, Radio Engineering Division, Air Traffic Services Department, Civil Aviation Bureau of Japan

9:50 BREAK sponsored by **American Mobile Satellite Corporation**

10:10 **Radio Technical Commission for Aeronautics (RTCA) Operational Standards for ADS Avionics** - B. Richard Climie, Consultant, Honeywell, Inc.

10:25 **Airlines Electrical Engineering Committee (AEEC)** - Michael D. Rockwell, Senior Avionics Engineer, ARINC (AEEC Staff)

10:40 **Status of the Oceanic Display and Planning System (ODAPS) Program** - William L. Umbaugh, Manager, Automation Engineering Division, Federal Aviation Administration

11:00 **System Improvements Identified by the North Atlantic Systems Planning Group (NAT/SPG) As Related to the Capabilities of the Oceanic Display and Planning System (ODAPS)** - Dan H. Iredell, Senior Programmer/Analyst, STX (Co-authors Rajan Srirangarajan, Senior Systems Engineer, STX and John H. Crimmins, Jr., Software Development Manager, STX)

11:20 **Panel Discussion: The Status and Interrelationships of Various ADS and SATCOM Standards**

Panel Members:
W. Frank Price, FAA
R. Andrew Pickens, AVCOM
Michael D. Rockwell, ARINC
James C. Crowling, FAA
B. Richard Climie, Honeywell
G. Keith Smith, INMARSAT
Joseph J. Fee, FAA

SESSION TWO: PROGRAMS, STANDARDS AND INSTITUTIONAL ISSUES

SESSION CHAIRPERSON

Yaroslav Kaminsky
Special Assistant
Satellite Program Office
Federal Aviation Administration

Yaroslav Kaminsky joined ARD-330 on October 1, 1990 as a Special Assistant to the Satellite Program Office. His responsibilities are to assist the Satellite Program Manager in the development and execution of the FAA's Satellite Communication Project, particularly in the preparation of pertinent national and international standards. Presently he serves as the Principal U.S. Spokesman for the ICAO AMC Panel Working Group on SARPs. Since 1961, Mr. Kaminsky has been involved in the development, design, testing, evaluation, and implementation of various civil and military satellite communication and distress alerting systems at MITRE (1964-1990) and at Bendix (1958-1963). Among other projects, Mr. Kaminsky participated in the joint MITRE/COMSAT/Rockwell International/ Ball Aerospace Aeronautical Satellite Data Link (ASDL) Experiment (1984-1985), in the FAA's ATS-6 aeronautical experiments and the AEROSAT Program (1971-1973), and in the establishment of the first geosynchronous (SYNCOM) communication satellite (1962-1963).

FAA AERONAUTICAL SATELLITE COMMUNICATIONS PROJECT PLAN

Joseph F. Dorfler (FAAHQ/ARD-330), Yaroslav Kaminsky (FAAHQ/ARD-330), and Jim Nussbaum (CTA Incorporated)

Washington, D.C.

ABSTRACT

The Federal Aviation Administration (FAA) Satellite Communications Project, which is a component of the FAA Satellite Program, consists of three complimentary activities that support current and future aeronautical satellite communications applications, including Automatic Dependent Surveillance (ADS). This paper presents the FAA Satellite Communications Project Plan. It outlines the tasks that are presently being pursued as well as the purpose of each task. The status of each task is also presented.

INTRODUCTION

The FAA Satellite Communications Project was established to enhance the efficiency of Air Traffic Management (ATM) in oceanic regions first and in the National Airspace System (NAS) later, and to enhance the efficiency of air carrier operations. To exploit satellite communications for maximum benefit of both the FAA and the aviation community, the Satellite Communications Project is divided into three complimentary activities, shown in Figure 1, whose objectives are as follows:

- To guide the development, test, and validation of national and international standards for the establishment and certification of the Aeronautical Mobile Satellite Safety (Route) Service (AMS(R)S).
- To select and test, in cooperation with the aviation community, several satellite communications applications in key areas (e.g., oceanic, offshore, polar, and low altitude communications) in order to demonstrate the substantial benefits gained by their implementation.
- To extend the benefits of satellite communications to general aviation through a study of the potential for future widespread use of satellite communications in the NAS considering the prospects of availability of new and innovative technologies and approaches to affect the desired benefits.

The first of these activities involves the development and validation of standards for the Aeronautical Mobile Satellite Service (AMSS). This includes the development of Standards and Recommended Practices (SARPs), the development of Minimum Operational Performance Standards (MOPS), the correlation of the SARPs and the MOPS with other evolving standards, and the validation and evaluation of the SARPs and the MOPS. The FAA will also collect data for avionics certification and validation of oceanic Air Traffic Services (ATS). The goals of this activity are to ensure that standards are practical, that they satisfy user requirements, and that they are consistent

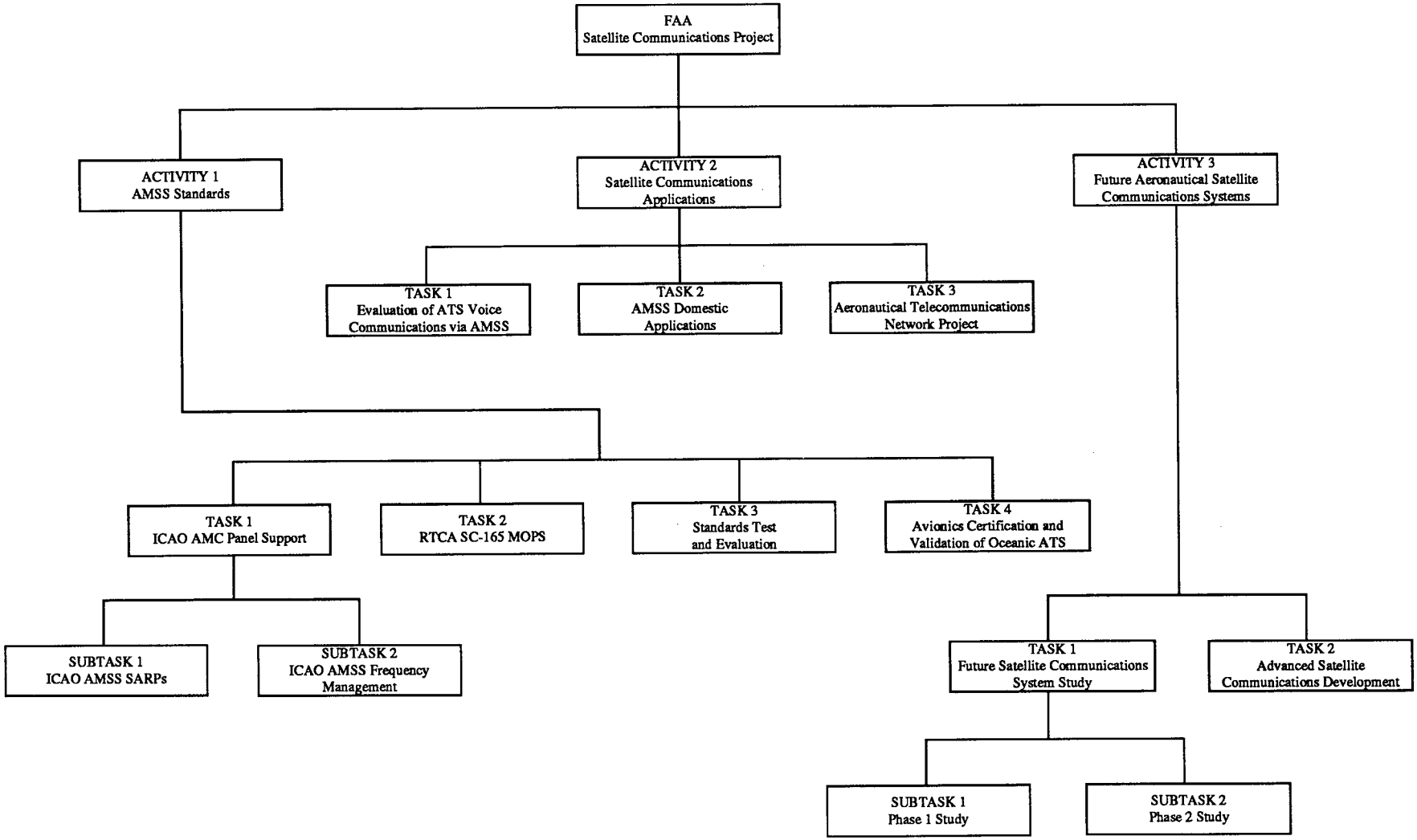


FIGURE 1. HIERARCHY OF SATCOM ACTIVITIES AND TASKS

with the goals of the FAA. The current plans call for the submission of the AMSS MOPS to the Radio Technical Commission for Aeronautics (RTCA) Executive Committee early in 1992 and for the support of the development of the associated Technical Standards Order (TSO). The draft International Civil Aviation Organization (ICAO) AMSS SARPs are expected to be submitted to the Air Navigation Commission (ANC) in the second quarter of 1993. Validation and evaluation of the AMSS MOPS and SARPs will be initiated in 1992 and will be completed in 1995. Collection of data for avionics certification and validation of oceanic ATS will be initiated at the end of 1993 and will be completed in 1998, by which time full scale world-wide implementation of satellite data and voice communications for oceanic ATS is anticipated.

The second of these activities involves the cooperative development of domestic applications. This includes the joint evaluation (FAA and airlines) of the effectiveness of high data rate digitized voice communications for oceanic ATS, the joint evaluation (FAA and satellite communications service providers) of the effectiveness of low data rate digitized voice and data communications for offshore (rotorcraft) applications, and the implementation of an Aeronautical Telecommunications Network (ATN) for satellite communications. The goals of this activity are to demonstrate to the user community the substantial benefits gained through the implementation of these techniques. A cooperative agreement with a major airline is being planned for late 1991 to conduct oceanic operational tests of the AMSS voice capability. A similar agreement with a satellite communications service provider is also being planned for 1991 to conduct low data rate satellite communications tests that will lead to recommendations for rotorcraft air traffic voice services in 1996. The FAA will provide test aircraft and test support for flight evaluations of avionics leading to an ATN functional specification in 1996.

The third of these activities involves the definition and development of future satellite communications. The FAA will initiate a study of the potential for widespread satellite communications use in the NAS considering the prospects for new technical approaches to provide the desired benefits. This study will consider as many of the available options as possible and will attain consensus support within the aviation community; it will consider transition strategies, user equipment costs, and other key parameters to assess the sensitivity of the results to the assumptions; and it will investigate promising approaches and will evaluate them in comparison with the existing NAS techniques. This study will assess the benefits of satellite communications to general aviation ATM and will initiate development of innovative technologies to extend the user base. The goal of this activity is to assess the advantages of satellite communications in the FAA's long-range plans for surveillance and communications. In FY 1993, a solicitation for a study of an advanced satellite communications system will be announced. The results of this study will be available in FY 1996 and will form the basis for further research and development of an advanced satellite communications system.

Each of these activities is described in detail below.

ACTIVITY 1 - AMSS STANDARDS

An important function of the FAA Satellite Communications Project is to guide the establishment of standards for the development and certification of AMS(R)S and equipment. AMS(R)S, i.e. safety services, include ATS and Aeronautical Operational Communications (AOC). The use of international standards ensures that all equipment developed in accordance with the standards will operate properly anywhere in the world, thereby guaranteeing interoperability, and satisfying applicable performance requirements.

Previous work has been carried out by the ICAO Future Air Navigation Systems (FANS) Committee, RTCA, and the Airline Electronic Equipment Committee (AEEC). SARPs are currently being developed within the ICAO Aeronautical Mobile

Communications (AMC) Panel. MOPS are currently being developed within RTCA Special Committee 165 (SC-165).

ICAO SARPs encompass overall system performance and interoperability whereas RTCA SC-165 MOPS focus on avionics requirements and system/service performance criteria. Consequently, the major thrust of the FAA's standards development effort is directed towards the development of SARPs. However, considerable involvement of RTCA SC-165 is required to assure compatibility between the SARPs and the MOPS.

Four tasks will be performed in this area. Task 1, which consists of two subtasks, addresses the development of SARPs and related Guidance Material, and issues related to AMSS spectrum. Task 2 addresses the development of MOPS. Task 3 addresses the evaluation, verification, and validation of both the SARPs and the MOPS through simulation and testing. Task 4 consists of collecting data for avionics certification and validation of oceanic ATS. The ultimate goal of these tasks is the approval of AMSS SARPs by ICAO and MOPS by RTCA. These four tasks are described in detail below.

TASK 1 - ICAO AMC PANEL SUPPORT

Task 1 comprises two subtasks. Subtask 1, ICAO AMSS SARPs, supports the development of AMSS SARPs and related Guidance Material. Draft SARPs are currently being developed within AMC Panel Working Group A (WG-A). AMSS SARPs focus on overall system performance and interoperability. Only top-level requirements are specified in the SARPs; supporting information is included as Guidance Material. Sections 1 through 4 of the SARPs (i.e., definitions and system capabilities, Radio Frequency [RF] characteristics, and channel types and rates) and associated appendices are the responsibility of the Canadian Delegation. The FAA, as well as others, has responsibility for reviewing these sections and providing comments to the Canadian Delegation as appropriate. The U.S. Delegation is responsible for the remainder (and bulk) of the SARPs, i.e., Sections 5 through 10 and associated appendices. Sections 5 through 10 address channel protocols, satellite subnetwork layer protocols, packet mode (data) and circuit mode (voice) services, and aircraft and ground earth station management. The U.S. Delegation also supports the development of the ICAO AMSS Advisory Circular.

Included in Subtask 1 is the support for miscellaneous activities related to the development of AMSS standards within other organizations such as the AEEC (Characteristics 741 and 745), ADS Panel, Inmarsat, FANS II, RTCA SC-162, and the Secondary Surveillance Radar Improvements and Collision Avoidance Systems (SICAS) Panel. Work in this area ensures that SARPs are internally consistent and that they are compatible with other related standards and vice versa.

Subtask 2, ICAO AMSS Frequency Management, supports work on AMSS spectrum requirements, including the spectrum model for North America and AMSS frequency coordination. Spectrum-related work is being performed within AMC Panel WG-B. The primary purpose of Subtask 2 is to develop requirements for the AMSS system design, to support efforts to finalize spectrum requirements for North America, to develop guidelines for frequency coordination, to prepare for the 1992 World Administrative Radio Conference (WARC), and to ensure that the outputs of both AMSS WG-A and WG-B are consistent with U.S. policy.

The FAA continues to provide technical expertise and leadership to the ICAO AMC Panel. The U.S. Preparatory Groups for WG-A and WG-B meet periodically to review progress in these areas to ensure agreement with the international community prior to working group meetings.

TASK 2 - RTCA SC-165 MOPS

Task 2, RTCA SC-165 MOPS, supports the development of AMSS MOPS. The MOPS address equipment performance requirements and test procedures, installed equipment

performance, and equipment operational performance characteristics. RTCA SC-165 is also defining end-to-end service criteria and subnetwork performance.

The purpose of this task is to develop technical characteristics for MOPS and to ensure that the MOPS are consistent with the AMSS SARPs. The MOPS for AMSS specify system characteristics that will be used by designers, manufacturers, installers, and users of the AMSS system and equipment as the basis for certification. Compliance with the MOPS is the principal means of ensuring that the AMSS will perform its intended functions satisfactorily under all conditions normally encountered in routine aeronautical operations.

The FAA continues to provide technical expertise and leadership to RTCA SC-165. Subworking groups of RTCA SC-165 meet periodically to review the progress of the MOPS and to ensure that the MOPS are consistent with the SARPs. The FAA participates in RTCA SC-165 plenary and subworking group meetings and responds to action items assigned at these meetings. The FAA also serves on the MOPS Editorial Committee.

Figure 2 illustrates the relationship between the aforementioned AMSS standards documents.

TASK 3 - STANDARDS TEST AND EVALUATION

Under Tasks 1 and 2 above, the FAA is supporting the development of AMSS standards, i.e., SARPs and MOPS. The need also exists to evaluate, verify, and validate these standards. Task 3, Standards Test and Evaluation, supports the verification and validation of SARPs and the testing of MOPS using several different techniques, including simulation. This task will ensure that these standards are practical, that they satisfy user requirements, and that they are consistent with the goals of the FAA.

Much of the material in the SARPs and MOPS is based upon the Inmarsat System Definition Manual (SDM) and ARINC (Aeronautical Radio, Inc.) Characteristic 741. Hardware is currently being designed and built. Prior to acceptance, the SARPs and MOPS require validation to verify their functionality and completeness.

A SARPs Validation Cross Reference Matrix (VCRM) has been developed and presented to the ICAO AMC Panel. The VCRM identifies several methods to validate the SARPs, e.g., simulation, analysis, testing, utilization of manufacturer's data, and demonstration. A test plan, which includes testing of RF standards, has been developed. A ground Communications Test Facility (CTF) is being developed to conduct system end-to-end and RF tests to validate standards not currently validated by manufacturer's data. In addition, a Flight Test Facility (FTF) is being developed to evaluate state-of-the-art equipment and system enhancements. Initial testing will be conducted using a low data rate AMSS system that accesses the maritime band and uses a subset of the ARINC Characteristic 741 avionics. Follow-on testing will be conducted using a high data rate AMSS system, when available, that accesses the AMSS band. Simulation will be conducted to evaluate the performance of the planned AMSS architecture under various communication traffic conditions. This simulation will indicate the performance limitations of the planned AMSS architecture. As airlines begin equipping, additional input will be available for the validation database. Figure 3 illustrates this task.

TASK 4 - AVIONICS CERTIFICATION AND VALIDATION OF OCEANIC ATS

In conjunction with Task 3, Standards Test and Evaluation, ARD-330 and its contractors will collect data to support the FAA certification of AMSS and the subsequent verification of related end-to-end services. To this end, ARD-330 will interact with the appropriate FAA organizations, e.g., AFS, AIR, AMS, and ATR, to identify data that can be used to support the certification process. SARPs validation will be coordinated with these FAA organizations. Formal collection of such data will begin in late 1993 and will be completed in 1998.

	System	Avionics & Service
Primarily Government	ICAO SARPs Standards and Recommended Practices (Treaty-Level Agreement) *{Adapts Capability Descriptions to Worldwide Service Basis}*	RTCA SC-165 MOPS Minimum Operational Performance Standards (FAA Basis for Technical Standards Order) *{Develops Testable Parameters and Tests for Minimum Avionics and AMSS Service Requirements)*
Primarily Industry	Inmarsat SDM System Definition Manual (AES and GES Interoperability Basis) *{Describes all Elements of the International System Except Avionics Details}*	AEEC ARINC Characteristic 741 *{Describes Avionics Interfaces, Performance, and Signal-in-Space}*
	Derived Internationally	**Derived Domestically**

FIGURE 2. STANDARDS DEVELOPMENT

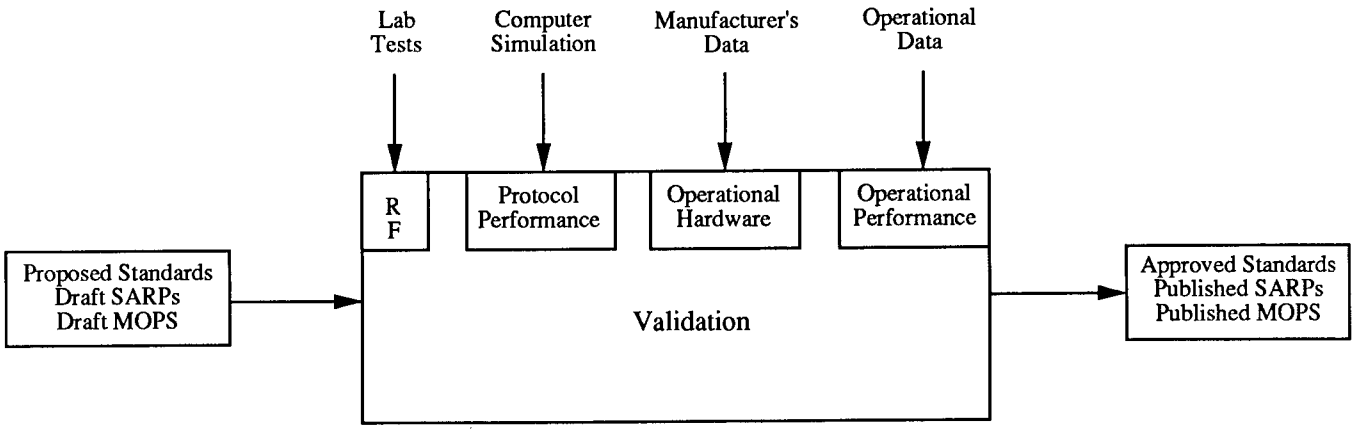


FIGURE 3. STANDARDS TEST AND EVALUATION

ACTIVITY 2 - SATELLITE COMMUNICATIONS APPLICATIONS

Airlines are currently equipping to standards (e.g., ARINC Characteristic 741, ICAO AMSS SARPs, and RTCA SC-165 MOPS) that are being developed to define the capabilities and performance requirements for AMSS operational equipment. The FAA will extend these standards into practical systems by selecting and testing several applications (e.g., oceanic, offshore, polar, and domestic low altitude communications) to demonstrate the substantial benefits gained by their implementation as well as to provide an operational evaluation of the aforementioned standards. The selected applications will demonstrate the capabilities of satellites to satisfy currently unmet communications needs in the NAS.

Currently-available equipment, which complies with a subset of the standards, and satellites accessing the maritime mobile band will be used for initial testing of AMSS data and digitized voice capabilities, and will support applications that satisfy the near-term requirements of the aviation community. Equipment that fully complies with the SARPs and the MOPS will be used when available.

Three tasks will be performed in this area. Task 1 addresses the need for the FAA to demonstrate satellite voice communications for ATS applications. Task 2 addresses testing of AMSS equipment onboard helicopters in support of low altitude off-shore operations and medical emergencies. Task 3 demonstrates the unifying concepts engendered by the ATN. The ultimate goal of these tasks is to demonstrate to the user community the substantial benefits gained through the implementation of satellite-based communications systems that adhere to AMSS standards, which the FAA will accomplish by demonstrating selected domestic applications that satisfy the currently unmet needs of the user community. These three tasks are described in detail below.

TASK 1 - EVALUATION OF ATS VOICE COMMUNICATIONS VIA AMSS

Several airlines and private aircraft operators intend to install the AMSS voice capability. To address the need to demonstrate high data rate digitized satellite voice communications for ATS applications, the FAA will demonstrate voice communications between pilots and controllers during oceanic flights. The results of this demonstration will be used to refine and enhance the evolving operational requirements for ATS communications using the AMSS voice system. This demonstration will also provide real-time operational AMSS voice system experience at a participating Air Route Traffic Control Center (ARTCC).

A cooperative agreement between the FAA and interested airlines, private aircraft operators, and communications service providers is being planned for late 1991 to conduct operational tests of the AMSS voice capability. A joint test plan will be developed to define the flight tests. The FAA's B-727 will be equipped with the AMSS voice capability and will participate in flight trials. An ARTCC communications architecture study will be conducted to define and evaluate the long-term options for providing direct voice connectivity between oceanic controllers and AMSS voice equipment. These studies will address Voice Switching and Control System (VSCS) interconnection, terrestrial call routing, call queueing and priority processing, and terrestrial voice internetworking issues. As part of this study, an interim approach for direct FAA Technical Center (FAATC) and ARTCC interconnection with the AMSS voice equipment will be developed in order to support the flight tests. The AMSS voice capability will be demonstrated to participants using the coder/decoder (CODEC) testbed at the FAATC. For the purposes of operational demonstration and evaluation, interconnections for direct two-way pilot-controller voice calls between the ARTCC and FAATC, and the AMSS voice equipment will be implemented using existing functional capabilities of AMSS Ground Earth Station (GES) equipment. This will support internetworking with private line telephony facilities. Contingent upon program phasing,

demonstrations may initially use the ARINC manual call routing function until direct AMSS voice interconnection capabilities to the ARTCC and FAATC are available. Figure 4 illustrates this task.

TASK 2 - AMSS DOMESTIC APPLICATIONS

The use of satellite communications in domestic areas has several near-term benefits, including rotorcraft service to oil platforms in offshore areas and helicopter emergency medical services, which are now widespread. As more aircraft are equipped with a data link communications capability, there is a potential to alleviate current VHF congestion. The initial purpose of this task is to evaluate prototype satellite communications hardware provided by the domestic service provider in flight tests using an FAA helicopter. The services tested will include data and extremely low data rate digitized voice using store-and-forward techniques. Subsequent evaluations will include planned helicopter avionics, which are expected to be compliant with AMSS SARPs and MOPS. Future tests may be conducted in other areas, e.g., Gulf of Mexico, and include testing of other satellite communications systems. This task will extend the utilization of satellite communications techniques to Continental U.S. ATS.

The FAATC is planning to sign a Cooperative Research Development Agreement (CRDA) with a domestic service provider for the loan of interim low data rate satellite communications equipment for test and evaluation. The FAATC will also coordinate with the FAA Vertical Flight Program Office during this task. The Jet Propulsion Laboratory (JPL) will conduct a study to resolve potential problems associated with installing satellite communications on helicopters. The interim avionics obtained from the domestic service provider will be installed and flight tested on an FAA helicopter to evaluate the system under operational scenarios where existing Very High Frequency (VHF) and radar coverage is limited. Low rate digitized voice methods will be evaluated using store-and-forward techniques. The initial tests will be conducted using Inmarsat satellites that access the maritime mobile band. Additional tests will be conducted using the domestic service provider's satellite system and commercial-quality avionics that are compatible with the AMSS architecture. These tests may involve potential users of AMSS. Figure 5 illustrates this task.

TASK 3 - AERONAUTICAL TELECOMMUNICATIONS NETWORK PROJECT

The ATN Project (ATNP) is a cooperative project initiated by The MITRE Corporation that includes various participating organizations (i.e., ATC authorities, end users, service providers, manufacturers, and contractors) to develop, validate, and evaluate the use of ATN routers in air-ground and ground-based configurations for air-ground data transmission that is independent of the type of radio link used. The ATNP is intended to develop implementable equipment using ATN protocols on an end-to-end basis. This ATNP will demonstrate an aeronautical implementation of an Open Systems Interconnection (OSI) packet data architecture, i.e., ATN.

The ATNP includes the design, construction, and installation of both airborne and ground ATN intermediate systems (i.e., routers) and end systems (i.e., host computers), and the interconnection of these systems into an operational aeronautical mobile network environment. The ATNP will utilize airline applications as well as ATS applications, e.g., ADS. Satellite and VHF subnetworks will be utilized.

The ATNP is defined as a series of steps, each having specific criteria established that define its completion. The FAATC will support ATN flight tests. The FAATC will develop an airborne router and will provide test aircraft and test support for flight evaluations of avionics provided by industry participants. The FAATC will develop automated test equipment to support bench testing of industry avionics. The FAATC will also develop a ground router that may use software developed by The MITRE Corporation. This router will be

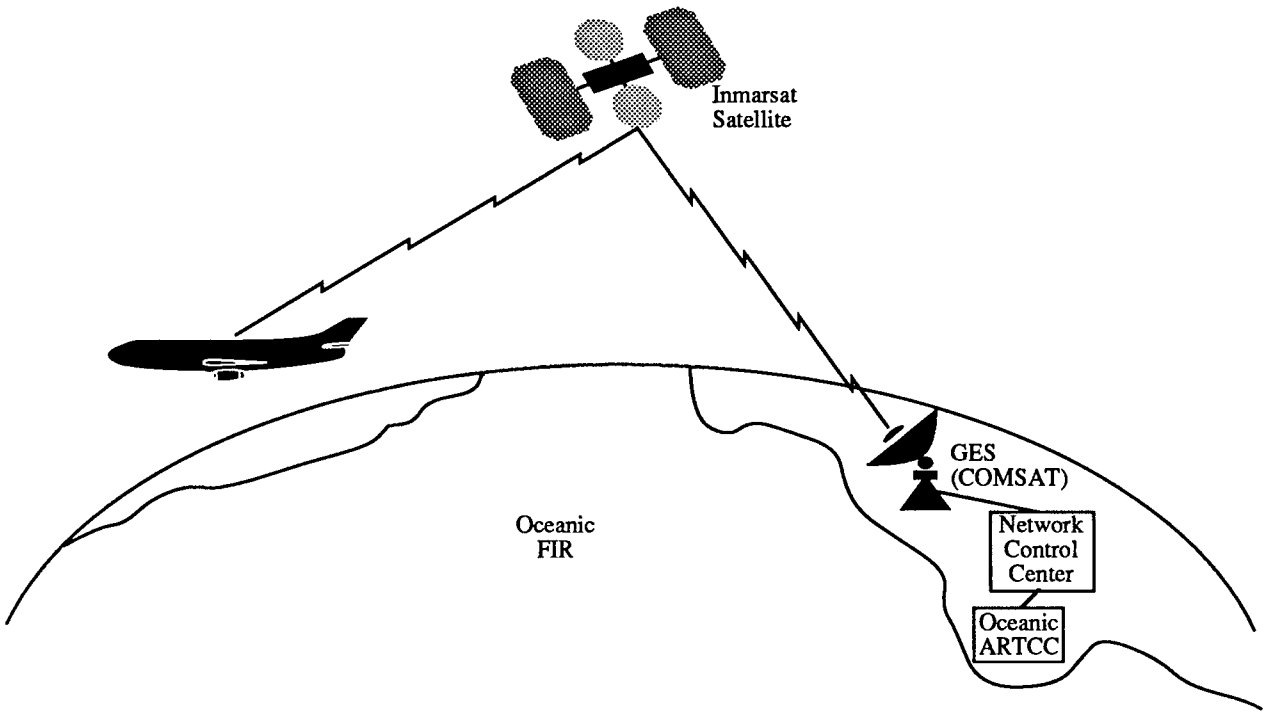


FIGURE 4. EVALUATION OF ATS VOICE COMMUNICATIONS VIA AMSS

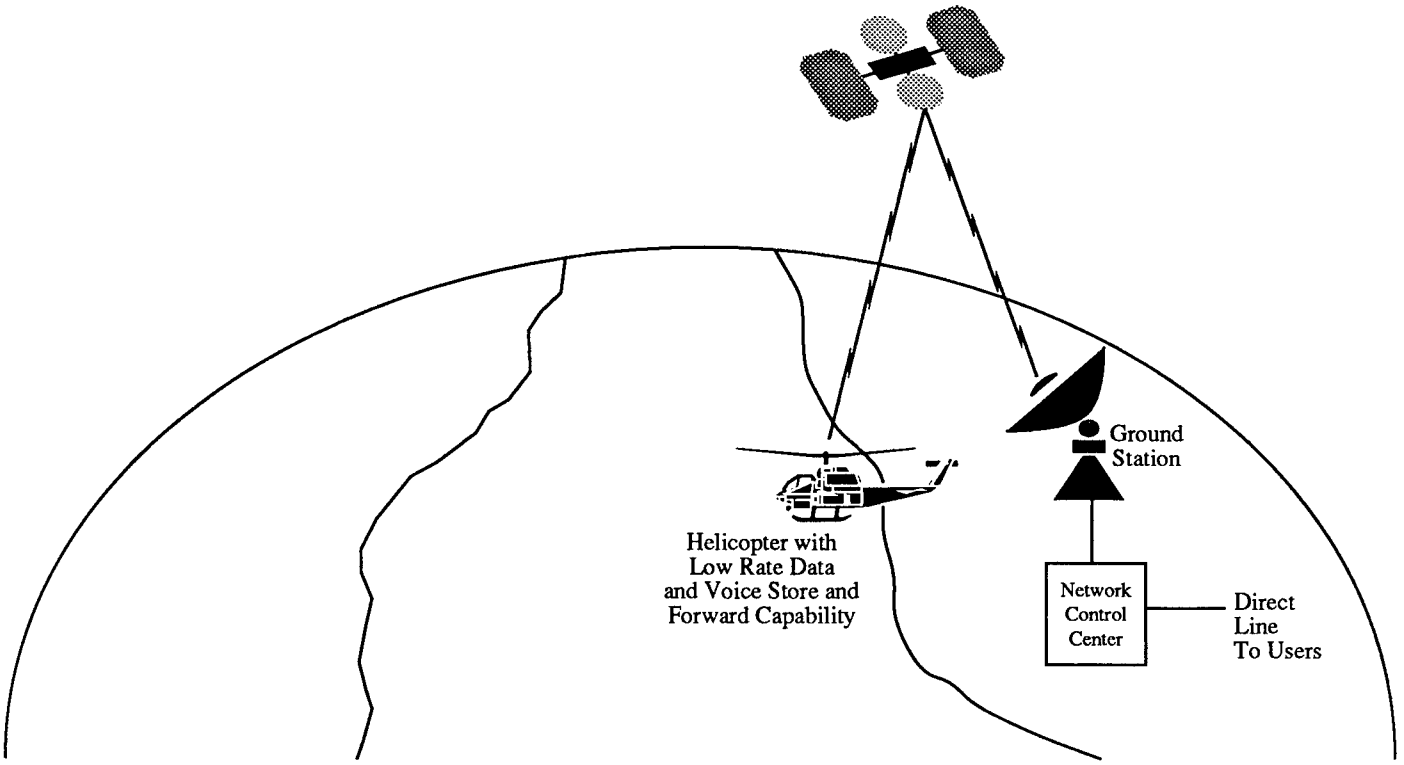


FIGURE 5. AMSS DOMESTIC APPLICATIONS

interconnected to other routers developed by The MITRE Corporation, ARINC, and airline participants. Figure 6 illustrates this task.

ACTIVITY 3 - FUTURE AERONAUTICAL SATELLITE COMMUNICATIONS SYSTEMS

The FAA has been challenged in a number of forums to consider the utilization of satellite communications to improve airspace management and reduce costs of communications and surveillance. It is unlikely that conventional satellite communications will ever serve more than a minority of U.S. aircraft and, therefore, any serious investigation of potential for widespread satellite communications use in the NAS must consider the prospects for new technical approaches to provide the desired benefits. The ultimate goal of this activity is to assess the advantage of satellite communications in the long-range plans for FAA surveillance and communication.

The purpose of this activity is to initiate a study which should attain consensus support within the aviation community. The study will consider as many of the available options as possible and will consider transition strategies, user equipment costs, and other key parameters to assess the sensitivity of the results to assumptions, and will investigate and evaluate promising approaches in comparison with existing NAS techniques. This activity will provide a blueprint for future inclusion of satellite communications in U.S. airspace management and will serve as a means for a well reasoned response to proposals for adoption of specific satellite systems. This activity will also initiate research and development efforts in support of satellite communications in the NAS.

Two tasks will be performed in this area. Under Task 1, which consists of two subtasks, studies related to future satellite communications will be performed. Task 2 will address the development of an advanced satellite communications system. These two tasks are described below.

TASK 1 - FUTURE SATELLITE COMMUNICATIONS STUDY

Under Task 1, proposals for a two phase advanced satellite communications study will be solicited. Multiple sources will be chosen for the first phase of the study, which will be completed within six months after award. Subtask 1, Phase 1 Study, is aimed at providing an overview of the contractor's approach, scope, and preliminary results. The Phase 1 study results will be reviewed by a panel of FAA and aviation community experts. This panel of experts will provide recommendations for selection of the contractor for Subtask 2. Subtask 2, Phase 2 Study, will provide in-depth trade-off analyses, including costs/benefits, and will consider major issues such as transition strategies and sensitivities of results to key assumptions. The draft Phase 2 study results will be presented to the panel of experts to provide a means for the aviation community to critique and influence the study results prior to publication of the final report. Task 1 will begin in late 1991 and will be completed in early 1996. Figure 7 illustrates this task.

TASK 2 - ADVANCED SATELLITE COMMUNICATIONS DEVELOPMENT

Task 2 is dependent on an FAA decision regarding the implementation of satellite-based en route ATS. Task 2 will support the analysis and development of an advanced satellite-based communications system for en route ATS and will begin late in 1996.

SATELLITE COMMUNICATIONS PROJECT SCHEDULE

Figure 8 presents the milestone schedule for the Satellite Communications Project.

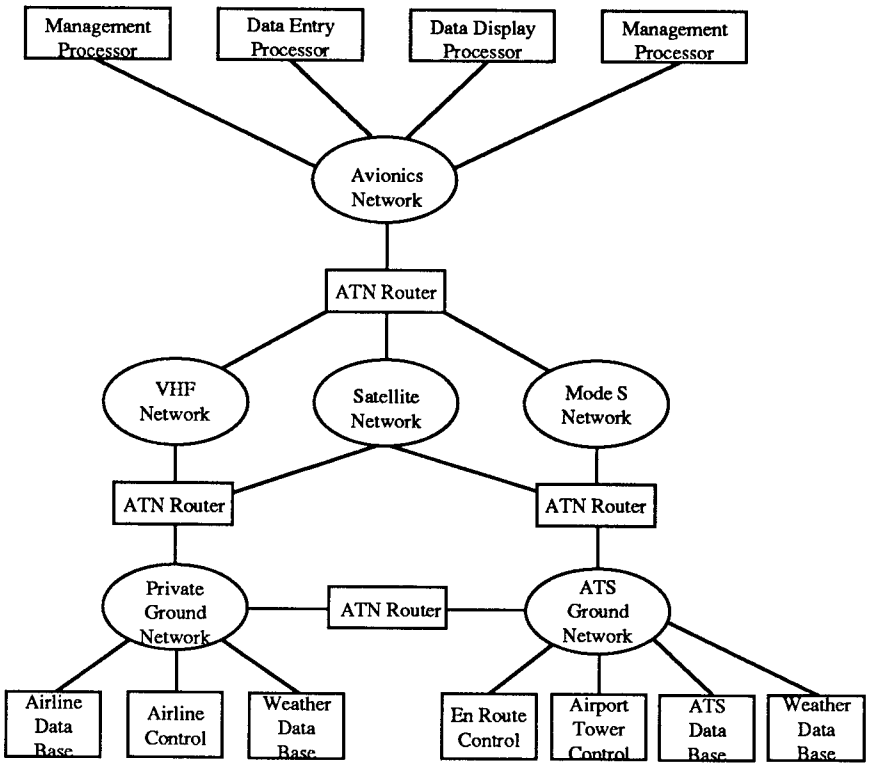


FIGURE 6. AERONAUTICAL TELECOMMUNICATIONS NETWORK

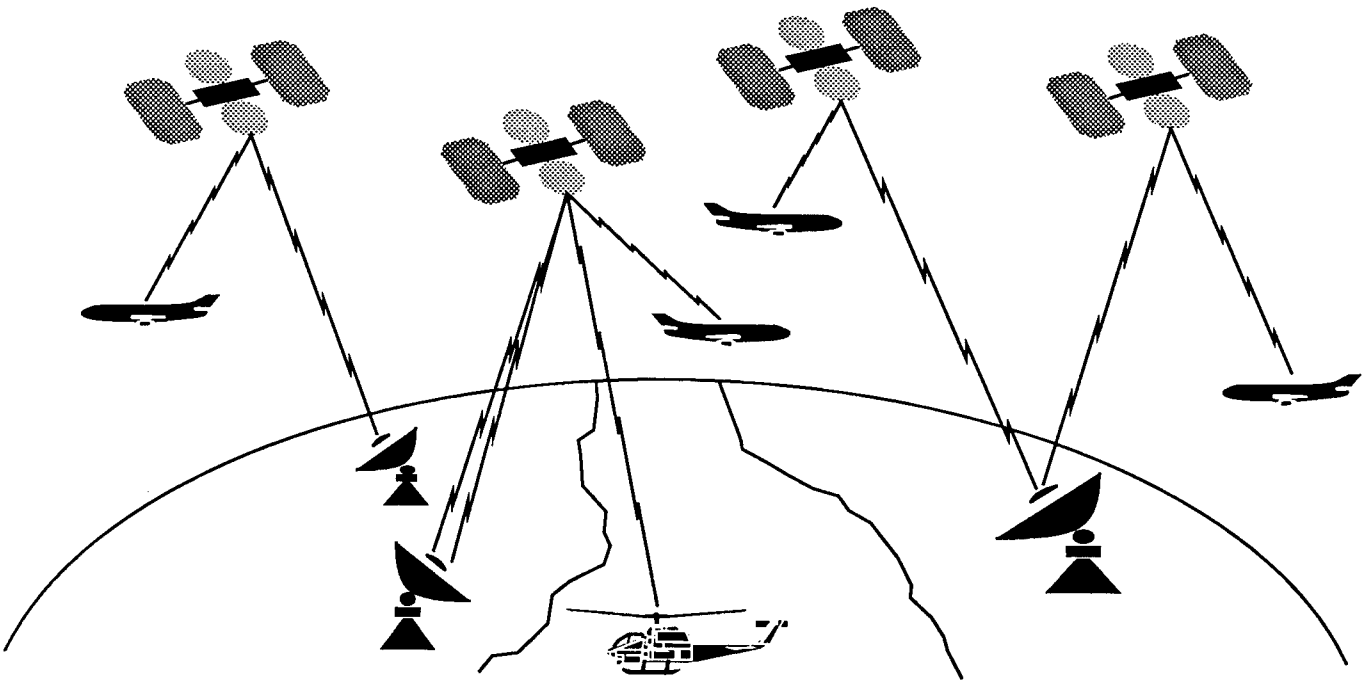
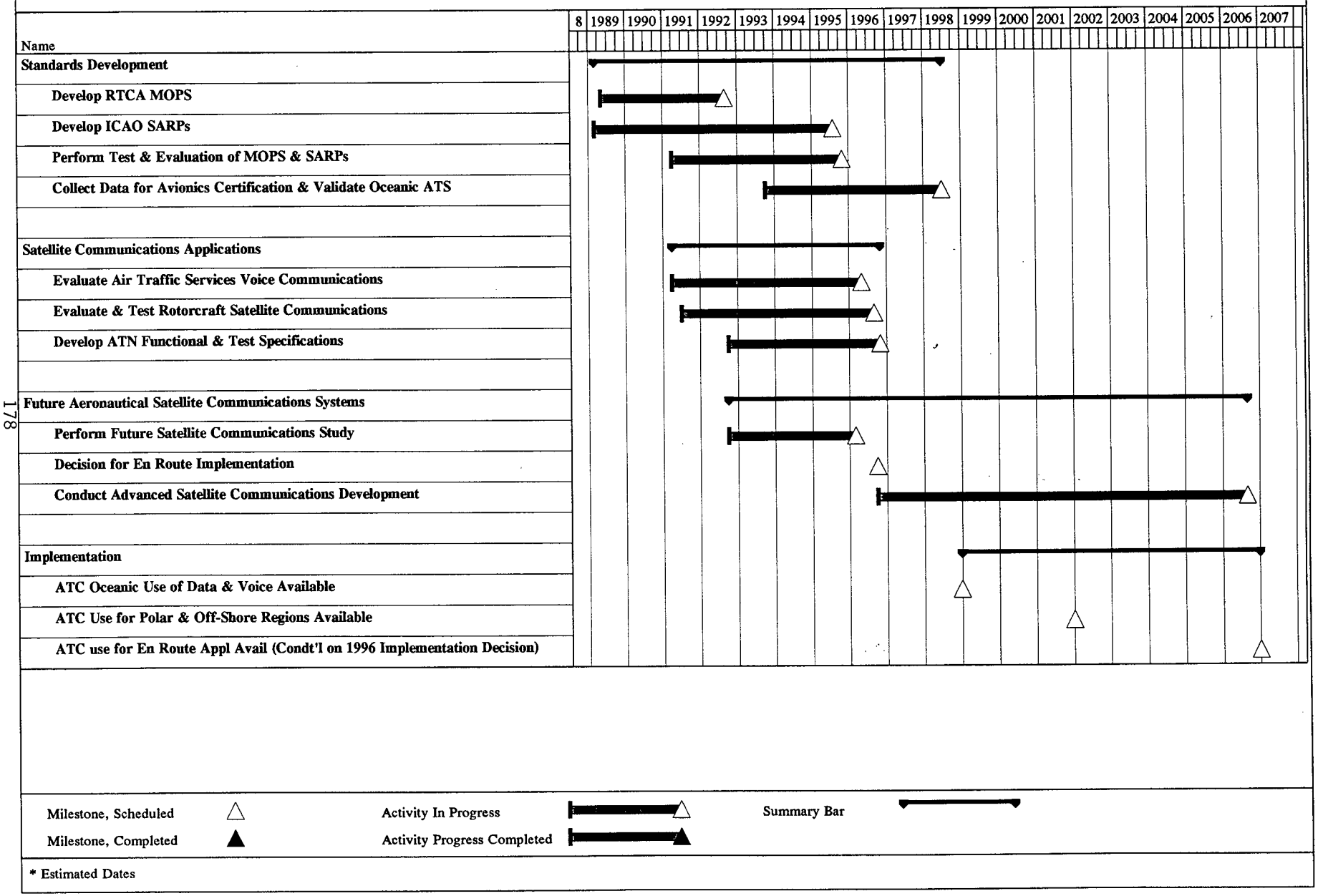


FIGURE 7. FUTURE AERONAUTICAL SATELLITE COMMUNICATIONS SYSTEMS

Figure 8.
Satellite Communications Project Schedule



* Estimated Dates

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SESSION TWO: PROGRAMS, STANDARDS AND INSTITUTIONAL ISSUES

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Thomas F. Dehel was born in Philadelphia, PA, on July 11, 1958. He received the B.S. degree in Computer Engineering from Lehigh University in 1980. From 1980 through 1984 he served in the U.S. Air Force. His first assignment was operational satellite command and control at the Sunnyvale Satellite Control Facility, CA; his second assignment was as a development officer on the Joint Tactical Information Distribution System at Hanscom Air Force Base, MA. He attended the University of Texas and received the M.S. degree in Electrical Engineering in December, 1985. Other professional positions include work on Air Force anti-jam radio at the Mitre Corporation in Bedford, MA, and development of a laser-infrared circuit board inspection techniques at IBM in Austin, Texas. For the past several years he has been at CTA Incorporated, McKee City, NJ, supporting the FAA Technical Center's work on the Aeronautical Mobile Satellite Service. He is a member of IEEE.

AERONAUTICAL MOBILE SATELLITE SERVICE (AMSS) MESSAGE AND VOICE ACCESS REQUEST TRANSIT DELAY

Thomas F. Dehel

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ABSTRACT

The Federal Aviation Administration (FAA) is supporting the development of standards for the use of satellite communications in aviation. As part of this support, the FAA has conducted a preliminary analysis and simulation of the Aeronautical Mobile Satellite Service (AMSS) to determine message transit delay of the system under a range of conditions. The conditions include various message lengths, channel loading, channel data rates, and bit error rates. The simulations focused on the link level and physical levels; the effect of upper layer protocols were not considered as part of this initial effort. Boeing provided the simulation programs ADSSIM and SATSIM which were used to generate results under a range of conditions. The distribution of the results are provided in this paper.

INTRODUCTION

The application of Aeronautical Mobile Satellite Service (AMSS) for Air Traffic Service (ATS) communications is in the process of becoming a reality. The FAA is supporting AMSS through the development of national and international standards, such as the RTCA Minimum Operational Performance Standards (MOPS) and the International Civil Aviation Organization (ICAO) Standards and Recommended Practices (SARPs). As an input to standards development, the FAA has conducted preliminary analysis and simulation of AMSS. This paper describes one of the simulation efforts and presents some results of the message transit delay expected over AMSS.

AMSS PROTOCOL

This section provides a cursory overview of the AMSS protocol. A detailed description of AMSS protocol can be found in the Inmarsat System Definition Manual [1].

AMSS is a subnetwork providing message transfer between an Aeronautical Earth Station (AES) and a Ground Earth Station (GES); the ultimate system will use ISO 8208 as the Subnetwork Access Protocol. At the link layer, the messages (including upper layer overhead) are segmented into Signal Units (SUs). The SUs in the air-to-ground direction can be transferred either over an R-Channel or a T-Channel. An R-channel is a slotted aloha channel which is used to transfer messages shorter than 34 octets. A T-channel is a Time Division Multiple Access (TDMA) channel which transfers messages of 34 octets or longer; use of the T-channel requires that a timeslot request SU be sent to the GES and that the GES responds with a reservation message. In the ground-to-air direction, the SUs are transferred over the P-channel.

Two types of service exist within the AMSS link layer, the Direct Link Service (DLS) and Reliable Link Service (RLS). DLS provides no capability for retransmitting SUs which were not received or received in error. DLS is not used for user message transmission. RLS is used for user data messages and provides up to 5 retransmissions to correct for SUs which were not delivered or delivered in error. The primary causes for SUs not being delivered are expected to be SU collisions on the R-channel (since other aircraft may also transmit SUs on these channels), and channel bit errors.

This paper focuses on the transmission of relatively short messages sent via RLS in the air-to-ground direction, consistent with the transmission of Automatic Dependent Surveillance (ADS) periodic position reports.

An additional use of the AMSS R-channel is to send access request messages for air-to-ground voice calls, which occur on the C-channel. Voice contact via AMSS C-channels is expected only for nonroutine and emergency situations, so the time required to set up a voice call is an area of interest. This paper also considers the transmission delay of the voice call access request message on the R-channel.

MESSAGE TRANSIT DELAY SIMULATION

The Boeing ADSSIM software (described in [2]) provides a simulation of AMSS which outputs message transit delay for messages of 1, 2, or 3 SUs over the R-channel under a given channel occupancy condition. The model assumes that the channel occupancy is random, and it provides a Monte-Carlo simulation of the R-channel protocol. The Boeing ADSSIM model was used to generate message transit delay time for the AMSS R-channel and also was used as part of an approximation for transit delay over the T-channel.

The following parameters were used to simulate R-channel operation:

a. R-channel occupancy (5, 10, 15, 20, and 25 percent);

b. Channel bit rates (600, 1200 bps);

c. Retransmission Timer (8 s, 15 s for voice setup);

d. Number of SUs (1, 2, 3);

e. Maximum number of retry attempts (5); and

f. Link service (RLS).

Other parameters which are requested by the ADSSIM model were given values appropriate for the goals of this simulation. These are:

g. Time to route from GES to destination (0 s); (to eliminate effects outside the AMSS subnetwork);

h. Number of SUs in P-channel queue (6); (6 is the minimum selectable number, chosen to isolate transmission delay from queuing delay);

i. Mix of message sizes on channel (1 SU - 34 percent, 2 SU - 33 percent, 3 SU - 33 percent); and

j. Link and miscellaneous processing delays (0.5 s)

The model was run to simulate the transmission of 20,000 messages, and the transit delay times were recorded. The 20,000 transit time delay calculations for each set of input conditions were stored on a disk and ordered by transit delay time. Messages which were not delivered were flagged to indicate nondelivery. From the ordered list, the transit delay times were plotted as a cumulative probability density function.

R-CHANNEL MESSAGE TRANSIT DELAY RESULTS

Figure 1 shows the message transit delay results for the 15 percent occupied 600 bps R-channel with the transmitted message consisting of a single SU. The cumulative probability is shown along the ordinate and the transit delay is shown on the abscissa. The results show that 50 percent of the messages are delivered in about 3 seconds, 95 percent of the messages are delivered in about 16 seconds, 99 percent of the messages are delivered in 30 seconds, and 99.9 percent of the messages are delivered in 54 seconds. The ADS message delivery time requirement has only been specified in relatively broad terms (5 seconds - 1 minute [3]). The transit delay times shown in Figure 1 cover this range, however,

short message transit delay times (in the 5 - 15 second range) will not be met by a small fraction of the messages transmitted.

Figure 2 shows the results for the 15 percent loaded 600 bps R-channel with the transmitted message consisting of two or three SUs (the one SU case is included for reference). The message delivery time increases more dramatically at the higher cumulative probability end of the curve; this is expected since messages consisting of more SUs are more likely to have collisions on the R-channel.

The remainder of the data is plotted in Figures 3 to 8, showing the change in the "high probability" transit delay time (95, 99, and 99.9 percent cumulative probabilities) with respect to R-channel occupancy. The data is plotted in this manner to emphasize the relationship of the probability of success to transit delay time.

Figure 3 shows the high probability transit delay time data as a function of channel occupancy for the 600 bps R-channel with a message length of 1 SU. Figure 4 gives the same data for 2 SU messages, and Figure 5 gives the same data for 3 SU messages. It should be noted that increasing the message length from 1 to 3 SUs on an R-channel with 15 percent occupancy increases the mean delivery time by only 2.2 s, but the 95 percent cumulative probability delivery time increases by 8.4 s, the 99 percent cumulative probability delivery time increases by 8.8 s, and the 99.9 percent cumulative probability delivery time increases by 21.4 s.

It should be noted in Figure 5 that at 20 percent and above channel occupancies, the probability of delivery is less than 99.9 percent. This result is important since, if the requirement for message delivery is 99.9 percent or greater, the additional reliability will need to be applied at the subnetwork or higher layers.

Figures 6 - 8 show the high probability delay time results for the 1200 bps R-channel.

One assumption made in the ADSSIM simulation of the R-channel is that the messages on an R-channel are transmitted at random times with respect to one another. This may not be the case if periodic reports from different aircraft have the same period. The result could be better performance, (i.e., when the periods are not in phase), or worse, (i.e., when many aircraft try to transmit simultaneously for every report).

T-CHANNEL APPROXIMATION

The ADSSIM program contains a T-channel approximation which does not take into account the time delay of the T-channel time slot request message. To account for this delay, a model of the T-channel protocol was constructed which uses the ADSSIM R-channel model for transmission of the time slot request message in addition to other approximations.

The T-channel message transit delay is approximated by the following simplified formula:

(R-chan req time) + (time to 1st assigned slot) + (Tx time) = total delay for T-channel

In this approximation, the "R-channel request time" is the time to transmit a 1 SU message on the R-channel; these results are provided in the R-channel simulation described previously. The "time to 1st assigned slot" is dependent on the P-channel rate, as described in the Inmarsat SDM[1]. This delay varies from 1.6 s to 3.0 s.

The "Tx" time is the time required to transmit the burst at the given channel rate, which can be calculated from Table 4 in the Inmarsat SDM.

In order to assure that the simulation provides a minimum bound for the performance of the T-channel, the model uses minimum time delay to the T-channel timeslots assigned. This simplification does not take into account T-channel delays caused by other message traffic. Work is currently in progress which will define T-channel delays more accurately.

T-CHANNEL MESSAGE TRANSIT DELAY RESULTS

The transmission delay for a 10 SU message on a 600 bps T-channel is 3.8 seconds, and the minimum transmission time for a 10 SU message on the 1200 bps T-channel is 1.9 seconds. (The calculations are derived from Table 5 in the SDM.) The transit delay for the 600 and 1200 bps R-channels for a single SU are shown in Figures 3 and 6. The resultant cumulative probability delivery delays on the 600 bps T-channel is 23.2 s for 95 percent, 37.4 s for 99 percent, and 60.4 s for 99.9%. The results for the 1200 bps T-channel are 16.1 s for 95 percent, 27.2 s for 99 percent, and 42.9 s for 99.9 percent.

VOICE CALL ACCESS REQUEST

The AMSS call setup protocol for an air-to-ground voice call is initiated by the transmission of a call access request SU on the R-channel. The call access request is transmitted as a Direct Link Service (DLS) message, but other protocol features cause retransmission if the request is not acknowledged. The basic timer for the retransmission is 15 seconds. The results indicate that, for an access request SU on a 15% occupied 600 bps R-channel the median (50 percent cumulative probability) time for delivery is 2.91 seconds, the 95 percent cumulative probability delivery time is 23.3 s, the 99 percent cumulative probability delivery time is 44.2 s, and the 99.9 percent cumulative probability delivery time is 71.6 s.

Voice channel availability is restricted to an AES with a high gain antenna, therefore it is likely that a 10500 bps R-channel would be available to transmit the voice call request. For the 10500 bps R-channel, the median time is 0.5 s; the 95 percent cumulative probability delivery time is 16.1 s; the 99 percent cumulative probability delivery time is 31.8 s; and the 99.9 percent cumulative probability delivery time is 48.2 s.

There is work in progress in the ICAO AMSS Panel and in Inmarsat to revise the voice call protocol to provide faster set up times for distress and flight safety voice calls. Simulation work will be performed in this area.

BER EFFECTS

After the simulation with ADSSIM was nearly complete, a revised version of ADSSIM, called SATSIM, was provided by Boeing. SATSIM includes the capability to vary the bit error rate (BER) of the channels being simulated. SATSIM results are provided to examine the effect of a range of BERs.

The SATSIM program is similar to ADSSIM but includes the capability to input the bit error rate (BER) of the channel being simulated. SATSIM was run for the 600 bps R-channels for the 3 SU message length case, with a channel BER set to $1x10^{-5}$. The 95, 99, and 99.9 percent cumulative probability transit delay results for the 600 bps R-channel are shown on Figure 9. The figure also includes the ADSSIM results for comparison. The figures show that ADSSIM and SATSIM give similar results, and that a BER of $1x10^{-5}$ has no significant impact on the message delivery delay times except for the 99.9 percent cumulative probability results. A 10 percent increase in transit delay is seen for the 99.9 percent results.

The target BER on AMSS P-, R-, and T-channels is $1x10^{-5}$, however, degradation to $1x10^{-4}$ is permitted by the power control mechanism. Loss of a P-channel is not declared until the BER exceeds $1x10^{-4}$ for a 3 minute averaging time. The effect of BER on the message delivery time (for a 3 SU R-channel message on a 600 bps channel) is shown in Figure 10. The most severe effect is on the 99.9 percent delay time; increasing the BER above $1x10^{-5}$ to $5x10^{-5}$ causes the probability of delivery to drop below 99.9 percent. As the BER increases from $1x10^{-5}$ to $1x10^{-4}$, the 99 percent cumulative probability delivery delay time increases by 5 seconds, and the 95 percent cumulative probability delivery delay increases by 2 seconds. The delays increase sharply when the BER exceeds $1x10^{-4}$. At a BER of $1x10^{-3}$, the probability of delivery drops below 99 percent.

CONCLUSIONS

A preliminary projection of transit delay performance has been provided using ADSSIM and SATSIM to simulate the AMSS link layer. These results consist of distributions of message transit delays under normal operation of the AMSS. The results indicate message transit delays due to the AMSS link layer are within expected ADS requirements. The voice call setup delays can be long, but the protocol for voice call setup may be revised for high priority use to reduce this delay.

REFERENCES

1. Inmarsat, Aeronautical System Definition Manual (SDM), through CN 40.

2. Judd, Thomas, ADS Delivery Time Analysis, ICAO AMSSP/3, 1990.

3. Scales, Walter, et.al., Preliminary FAA Requirements for the Aeronautical Mobile Satellite Service (AMSS), ICAO AMSSP/3, 1990.

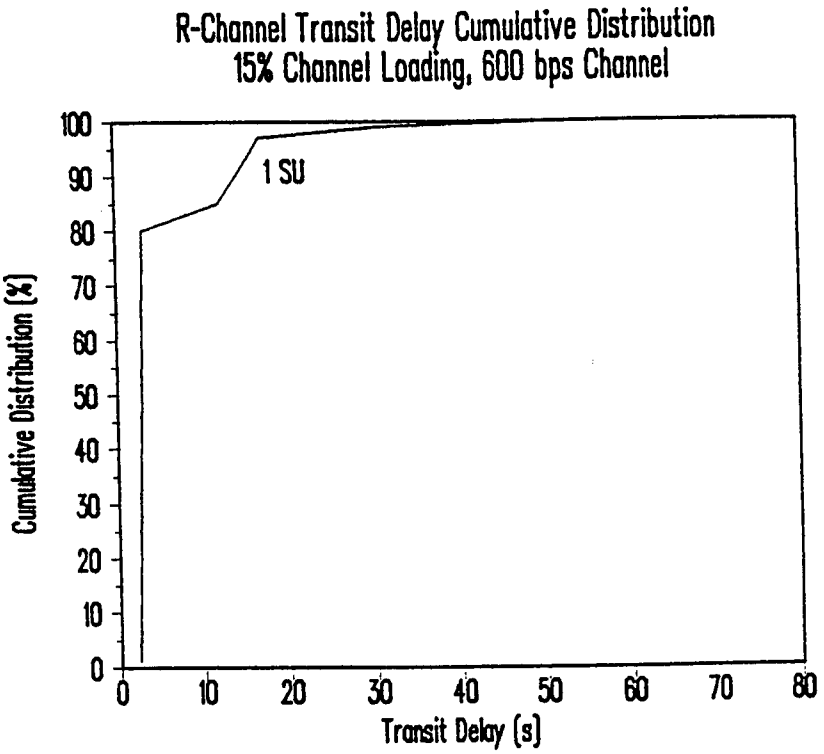


FIGURE 1. R-CHANNEL DELAY FOR 1 SU MESSAGE

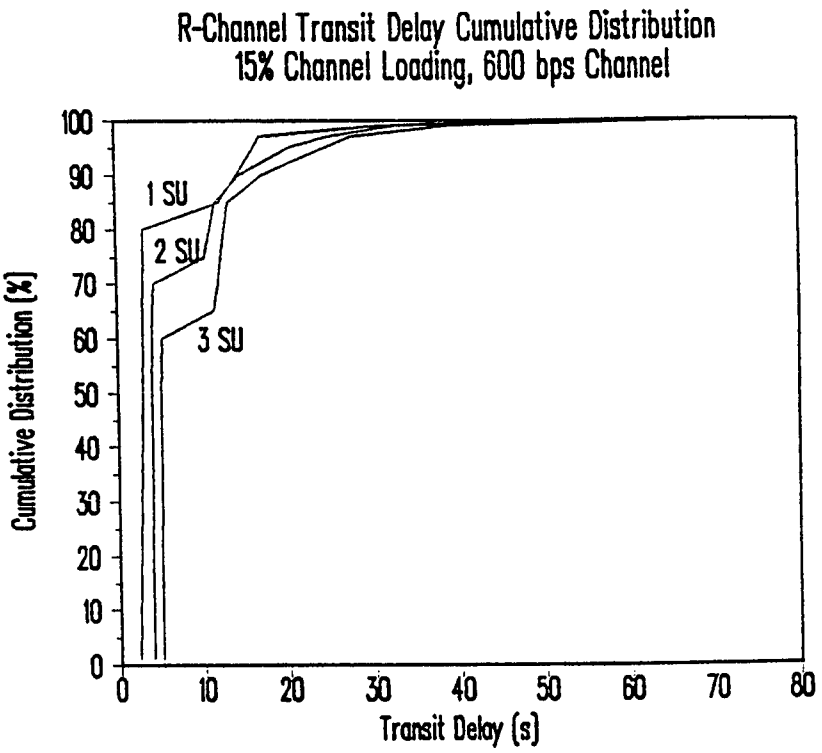


FIGURE 2. R-CHANNEL TRANSIT DELAY FOR 1-3 SU MESSAGES

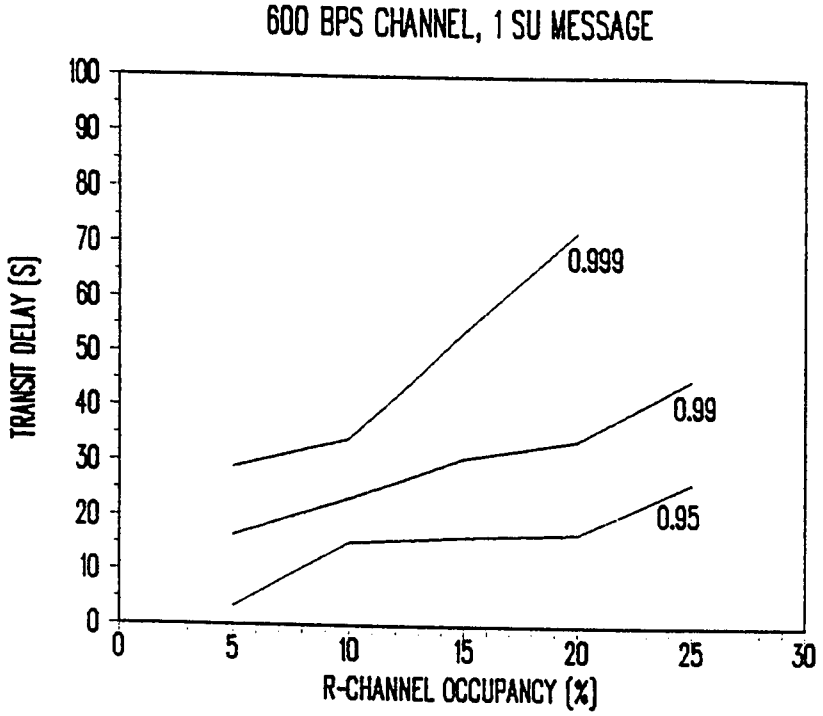


FIGURE 3. R-CHANNEL TRANSIT DELAY FOR 1 SU MESSAGE

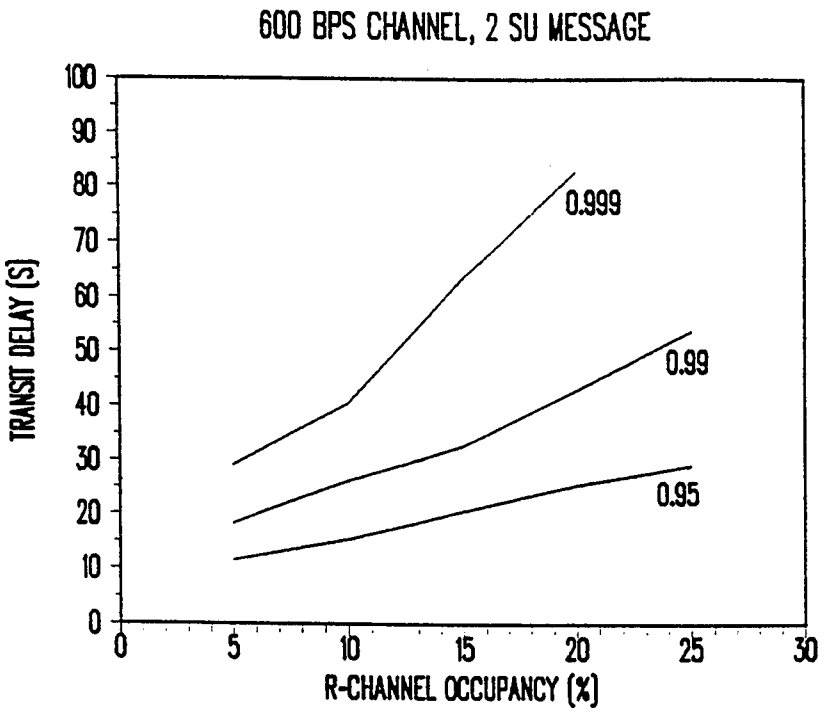


FIGURE 4. R-CHANNEL TRANSIT DELAY FOR 2 SU MESSAGE

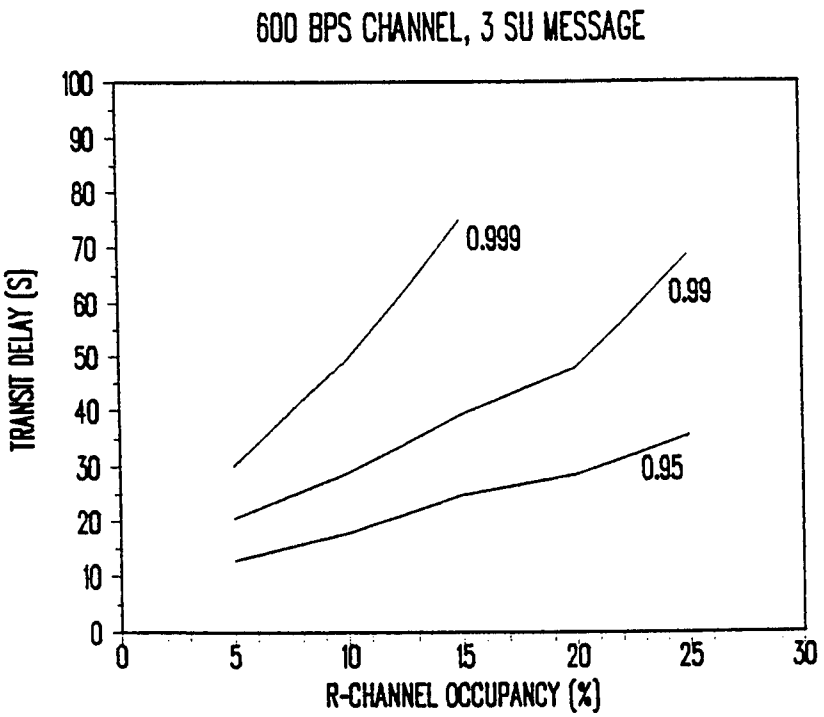


FIGURE 5. R-CHANNEL TRANSIT DELAY FOR 3 SU MESSAGE

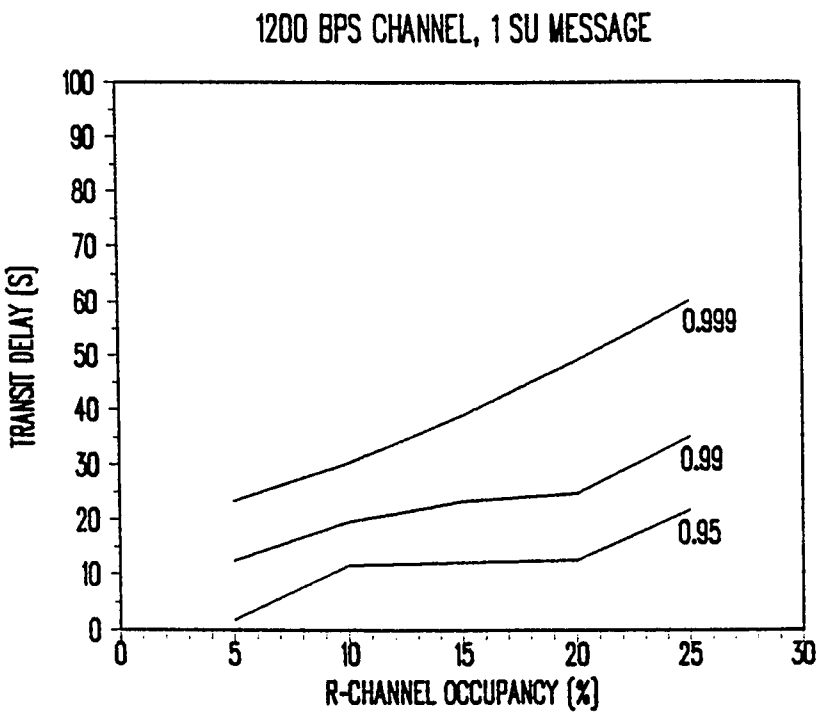


FIGURE 6. R-CHANNEL TRANSIT DELAY FOR 1 SU MESSAGE

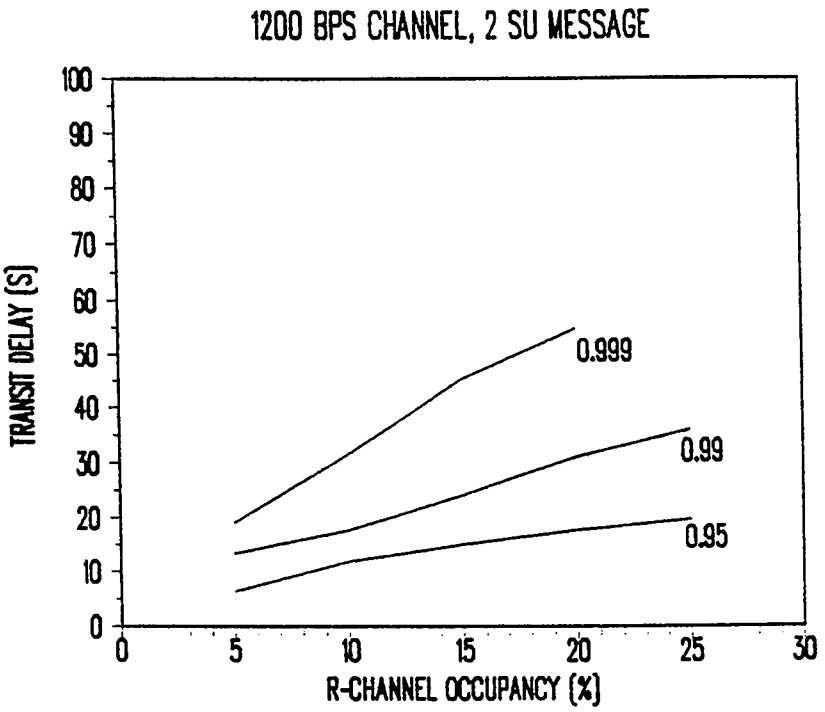


FIGURE 7. R-CHANNEL TRANSIT DELAY FOR 2 SU MESSAGE

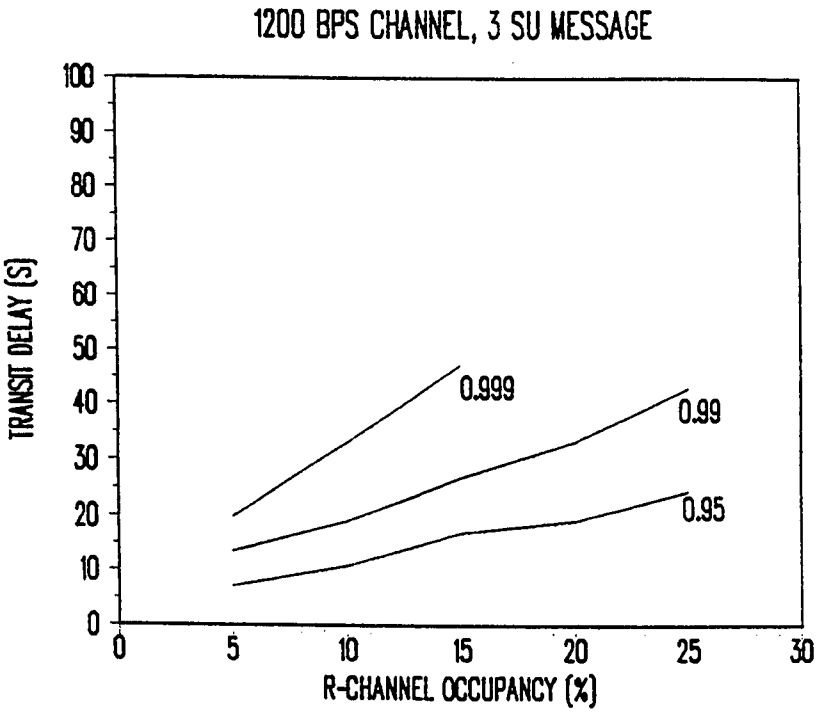


FIGURE 8. R-CHANNEL TRANSIT DELAY FOR 3 SU MESSAGE

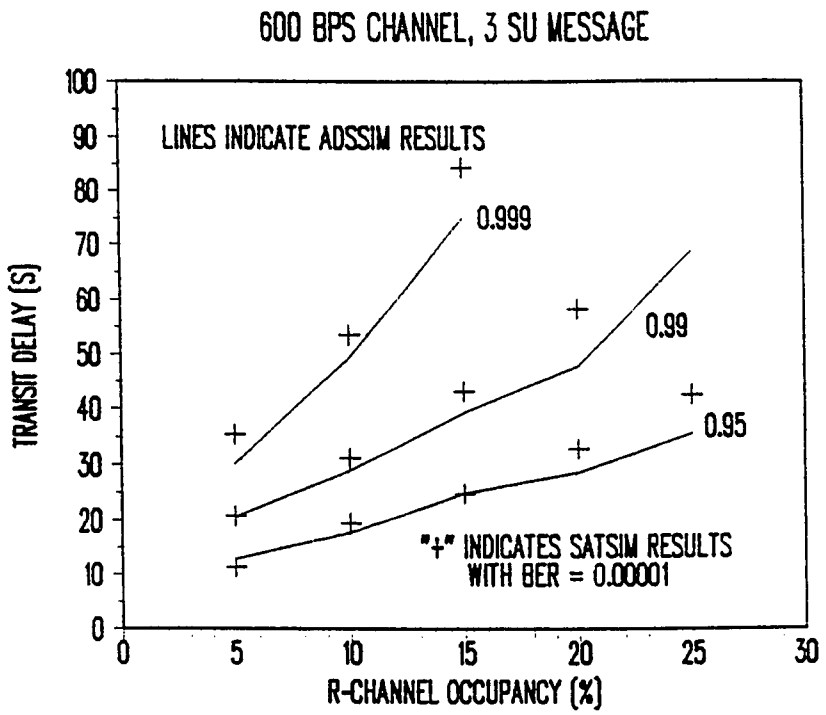


FIGURE 9. ADSSIM AND SATSIM RESULTS FOR 3 SU MESSAGE

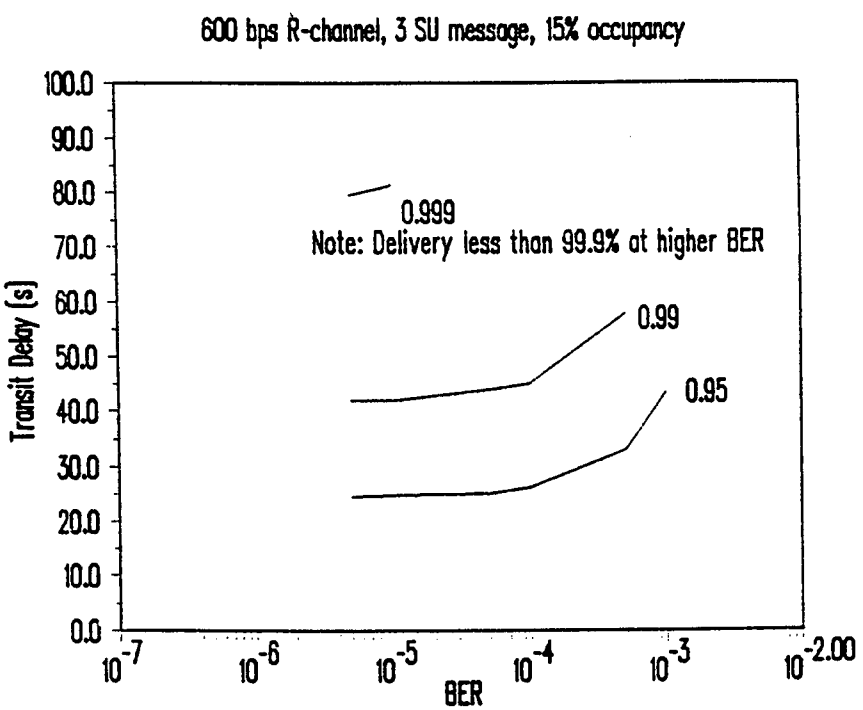


FIGURE 10. EFFECT OF BIT ERROR RATE ON TRANSIT DELAY

SESSION TWO: PROGRAMS, STANDARDS AND INSTITUTIONAL ISSUES

Dr. G. Keith Smith
Manager, Engineering
Aeronautical Services Division
INMARSAT

"An Improved Periodic Reporting System by Satellite"

Not available for publication

SESSION TWO: PROGRAMS, STANDARDS AND INSTITUTIONAL ISSUES

Hiroki Takeda
Special Assistant to the Director
Radio Engineering Division
Air Traffic Services Department
The Japan Civil Aviation Bureau
Ministry of Transport

Hiroki Takeda graduated from the Keio University in 1975 with a Bachelor of Science in Electrical Engineering. He then worked with the Japan Civil Aviation Bureau, Ministry of Transport charging with the development of the Radar Data Processing System (RDP). In 1977 he was transferred to the International Affairs Division, Secretariat to the Minister charging with the international technical cooperations to developing countries in transport fields. In 1979 he was sent to the Stanford University, CA., where he studied infrastructure planning and management, and graduated in 1981 with a Master of Science degree in Civil Engineering.

Following his study abroad, he worked in the Noise Abatement Division, Aerodrome Department, Civil Aviation Bureau to forecast the noise contour around the airport. He then worked in the Radio Engineering Division, Tokyo Regional Civil Aviation Bureau to implement the ATC as well as navigational facilities such as ASR/SSR, RCAG, VOR/DME and ILS.

Mr. Takeda was then transferred to the Business Administration Office, Corporate Planning Department, Kansai International Airport Co. Ltd. charging with the preparation of the business plan and budget.

He has been working for the radio engineering division, Civil Aviation Bureau since 1988 in charge with the new technologies in the aeronautical communications fields. He is now involved in the development of data link systems (VHF data link, SSR mode S and AMSS) also covering the international activities like ICAO. He is a Japanese nominated member of ICAO SICASP (SSR Improvement and Collision Avoidance System Panel) as well as AMSSP (Aeronautical Mobile Satellite Services Panel).

SATELLITE DATA LINK R & D PROGRAM IN JAPAN

Hiroki Takeda, Special Assistant, Radio Engineering Division,
Air Traffic Services Department, The Japan Civil Aviation Bureau

1. INTRODUCTION

In parallel with the Automatic Dependent Surveillance (ADS) Pacific Engineering Trial (PET) program which is being initiated by Australia, the United States and Japan, the research and development (R & D) program called "Satellite Data Link" has been promoted in Japan.

Apart from ADS PET program, the Aircraft Earth Station (AES) and the Ground Earth Station (GES) to be used in this satellite data link R & D program are designed to be fully compatible with the ICAO AMSS Draft SARPs and INMARSAT SDM (System Definition Manual). The main purpose of this R & D program is to validate the bit oriented AMSS system based on the OSI (Open System Interconnection) model which is now under development in ICAO AMSSP (Aeronautical Mobile Satellite Service Panel).

2. OBJECTIVE

The objectives of this satellite data link R & D program are to verify the AMSS SARPs now under development by the ICAO AMSSP, and to develop and evaluate ADS as well as ATC data communications.

Overall evaluation of ADS and other ATC data communications by air traffic controllers is also expected to be conducted.

3. SYSTEM CONFIGURATION

The concept of the satellite data link R & D program using the INMARSAT satellite is shown in Figure 1. Although this system configuration seems quite similar to the ADS PET program, most of the components except for a space segment are different. The aircraft, Ground Earth Station (GES) and ground computer system are all different. The details of the system components in this program are explained below.

(1) Avionics

The block diagram of the airborne system is shown in Figure 2. The avionics which will be installed in Electronic Navigation Research Institute's (ENRI), Ministry of Transport (MOT) B99 (Beechcraft) consists of three parts, that is, satellite communication part, ADS sensor part and communication control & data processing part.

The satellite communication part includes a L band low gain antenna, a High Power Amplifier (HPA), Low Noise Amplifier (LNA), Radio Frequency Unit (RFU), Satellite Data Unit (SDU) and SDU interfaces. The SDU is being newly developed so as to provide the communication functions specified in the Draft SARPs. The SDU is capable of transmitting R and T channel communication signals and receiving P channel communication signals.

The ADS sensor part includes Global Positioning System (GPS), Inertial Reference Unit (IRU) and a barometric altimeter, etc.. The data except for GPS and IRU derived ones will be obtained through Air Data Computer (ADC). All data will be input through ADS I/F to data processing computer.

The communication control & data processing computer part includes two laptop computers with different functions. The communication control computer has functions of link control, data formatting for transmission and received data reconstruction. The data processing computer has functions of ADS message creation (position data such as latitude, longitude and altitude, weather data) and ATC data creation.

Spectrum analyzer will be used to measure basic parameters needed to analyze transmission performances such as C/N_0 and frequency, etc..

(2) Satellite

In this R & D program, the International Maritime Satellite Organization's (INMARSAT) Pacific Ocean Region (POR) satellite as well as Indian Ocean Region (IOR) satellite will be used. By the time the actual flight test begins, it is expected that the second generation of INMARSAT POR and IOR will be available. Accordingly, a 3 Mhz band of AMSS transponders of both satellites will be utilized.

(3) Experimental GES

In this R & D program, the experimental GES will be designed and procured by ENRI, MOT and it will be installed at KDD (Kokusai Densin Denwa Co.) Yamaguchi Satellite Communication Center for evaluation. The commercial GES which is referred to DATA-2 by INMARSAT for operational use of I-ACARS will be procured and installed by KDD at the same Coast Earth Station (CES) site. Those two different GESs will be interfaced at Intermediate Frequency (IF) level. Antenna or Radio Frequency (RF) units will be commonly utilized by those two GESs.

The system configuration of the experiment GES is shown in Figure 3. The experiment GES is composed of IF interface part, modem part and protocol converter part. The IF interface part will be connected with the intermediated frequency (70 Mhz) of CES of KDD.

The modem part is composed of P channel modulator, R channel and T channel demodulator and the CPU. While the P channel modulator supports the transmission speed of only 600 bps with A-BPSK modulation, the R and T channel demodulators support the transmission speed of 600 bps and 1,200 bps with A-BPSK modulation. The CPU has the function of access control and signalling based on the bit oriented protocol.

The protocol converter is composed of the laptop computer and u-OSI board to support the bit oriented protocol (X.25). The protocol converter will be connected with modem part through the RS232C with the speed of 9,600 bps.

The measurement system will be also implemented at GES site to measure the C/N_0 and Bit Error Rate (BER) characteristics to verify several items on modulation/demodulation performances specified in the draft SARPs. The C/N_0 will also be measured during ADS and other ATC data communication experiments as a basic parameter.

(4) Ground data network

In this R & D program, the experimental GES will be connected directly with the ATC data processing and display system located at ENRI, MOT through the dedicated leased telephone line in order to avoid the transit delay of any commercial data link networks. As shown in Figure 1., the commercial GES will be connected to AVICOM JAPAN's Data Link Computer (DLC) for message delivery to airline host computers.

(5) ATC data processing and display system

The ATC data processing and display system is composed of computer, ADS display, ATC data communication terminal and GPS as shown in Figure 4. The computer has functions of interfacing with the experiment GES, communication control, ADS display control, ATC terminal control and data collection.

The ADS display will show aircraft positions in symbols and other associated alphanumerical data in data blocks over maps on its screen.

Received ATC messages will be shown on the screen of the ATC data communication terminal. Transmitted messages will be input and compiled through simple key in procedures.

GPS will be used for time and position reference. The synchronized time reference for the aircraft and the ground makes it possible to measure transit delays in ADS messages as well as ATC data communications.

4. ADS DATA FLOW

While the ICAO Automatic Dependent Surveillance Panel (ADSP) is now developing the SARPs for ADS, four items (latitude/longitude, altitude, time and figure of merit (FOM)) must be included as a basic ADS information in each transmission. The other items such as waypoint information and weather information may be included when requested from the ground.

As described in 3.(1), the latitude and longitude data will be derived from either IRU or GPS. The altitude data will be derived from either barometric altimeter or GPS. The GPS time will be used as a time reference both on the aircraft and on the ground. Since the current navigation systems are not capable to output FOM values, the FOM will be input manually.

The ADS update rates and "on-request" data transmission will be controlled from the ground when needed. While this can be done manually on the ground, the airborne system responds automatically without any aircrew intervention.

ADS data and ATC data will be relayed to ENRI directly through the experimental GES at KDD. ADS data as well as ATC data will be processed by the computer system at ENRI, displayed on a high resolution ADS display and recorded on MT or Disks at the same time for later analysis.

5. DATA ANALYSIS METHOD

Though the details of the data analysis method have not been determined yet, the following items will be at least evaluated.

(1) Measurement of radio propagation characteristics

The level and frequency variations in the flight environment will be measured for low and medium elevation angles. Since the flight distance of B99 is very limited, ie. it will fly only over Japanese islands, the low elevation angle situation will be emulated with the use of IOR satellite and the medium elevation angle situation will be emulated with the use of POR satellite.

(2) Measurement of data transmission characteristics

The bit error and synchronization characteristics will be measured in the flight environment for both low and medium angles.

(3) Measurement of ADS characteristics

The transit delay characteristics will be measured. The GPS system time will be used as a time reference for both air and ground so that the maximum time measurement accuracy can be secured.

(4) Evaluation of ADS applications

The performance of ADS using GPS and INS will be evaluated in terms of accuracy and protocol.

The validation items for each section of the draft ICAO AMSS SARPs are now under examination. It will be coordinated carefully with concerned bodies such as ICAO AMSSP and INMARSAT.

6. PROGRAM SCHEDULE

The program schedule of this satellite data link R & D is shown in Figure 5. The on-board and ground systems for this R & D program are now under development. They will be completed by the end of FY 1991. Installation of avionics on the B99 is planned in the beginning of FY 1992. After installation, experiments and evaluations will start. The acquired data and experiment results will be made available to interested parties and they will be used to validate the current draft SARPs.

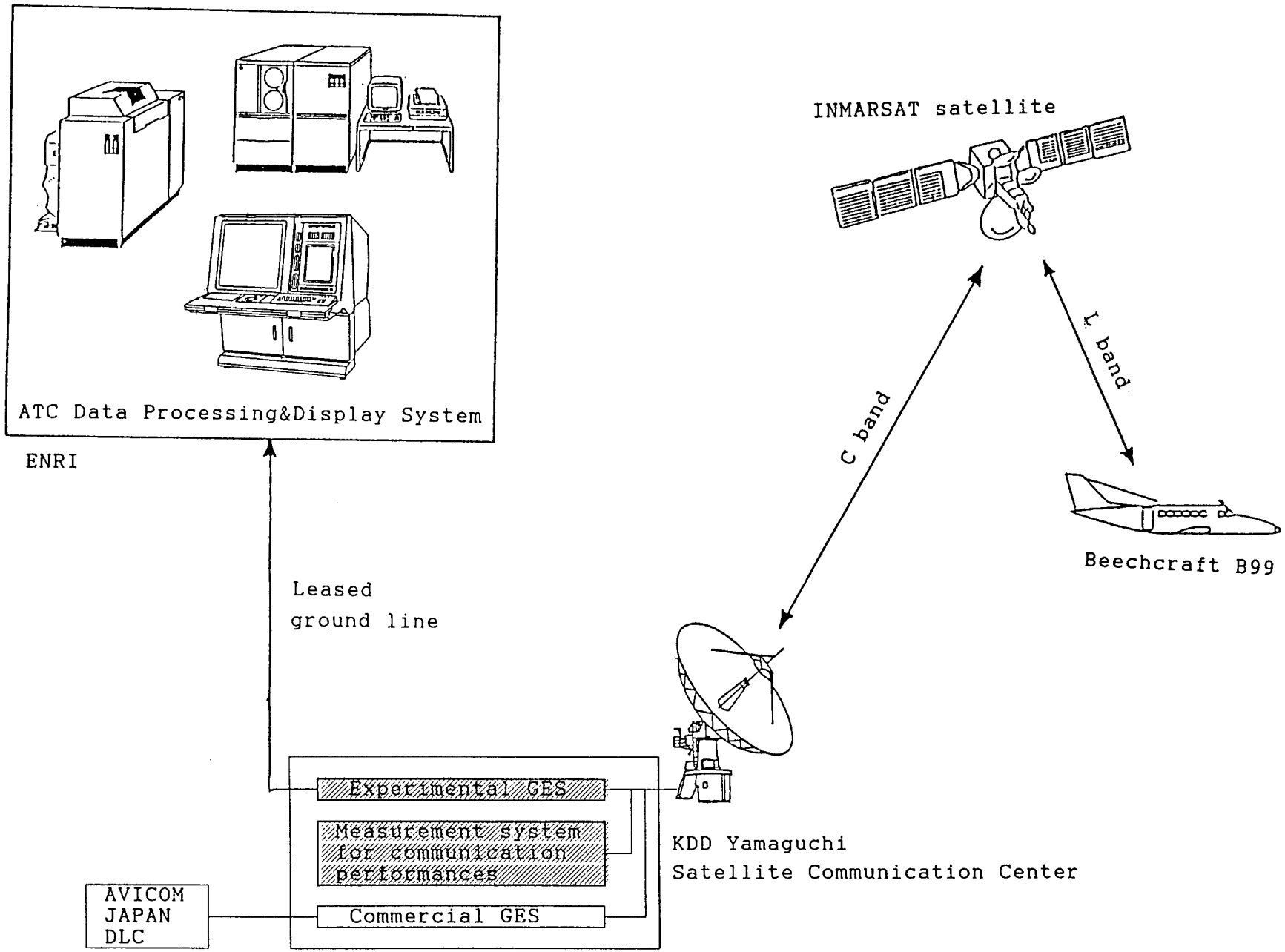
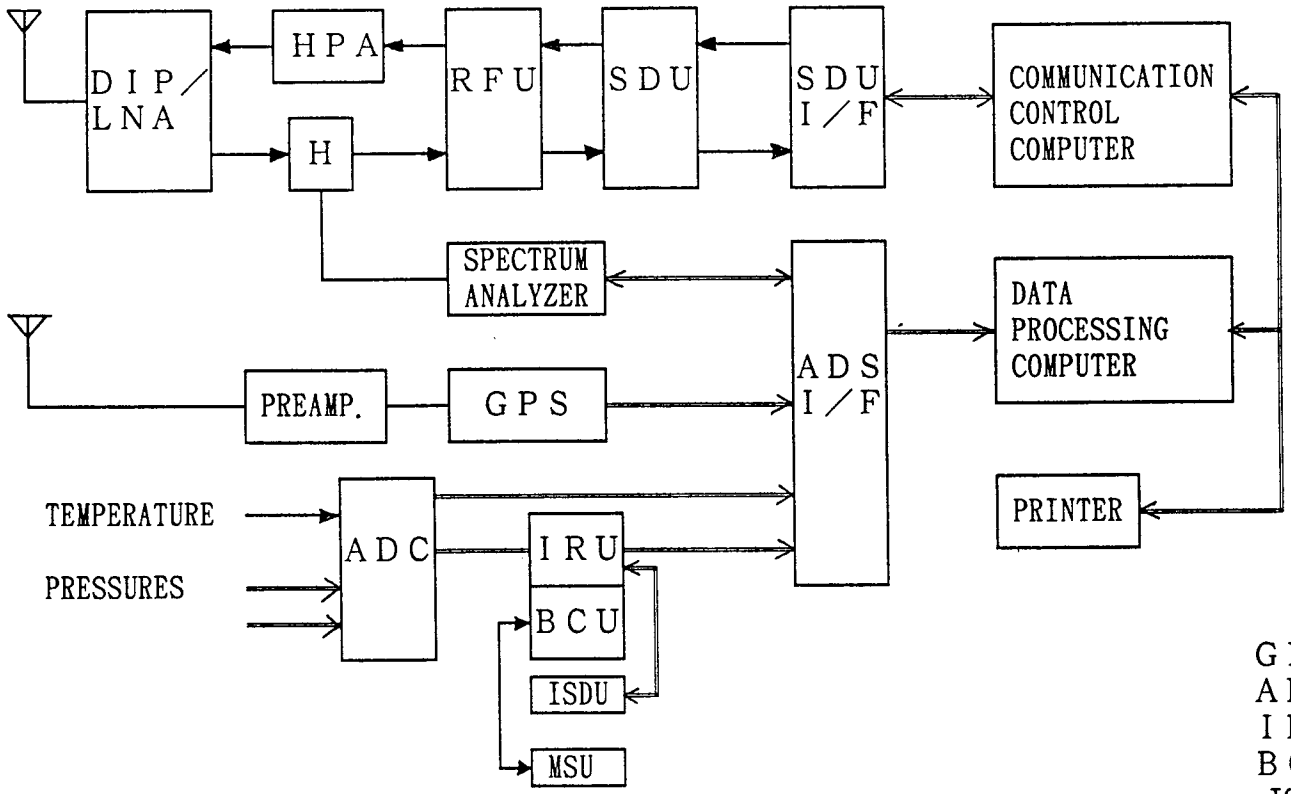


Fig.1 Concept of Satellite Data Link Experiment



DIP : Diplexer
LNA : Low Noise Amplifier
HPA : High Power Amplifier
RFU : Radio Frequency Unit
SDU : Satellite Data Unit
I/F : Interface
GPS : Global Positioning System
ADC : Air Data Computer
IRU : Inertial Reference Unit
BCU : Battery Charge Unit
ISDU : Inertial System Display Unit
MSU : Mode Select Unit

Fig. 2 Experimental Airborne System Block Diagram

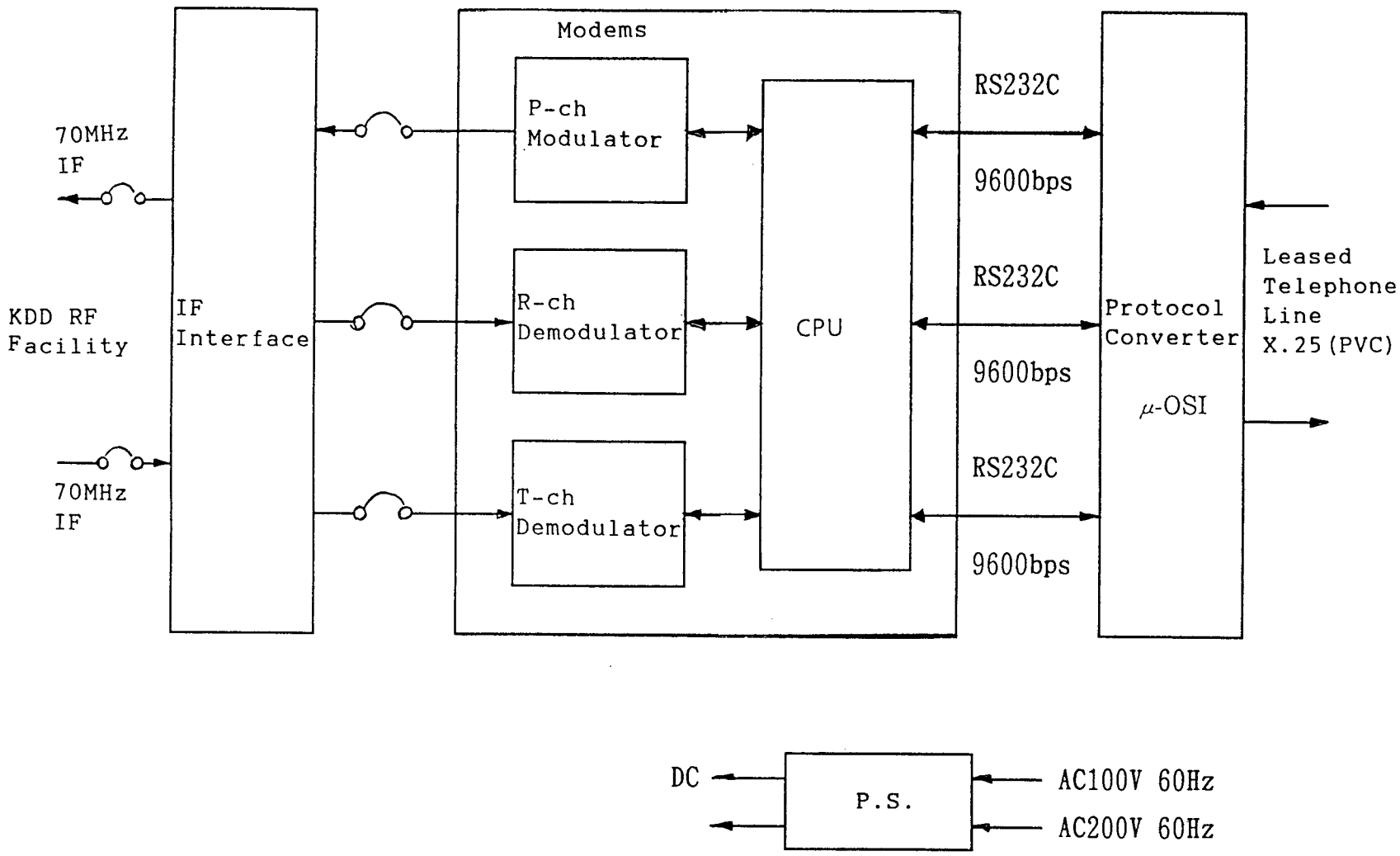


Fig.3 Configuration of Experimental GES

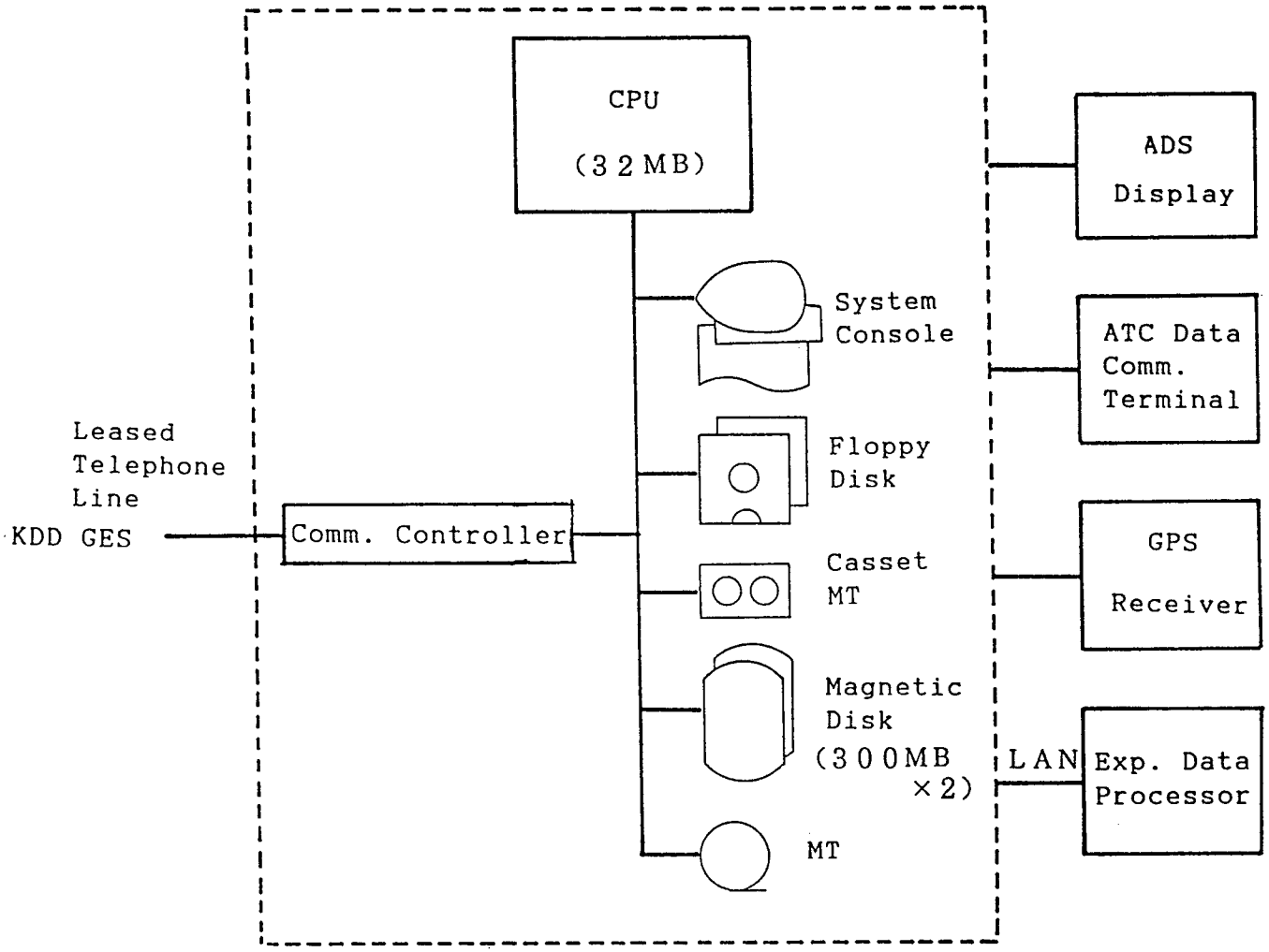
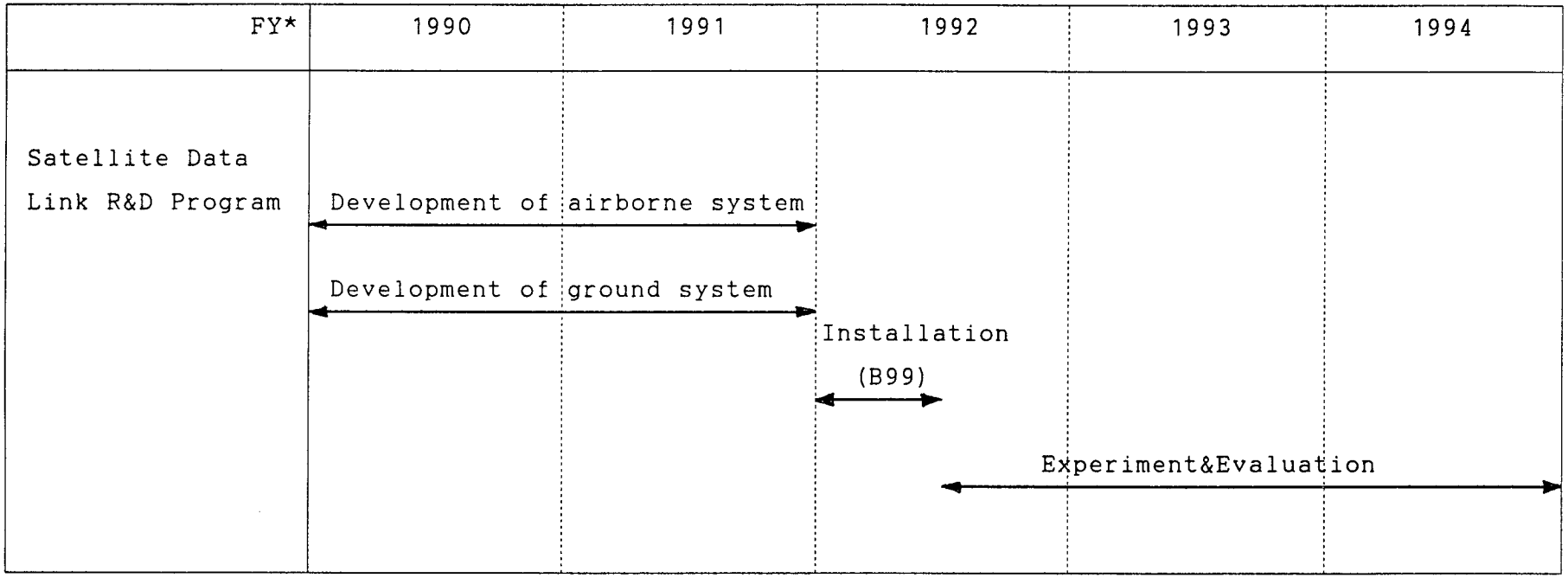


Fig.4 Configuration of ATC Data Processing&Display System

Fig.5 Satellite Data Link R&D Program Schedule



* : Fiscal Year(1 April ~ 31 March)

SESSION TWO: PROGRAMS, STANDARDS AND INSTITUTIONAL ISSUES

B. Richard Climie
Consultant
Honeywell, Inc.

B. Richard Climie is one of RTCA's designated Technical Advisors and chairman of RTCA Special Committee 170. The latter is charged with developing Minimum Operational Performance Standards (MOPS) for Automatic Dependent Surveillance (ADS) avionics.

Since Mr. Climie's retirement last year as Senior Director - Industry Activities for Aeronautical Radio, Inc. (ARINC), he has served as a consultant to the Commercial Flight Systems Group of Honeywell, Inc. He is perhaps best known as the Past Chairman of the Airlines Electronic Engineering Committee (AEEC). The Committee establishes the voluntary "form, fit and function" standards for avionic systems used in civil air transports. He also has participated in many international avionics standardization and regulatory activities of EUROCAE, ICAO and ITU.

Mr. Climie is Past President of the Aerospace and Electronics Systems Society of The Institute of Electrical and Electronics Engineers (IEEE). He was instrumental in developing the original ARINC and IEEE versions of the ATLAS language for automatic testing of avionics.

Mr. Climie was educated in southern California where he attended La Verne College and UCLA. Prior to joining ARINC in 1962 he held posts of engineer in radio systems and installation design at Douglas Aircraft and avionics systems development at Collins Radio.

SESSION TWO: PROGRAMS, STANDARDS AND INSTITUTIONAL ISSUES

Michael D. Rockwell
Senior Avionics Engineer
Aeronautical Radio, Inc.
(AEEC Staff)

Michael D. Rockwell is an Airline Electronic Engineering Committee (AEEC) Staff Member in the Aircraft Telecommunications Systems Group within ARINC's Industry Activities Division. Mr. Rockwell's primary project responsibilities include providing support for the AEEC's Satellite System Subcommittee, Automatic Dependent Surveillance (ADS) Subcommittee, Data Radio Subcommittee and AVPAC Working Group. Mr. Rockwell also serves as the secretary to the RTCA Special Committee 172, Future Air-Ground Communications for the VHF Aeronautical Band (118-137 MHz).

Mr. Rockwell obtained a BSEE degree from the University of Lowell in Lowell, Massachusetts. He also has an Associate Degree in Applied Science from the Community College of the Air Force and is a graduate of the Academy of Military Sciences, McGee Tyson AFB in Tennessee.

SESSION TWO: PROGRAMS, STANDARDS AND INSTITUTIONAL ISSUES

William L. Umbaugh
Manager
Automation Engineering Division
Federal Aviation Administration

William L. Umbaugh joined the FAA at Erie, PA as an electronics technician trainee and progressed to supervisory systems engineer at Cleveland ARTCC before coming to headquarters in 1975. He has held several positions of increasing technical management responsibility as program manager, branch manager and Deputy Manager, ATC Automation Division prior to assuming his present position in April, 1990.

Mr. Umbaugh holds an AEE degree from the Pennsylvania State University and has completed additional studies at Cleveland State University and American University. He has also completed more than 2 years of specialized studies at the FAA Academy in Oklahoma City.

As the Automative Engineering Division Manager, the responsibility encompasses the engineering support for the enroute, TMS, technical, and maintenance automation programs.

ODAPS TODAY
AND ITS ROLE IN FUTURE OCEANIC AUTOMATION

Presented by:

William L. Umbaugh
Manager, Automation Engineering Division, ANA-100

September 25, 1991

Overview

- ODAPS Requirements
- ODAPS Design
- ODAPS Implementation Status
- Planned ODAPS Milestones
- ADS Operational Concept
- Current ADS Activity

Oceanic Automation Requirements for ODAPS

- Oceanic air traffic control automation for Oakland and New York ARTCCs
- Dedicated oceanic flight data processing
- Interfaces with adjacent ARTCCs, ARINC, and NADIN
- Situation displays
- Conflict probe

ODAPS Design

- Modified NAS en route code
  - Unique adaptation and operational features
- Conflict probe
  - Algorithms based on FAA Order 7110.83b, Oceanic Air Traffic Control
- COTS processor complex
  - IBM 4381 mainframe and peripherals
- Existing NAS displays

ODAPS Implementation Status

- Commissioned at Oakland ARTCC on December 14, 1989 with conflict probe inhibited
  - Conflict probe undergoing software refinement
- Second release of operational software delivered to Oakland ARTCC in September
  - Implementation of NCPs developed after commissioning
- Third release of operational software under development
  - Implementation of NCPs to enhance data input and conflict probe performance

Planned ODAPS Milestones

- Oakland operational on second release of software - November 1991
- Contractor delivers third release to FAATC for testing - July 1992
- Third release delivered to Oakland ARTCC - September 1992
- New York ARTCC commissions with third release - June 1993

ADS Operational Concept - ADS Step 1

- ODAPS is the FAA certified system selected for ADS enhancements
- Aircraft position data automatically downlinked via satellite from inertial navigation avionics
- Frequent reports provide near real time position data
- ADS reporting aircraft are uniquely identified on the situation display

Current ADS activity

- ADS Step 1 contract awarded July 1991
- PDR scheduled for November 1991
- CDR scheduled for January 1992
- First site (Oakland ARTCC) testing - February 1993
- ADS commissioned - December 1993

Summary

- ODAPS is operational, providing oceanic air traffic control automation
- Enhancements under development will improve ODAPS utility
- Implementation of ADS Step 1 —
  - Will improve the accuracy of position data
  - Sets the stage for ADS evolution providing two-way data link and controller/pilot voice communications

ODAPS TODAY
AND ITS ROLE IN FUTURE OCEANIC AUTOMATION

Presented by:

William L. Umbaugh
Manager, Automation Engineering Division, ANA-100

September 25, 1991

ODAPS TODAY
AND ITS ROLE IN FUTURE OCEANIC AUTOMATION

Overview

- ODAPS Requirements
- ODAPS Design
- ODAPS Implementation Status
- Planned ODAPS Milestones
- ADS Operational Concept
- Current ADS Activity

ODAPS TODAY
AND ITS ROLE IN FUTURE OCEANIC AUTOMATION

Oceanic Automation Requirements for ODAPS

- Oceanic air traffic control automation for Oakland and New York ARTCCs
- Dedicated oceanic flight data processing
- Interfaces with adjacent ARTCCs, ARINC, and NADIN
- Situation displays
- Conflict probe

ODAPS TODAY
AND ITS ROLE IN FUTURE OCEANIC AUTOMATION

ODAPS Design

- Modified NAS en route code
  - Unique adaptation and operational features
- Conflict probe
  - Algorithms based on FAA Order 7110.83b, Oceanic Air Traffic Control
- COTS processor complex
  - IBM 4381 mainframe and peripherals
- Existing NAS displays

ODAPS TODAY
AND ITS ROLE IN FUTURE OCEANIC AUTOMATION

ODAPS Implementation Status

- Commissioned at Oakland ARTCC on December 14, 1989 with conflict probe inhibited
  - Conflict probe undergoing software refinement
- Second release of operational software delivered to Oakland ARTCC in September
  - Implementation of NCPs developed after commissioning
- Third release of operational software under development
  - Implementation of NCPs to enhance data input and conflict probe performance

ODAPS TODAY
AND ITS ROLE IN FUTURE OCEANIC AUTOMATION

Planned ODAPS Milestones

- Oakland operational on second release of software - November 1991
- Contractor delivers third release to FAATC for testing - July 1992
- Third release delivered to Oakland ARTCC - September 1992
- New York ARTCC commissions with third release - June 1993

ODAPS TODAY
AND ITS ROLE IN FUTURE OCEANIC AUTOMATION

ADS Operational Concept - ADS Step 1

- ODAPS is the FAA certified system selected for ADS enhancements
- Aircraft position data automatically downlinked via satellite from inertial navigation avionics
- Frequent reports provide near real time position data
- ADS reporting aircraft are uniquely identified on the situation display

ODAPS TODAY
AND ITS ROLE IN FUTURE OCEANIC AUTOMATION

Current ADS activity

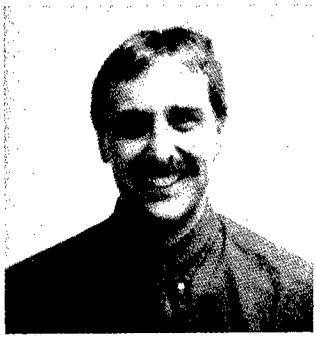
- ADS Step 1 contract awarded July 1991
- PDR scheduled for November 1991
- CDR scheduled for January 1992
- First site (Oakland ARTCC) testing - February 1993
- ADS commissioned - December 1993

ODAPS TODAY
AND ITS ROLE IN FUTURE OCEANIC AUTOMATION

Summary

- ODAPS is operational, providing oceanic air traffic control automation
- Enhancements under development will improve ODAPS utility
- Implementation of ADS Step 1 —
  - Will improve the accuracy of position data
  - Sets the stage for ADS evolution providing two-way data link and controller/pilot voice communications

SESSION TWO: PROGRAMS, STANDARDS AND INSTITUTIONAL ISSUES



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Dan H. Iredell has over five years experience in ATC software development. He has participated in the design and development of the ODAPS conflict Probe subsystem and supported the ODAPS ORD effort in Oakland in December 1989. Mr. Iredell has also contributed on the Software Engineering Group in the presentation of the Functional Design Review for the Automatic Dependent Surveillance (ADS) function. He received a B.S. degree in Computer Science from the University of Maryland.

SYSTEM IMPROVEMENTS IDENTIFIED BY THE NORTH ATLANTIC SYSTEMS PLANNING GROUP (NAT/SPG) AS RELATED TO THE CAPABILITIES OF THE OCEANIC DISPLAY AND PLANNING SYSTEM (ODAPS)

Dan H. Iredell,
Rajan Srirangarajan,
John H. Crimmins, Jr.

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INTRODUCTION

The need for improving oceanic Air Traffic Services (ATS) is being given significant attention by numerous countries and forums throughout the world. The issues being addressed range from concepts, standards, and procedures, all the way to procurement and implementation strategies. Leadership in these endeavors has come from the International Civil Aviation Organization (ICAO). The Oceanic Area System Improvement Study (OASIS) report (1), completed in 1981 under sponsorship by the U.S. Federal Aviation Administration (FAA) in coordination with ICAO, quantified the benefits of reducing oceanic separation standards. The OASIS report suggested the use of satellites for improved oceanic communications, navigation, and surveillance (CNS) services as one means of attaining these benefits. The ICAO Special Committee on Future Air Navigation Systems (FANS) was formed in 1983 to further develop the concepts suggested in the OASIS report. The Fourth Meeting of FANS, held in May of 1988, produced a report (2) that provided a detailed set of recommendations and guidelines to be applied to the development of international standards for satellite-based CNS services, including automatic dependent surveillance (ADS).

As the future CNS concepts began to mature, and new technology was becoming more readily available, the need to coordinate the implementation of these new CNS services on an international scale became apparent. Since the oceanic areas are controlled jointly by numerous countries sharing responsibility, the benefits of introducing new concepts cannot be fully realized without international participation and coordination. In recognition of this need, the North Atlantic Systems Planning Group (NAT/SPG), under the auspices of ICAO, developed a "System Concept Description" for the future North Atlantic Air Traffic Services (3). This document defines a set of requirements that need to be met to enable realization of the recommended concept.

At the same time that FANS was being formed, the FAA

initiated development of a significant new tool to support oceanic Air Traffic Control (ATC). Referred to as the Oceanic Display and Planning System (ODAPS), the contract for development and implementation was awarded to ST Systems Corporation (STX) in 1985. Now operational in Oakland, California, and soon to be operational in New York, ODAPS inaugurates a new era of oceanic ATC. ODAPS introduces to the oceanic controller a wide spectrum of automation capabilities, and a baseline infrastructure within which new capabilities and improved technology can be effectively accommodated.

Much of the functionality identified as being desirable by OASIS, FANS, and NAT/SPG is already provided by ODAPS. (Since the NAT/SPG system concept has its derivations in OASIS and FANS, further references to requirements will be associated only with the NAT/SPG system concept description document.) In addition to the baseline capabilities of ODAPS, STX has started work on a recently awarded FAA contract to implement ADS as an enhancement. It is envisioned that the ADS enhancement will be closely followed by the addition of two-way, air-ground datalink communications capability.

This paper intends to relate the current, and projected, capabilities of ODAPS to a set of the most demanding requirements included in the NAT/SPG system concept description. Specifically, this paper will address controller-pilot communications, position report processing, conflict prediction, and human-computer interfaces. Each of these subject areas will be assessed relative to three environments: (1) non-ODAPS (i.e., the manual, procedural environment that is currently dominant throughout the world); (2) ODAPS; and (3) ADS/datalink (i.e., enhancements to ODAPS).

CONTROLLER/PILOT COMMUNICATIONS

NAT/SPG identifies direct controller/pilot communication as an area where there is need for improvement. Much benefit could also be realized by improving computer-to-computer communications (e.g., ground-based inter-facility as well as between ground and airborne systems).

Non-ODAPS

Communications between the pilot and the controller currently relies on High Frequency (HF) radio and a ground station operator. The pilot transmits position reports and any other ATC messages, such as flight profile change requests, by voice on the HF radio. In the U.S. oceanic airspace, these HF messages are received by Aeronautical Radio, Inc. (ARINC), where they are transcribed and entered over a teletype interface and sent directly to a printer at the controlling oceanic sector. Any messages initiated by the controller for transmission to the pilot are first conveyed to the HF operator by telephone and

then relayed to the pilot over HF radio.

ODAPS

In ODAPS, the mode of communication between the oceanic ATC center and the aircraft is the same as in the non-ODAPS environment. However, since there is a one-way datalink between the HF operator and ODAPS, transcribed position report messages from the pilot are automatically received and processed. Messages are routed and displayed to the appropriate sector controller for action. This highlights an opportunity for immediate improvement by enhancing ODAPS to provide a digital datalink in the other direction, from the controller to the HF operator. This link would enable ODAPS to provide automatic message generation for the controller to approve and convey to the HF operator quickly and easily, eliminating the need for a telephone/voice link in most circumstances. It would also provide the controller with the tools to implement a future direct controller-to-pilot datalink interface.

ODAPS has the capability to communicate with a number of other external systems, including adjacent Air Route Traffic Control Centers (ARTCC), the Aeronautical Fixed Telecommunications Network (AFTN) and the Service B network through the National Airspace Data Interchange Network (NADIN), and the North American Air Defense Command (NORAD).

ADS/Datalink

The earliest phase of ADS will implement the capability for automatic transmission of ADS position reports, derived from on-board avionics, to the oceanic ATC center via a satellite datalink. Future enhancements will provide a two-way datalink between the pilot and the controller. Rapid and reliable direct controller/pilot communication over the datalink will provide the capability to relay both routine and non-routine messages rapidly and accurately. If the pilot desires to change the flight profile while in flight, he or she can request the change over the datalink, and the controller can process the request expeditiously. If the request is approved, the controller can transmit the clearance over the datalink. The pilot can acknowledge the clearance and indicate compliance intentions. These messages can be standardized or free-form, however, the standardization of format and content will require international participation and coordination. The oceanic ATC automation system could also have the capability to directly exchange data with the on-board Flight Management System (FMS).

Benefits

The use of the satellite datalink in lieu of HF communication will mitigate the problems of misinterpretation and ambiguity that are associated with verbal exchanges over an often noisy and unreliable transmission medium. Increased reliability in pilot-

controller communications will make the oceanic ATC system more responsive to the ever-increasing demands of the user community.

ADS reports are automatically generated and transmitted with minimal pilot involvement. Elimination of the human link in the communication path between the aircraft and the flight data processing computer will reduce the possibility of human error.

The applications and benefits of direct controller/pilot communication via datalink are extensive. The ability to communicate directly with airborne and ground-based systems, as well as directly between pilots and controllers, using a standardized set of messages, will help reduce both pilot and controller workload, speed communication response times, and enable the oceanic airspace to be utilized more efficiently.

POSITION REPORT PROCESSING

The acquisition, checking and tracking of flight position information are the primary functions of an air traffic controller in an oceanic ATC system. The change from manual techniques and infrequent reports to the automated processing of periodically generated and transmitted ADS reports is one of the significant benefits to be provided to air traffic controllers though improvements in communication and automation. NAT/SPG identifies clearance compliance and conformance monitoring as important functions to be automated.

Non-ODAPS

At present, the North Atlantic airspace is largely without radar surveillance. The voice-generated HF position reports typically arrive once every 30-60 minutes for most trans-Atlantic flights. Controllers manually perform the comparison of the reported altitude, waypoints and times against those printed on the flight strips.

ODAPS

ODAPS provides the controller with a wide variety of tools to assist with many of the previously manual tasks involved in processing position reports. The current ODAPS environment supports the processing of the HF position reports and pilot requests by directly connecting the teletype link from the ground operators into ODAPS. The reports and requests are processed and displayed to controllers on a display screen. Additionally, the position, altitude and any weather information is extracted and used to automatically update the flight's position.

ODAPS currently performs conformance monitoring and clearance compliance on the position reports by matching the reported altitude and present position, as well as the next and next-plus-one waypoints against the cleared flight plan. Any discrepancies in the reported altitude, waypoints and

times are highlighted on a display for the controller. ODAPS is designed to automatically invoke the Conflict Probe function (described in the next section) when position reports are received. Together with the position information, ODAPS uses the winds aloft data contained in the position reports to update the database of wind stations which are used to more accurately calculate times of arrivals for other flights. This contributes to the accuracy of the Conflict Probe function. In addition, when a flight has not submitted a position report within a specified time after passing an expected reporting fix, ODAPS automatically informs the controller.

ADS/Datalink

NAT/SPG has identified a need to replace HF reports with ADS reports. The ADS reporting rate will be much more frequent than that provided by pilots through HF. While the reporting rate can range from every twenty minutes to every ten seconds, the nominal rate is expected to be once every five minutes. The controller will be able to adjust the rate of the transmission of the reports. When the ADS function is implemented, the ADS position reports will be compared to the cleared flight plan using three conformance checks: vertical, lateral, and longitudinal. Conformance conditions will be based on adjustable parameters to define the tolerance envelope, and the controller will be alerted if the reports deviate significantly from the cleared route. As changes in separation standards evolve over time, the adjustable parameters can be changed to reflect new demands and requirements. When the ADS reports are in conformance, they will be used to automatically update the flight position. If the checks indicate significant longitudinal deviations from the cleared route, the Conflict Probe function will be automatically invoked. The automation system will monitor the means by which the flights are reporting their positions in a mixed environment, i.e., through either ADS or HF, and adjust the separation criteria accordingly.

Benefits

ODAPS provides many automated tools to assist the controller in processing position information. It can automatically perform many of the tasks which were previously performed manually. A study was made on the processing of HF position reports by the operational Oakland ODAPS system during days in January, May and June 1990. It showed that even though there is variability in the format of the HF reports, ODAPS was able to process more than 84% of the received position reports, and more than 72% of them were within the conformance checks and were used to update the flight plan database automatically. Since that time, the rate of reports processed has continued to improve to over 90%.

NAT/SPG has identified the lack of real-time surveillance

as the major shortcoming affecting the vast majority of the North Atlantic Region. The ADS capability both in the aircraft and the air traffic control systems is a necessary and fundamental building block with which many of the planned improvements in the oceanic region will be realized. The automated conformance monitoring function helps ensure that a flight remains on its cleared flight plan by detecting waypoint insertion errors and other blunders. The greater frequency and reliability of the ADS position reports provides an increased degree of confidence in the knowledge of aircraft position that could be used to support a reduction in separation standards.

CONFLICT PREDICTION

NAT/SPG identifies conflict prediction and conflict resolution as essential functions to be automated. NAT/SPG states that a conflict prediction function is required in order to ensure a conflict-free path of a length deemed appropriate at each stage of CNS evolution.

Non-ODAPS

In most of the North Atlantic region, conflict prediction and separation assurance are achieved manually without the use of a computer. The methods used include visual inspection and comparison of flight strips, and tracking of aircraft position manually on maps.

ODAPS

ODAPS has a conflict prediction function, called Conflict Probe, that examines a cleared flight plan for conflicts and informs the controller of any predicted loss of separation. Conflict Probe is invoked automatically by flight plan activation, flight plan amendment, receipt of a HF position report, or periodically if an aircraft's data has not changed over an adjustable period of time. Conflict Probe can also be invoked directly by controller request. An adjustable parameter within the look-ahead function specifies how far in the future the Conflict Probe function should inspect an aircraft's flight path for conflict.

The ODAPS Conflict Probe is able to monitor air traffic in an airspace that has varying separation criteria. ODAPS uses discrete separation minima with regard to aircraft type (e.g., turbojet), the Minimum Navigation Performance Specification (MNPS), and altitude stratum, which allows aircraft with different characteristics to have different separation criteria applied. In the event of changes to the definition of the separation standards, such as use of the Required Navigation Performance Capability (RNPC) criteria instead of MNPS, the Conflict Probe parameters can be easily modified to reflect these changes.

Conflict Probe also has the capability to check for a conflict situation between an

aircraft and temporary airspace reservations or warning areas. These airspace reservations are dynamic; they can be activated or de-activated while the system is operational.

ODAPS allows the controller to use the Conflict Probe function to perform "What if?" trial amendments to check for potential conflict resolutions without changing the flight plan database. The controller can manually attempt different trial flight plan amendments before selecting one of them. This feature can be applied to cleared flight plans as well as to flights that have not yet entered the airspace. Although this is not a fully automated conflict resolution function, it does provide the controller a means of resolving conflicts using an automated tool.

ADS/Datalink

With the advent of ADS, the Conflict Probe function will also be applied to the ADS position reports. If there is a sufficient deviation between the ADS position report and the cleared flight plan, the probe function will be automatically invoked.

The availability of direct two-way communications between the pilot and controller using datalink will enable rapid coordination of resolutions to potential conflicts.

Benefits

The automation of conflict prediction, through Conflict Probe, reduces controller workload and enhances safety. By providing advance warning of a potential conflict situation, the controller is able to evaluate alternative solutions. Thus Conflict Probe offers a margin of safety that may eventually result in a reduction in the required separation between aircraft. Such reductions would enable increased airspace capacity and provide more freedom for aircraft to fly their preferred routes.

HUMAN-COMPUTER INTERFACES

NAT/SPG states the human-computer interfaces (HCI) should optimize the system display capabilities by providing the controller a highly effective interface to the ATC system.

NAT/SPG emphasizes that the controller's role in the automated system must be that of decision maker. ATC automation should be designed to increasingly relieve controllers from the repetitive and routine tasks required in manual systems.

Non-ODAPS

Many existing oceanic ATC systems rely heavily on manual procedures. While domestic systems have undergone significant upgrades, the oceanic ATC systems have remained essentially unchanged for many decades. The current method of monitoring oceanic air traffic is dependent on paper flight progress strips that require manual updating by the

controller on the basis of the HF position reports.

ODAPS

ODAPS provides improved HCI to the oceanic controller through automation functions specifically developed for oceanic ATC. Newly available to the oceanic controller is a situation display of the flights under his or her control. ODAPS employs a Plan View Display (PVD) that is similar to those used in a radar environment for the monitoring of air traffic. It provides the controller a visual picture of the airspace, including aircraft positions, airspace map and tabular list information. In each sector, along with the situation display, ODAPS provides the controller a Flight Data Input/Output (FDIO) device. The FDIO provides the controller the capability to examine and modify the flight plan database and to display informational alerts and updates, including the HF position reports and requests. The FDIO printer provides paper flight progress strips. The FDIO and the PVD facilitate the traffic monitoring capability.

An internal research and development effort at STX has begun to develop an FDIO replacement. It will address controller needs in the areas of improved display and management of messages. It will allow the recall and free-text search of messages already received and will operate on an off-the-shelf workstation with a color display and with a modern windowing environment. Its programming flexibility will allow for future enhancements in the HCI for the controller. These enhancements could include the automation of the processing of pilot requests, such as altitude changes.

ADS/Datalink

STX has also begun an internal research and development effort to develop a Situation Display to replace the current PVD. This situation display would run on a workstation similar to the one used for the FDIO replacement and provide the controller with an improved HCI not available on the current equipment.

Enhancements to a replacement FDIO system could be accomplished to provide a controller workstation to efficiently develop and manage the messages used in two-way datalink communications.

Benefits

Improvements to automation take human performance capabilities into account and are designed to assist the controller in performing complex activities. For example, it can be very time-consuming for a controller to determine through manual processes whether a flight requesting a random route has sufficient separation from other flights. In contrast, there is basically no difference in the effort required of an automated Conflict Probe function to examine a random or organized route. As traffic levels and the demand for random routes increase, it may become increasingly difficult for

controllers to mentally visualize the air traffic situation solely from flight strip information. The improvements provided by ODAPS and ADS/datalink will help optimize the interfaces between the pilot, the controller, and their respective automation systems.

LOOKING TO THE FUTURE

It is clear that the technology and functionality associated with oceanic Air Traffic Services are rapidly and continually evolving. As planned enhancements are implemented, new ideas emerge that result in new developments, always taking advantage of the capabilities of new technology. Migrating from mainframe computers to more flexible and powerful workstations is one example of system evolution.

From a functional perspective, it is possible to envision the use of dynamically changing separation standards, by associating RNPC categories with the performance level of the on-board navigation system as identified by the Figure-of-Merit (FOM). The FOM would be included in each ADS report that is downlinked to the oceanic ATC Center. The required separation between aircraft would be based on their respective FOMs. The ground-based automation system would continually monitor the FOM and position of each aircraft, and alert the controller if the FOM was degrading to a point that would require intervention in order to maintain an adequate margin of separation.

As weather models become more accurate, a time can also be envisioned where flight profiles are changed dynamically through direct interaction between the on-board Flight Management System (FMS) and ground-based databases. Both the pilot and controller would be kept aware of recommended changes in the flight profile through computer-generated messages.

Adjacent oceanic centers would be continually sharing flight information data that would ensure consistency between all databases and ATC centers associated with a particular flight. This degree of inter-facility coordination, computer-to-computer, would enable center handoffs to be performed without the need for intervention by the pilot or controller.

As future enhancements are implemented, the ultimate objective of global travel using standards and procedures that make crossing of international boundaries transparent to the pilot will become closer to reality.

ODAPS has already shown the ability to accommodate new capabilities and new technology. This same flexibility enables tailoring to whatever requirements of a procedural nature that may be imposed. NAT/SPG has provided a concept, and ODAPS provides a means for implementation.

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CO-AUTHORS

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Rajan Srirangarajan was involved with system integration and testing for ODAPS. His prior assignments include technical evaluation of the Display software in the Advanced Automation System for the FAA. His interests include software design, prototyping the concepts and software methodology. Mr. Srirangarajan holds M.S. degrees in Computer Science, Chemical Engineering, and Petroleum Engineering, and has over ten years experience in the area of Computer Science.

John H. Crimmins, Jr.
Software Development Manager
ST Systems Corporation (STX)

John H. Crimmins, Jr. has been involved in the development of ODAPS and its enhancements including the inclusion of the ADS function, since joining STX in 1986. He has over eleven years experience in the design and development of interactive computer systems. He received his B.A. degree with distinction in (Experimental) Psychology from the University of Rochester. Mr. Crimmins is a member of the Association for Computing Machinery.

SESSION TWO: PROGRAMS, STANDARDS AND INSTITUTIONAL ISSUES

PANEL DISCUSSION:

"The Status and Interrelationships of Various ADS and SATCOM Standards"

PANEL MEMBERS

B. Richard Climie
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INMARSAT

SESSION TWO: PROGRAMS, STANDARDS AND INSTITUTIONAL ISSUES

PANEL BIOGRAPHIES

ONLY THOSE BIOGRAPHIES ARE LISTED THAT DO NOT APPEAR ELSEWHERE.

James C. Crowling
Federal Aviation Administration

James J. Crowling, Jr. is a Program Analyst and Aviation Inspector in FAAs Flight Standards Service. He is Flight Standards Global Positioning Satellite Systems Operational Implementation Coordinator. He coordinate the activities of the FAAs operational services in order to ensure the international and domestic satellite navigation and communication requirements are systematically implemented.

Mr. Crowling was a Program Analyst in the Office of Safety Policy and Programs from 1988 to 1989. He was the FAA's Program Manager to research, develop and evaluate, for national consideration, an innovative new concept in charting VFR routes to safely navigate in and around TCA's, ARSA's, and airport traffic areas in highly congested airspace areas.

Mr. Crowling was the manager of the United States Notice to Airman Office Facility (USNOF), Flight Procedures and Airspace Branch and Airports and Navigation Aids Branch from 1977 to 1987.

As an Air Reserve Technician in the Department of Defense from 1972 to 1977, he was the primary Flight Examiner Navigator for the Air Force Reserve Airlift Wing.

He obtained a Bachelor of Science degree from Old Dominion University.

SESSION TWO: PROGRAMS, STANDARDS AND INSTITUTIONAL ISSUES

PANEL BIOGRAPHIES

ONLY THOSE BIOGRAPHIES ARE LISTED THAT DO NOT APPEAR ELSEWHERE.

R. Andrew Pickens
AVCOM

Mr. Pickens has an extensive background in aeronautical communications, navigation and surveillance systems, and in data communications networks. He currently is Chairman, RTCA SC-165, writing Minimum Operational Performance Standards (MOPS) for Aeronautical Mobile Satellite Services (AMSS), and Chairman of its System/Service Performance Criteria Working Group. He is active in numerous other RTCA and related AEEC projects involving communications, data links and airspace management technologies; is a member of the U.S. Aeronautical Mobile Communications Panel (AMCP) Technical Advisory Group; and is a member of the FAA Advisory Committee.

Mr. Pickens is Principal of AvCom, Inc., a consulting firm providing services to government and industry in CNS, with emphasis on the special requirements of the aviation community. Previously, he has served as Chief Engineer and Vice-President, Industry Affairs, with Aeronautical Radio (ARINC); as Director of Research and Advanced Systems, Contel Page Engineers; and as head of Communications and Radar Departments with Bendix Communications Division. He is internationally recognized in his fields of expertise, and is the author of numerous publications and presentations. Mr. Pickens is a Senior Member of IEEE and AFCEA.

SESSION THREE: LINK ENVIRONMENT/AVIONICS INTEGRATION

Wednesday, September 25, 1991

Session Chairperson - Elizabeth L. Young, PhD, Vice President Aeronautical Services, COMSAT

2:00 **INMARSAT Access Approval** - Johnny Nemes, Group Leader, AES Engineering, INMARSAT

2:20 **Operational SATCOM: Moving from Trials to Service** - David W. Lipke, Director of Government Aviation, COMSAT

2:40 **The FAA/ARINC Initial Implementation of AMSS** - Angus D. McEachen III, Senior Director, Civil Aviation Services, Aeronautical Radio, Inc., (ARINC)

3:00 **BREAK** sponsored by **COMSAT**

3:20 **SITA Satellite Air Communications Implementation** - Graham C. Lake, Deputy Director International Relations, Societe Internationale de Telecommunications Aeronautiques (SITA).

3:40 **ADS Integration into the Flight Management Computer** - Ingeborg L. Ray, Staff Engineer, Communications Management, Honeywell, Inc.

4:00 **International Organization for Standardization (ISO) Protocols** - Stephen P. Van Trees, Senior Systems Engineer, Stanford Telecommunications

4:20 **Panel Discussion: Evolutionary Implementation of Satellite Communications**

Panel Members:

Keith Smith, INMARSAT	Angus D. McEachen, ARINC
David W. Lipke, COMSAT	William B. Garner, AMSC
Graham C. Lake, SITA	Hal F. Ludwig, FAA

5:00 **Closing Remarks** - Master of Ceremonies - Joseph J. Fee

SESSION THREE: LINK ENVIRONMENT/AVIONICS INTEGRATION

SESSION CHAIRPERSON

Elizabeth L. Young, Ph.D
Vice President Aeronautical Services
COMSAT

Elizabeth L. Young is currently Vice President, Aeronautical Services, in COMSAT's Mobile Communications division. She has previously served as Vice President, INMARSAT Policy and Representation and joined COMSAT initially as Vice President for Sales and Marketing in COMSAT General Corporation.

For five years, Dr. Young was President of the Public Service Satellite Consortium, a membership organization that pioneered in the use of communications satellites for public service. During her tenure with PSSC, she also served as President of its subsidiary, Services by Satellite, Inc.

Prior to her work in the satellite industry, Dr. Young held a number of positions in public broadcasting, including the directorship of the public radio and television stations at The Ohio State University, Executive Director of the Kansas Public Television Commission, and Director of Station Relations for National Public Radio.

Dr. Young holds degrees from Columbia University in New York and The American University in Washington, D.C. She completed her undergraduate work at Wellesley College in Massachusetts.

She has published widely in professional journals and has chapters in several books about public broadcasting, cable television, communication satellites and instructional media.

Dr. Young resides in Alexandria Virginia.

SESSION THREE: LINK ENVIRONMENT/AVIONICS INTEGRATION

Johnny Nemes
Group Leader, AES Engineering
Aeronautical Services Division
INMARSAT

Johnny Nemes has been involved over the last eight years with the development, testing and Inmarsat approval of satcom terminals. He is currently Group Leader of AES Engineering, a group with responsibility on the development of the technical requirements for Aircraft Earth Stations and the development and application of the Inmarsat Access Approval procedures.

Mr. Nemes has participated in many Inmarsat activities during the past several years, including responsibility for the setting up of the Inmarsat test facilities and its associated activities, e.g., development of new services and new applications for existing services. He was recruited by Inmarsat from Brazil, where he worked for the communications division of Telefunken with the development of communications equipment for the local market.

INMARSAT ACCESS APPROVAL

Johnny Nemes

Aeronautical Services Division, Inmarsat, London, England

ABSTRACT

This paper describes the Inmarsat Access Approval Process that each new SATCOM installation type (i.e., Aircraft Earth Station - AES) must go through. The understanding of the Inmarsat approval process will help avionics and antenna manufacturers to plan the future activities required for timely and successful implementation of the ADS/SATCOM program.

The objectives and details of the Inmarsat approval process and the testing required are described, including information on the entity that has the responsibility for leading the approval, the ***AES Integrator***.

The paper concludes with a brief description of the "commissioning" tests that will be carried out on each example of an AES installation, of an access approved type, before entering service.

INTRODUCTION

As part of the Inmarsat convention [1], the Inmarsat Council has responsibility for the adoption of criteria and procedures for the approval of earth stations having access to and utilization of the Inmarsat space segment. The primary purpose of the access approval process adopted by the Inmarsat Council is intended to ensure that AESs operating within the Inmarsat satellite network will not endanger the integrity of the system. In addition, it is intended to ensure that the service quality objectives have been achieved.

It is important that entities considering the manufacture, integration, installation and use of SATCOM avionics for Automatic Dependent Surveillance (ADS) have full understanding of this approval process. This should allow these entities to plan properly this important milestone.

INMARSAT ACCESS APPROVAL

The "Access Approval Procedures for Inmarsat Aircraft Earth Stations" document (Module 6 of the Inmarsat Aeronautical System Definition Manual) [2] describes the formalities and testing required to obtain Inmarsat access approval. This section provides a summary of this approval process.

Definitions

Aircraft Earth Station (AES): An aircraft radio station capable of communicating through satellites. An AES is composed of a set of subsystems, including antenna(s), transmitter(s), receiver(s) and the dedicated control equipment. For an AES configured according to ARINC Characteristics 741, it includes the antenna, diplexer, LNA, HPA, RFU and SDU and the relevant interwiring.

AES Installation: A specific example of an AES installation type.

AES Installation Type: An AES defined by its configuration details on an specific airframe in terms of Part and Drawing Numbers.

AES Integrator: An entity that defines an AES installation type for use in the Inmarsat system in terms of its constituent subsystems and interwiring. The Integrator is the entity that applies for access approval and has responsibility for the demonstration of compliance with the relevant Inmarsat technical requirements.

Ground Earth Station (GES): A fixed ground station which interworks with AESs via satellite, and interconnects them to terrestrial communication networks.

Inmarsat Access Approval: Approval by Inmarsat of an AES installation type, following satisfactory completion of tests which demonstrate that it complies with Inmarsat requirements.

Inmarsat AES commissioning: The process of bringing a newly-installed AES (of access approved types) into service, involving an administrative procedure and a series of "checkout" tests.

General

An application for access approval of an AES Installation Type must be submitted by an *AES Integrator*, which should be forwarded to the Inmarsat headquarters in London. The *AES Integrator* may be an airframe manufacturer, subsystem manufacturer, company involved with aircraft modifications, completions, overhauls, or other specialized body.

Only complete AES installations are access approved, and currently there is no provision for the approval of individual subsystems. But, for antenna subsystems, on request, Inmarsat can provide to an antenna manufacturer an assessment on the *access approvability* of AES installations fitted with his antenna. Access approval testing is done only on the first example of each new AES installation type and consists of two main phases. These are laboratory/bench tests, which are called phase 1 tests, and installed/over the satellite tests, which are called phase 2 tests.

The duration of the approval process is mostly driven by the quality and timing of the submissions made by the *AES Integrator*. A typical access approval process, for a completely new set of avionics and for an *AES Integrator* with previous Inmarsat approval experience, should take between 4 to 6 months.

Phase 1 Tests

Phase 1 testing is intended to demonstrate in a laboratory or comparable context, that the AES installation type complies with the relevant Inmarsat technical requirements. Annex 1 to Module 6 [2] provides an outline of the minimum tests, including environmental tests. The *AES Integrator* is responsible for submitting to Inmarsat, for review, a proper phase 1 test plan and procedures. Upon approval of the test plan and procedures, the *AES Integrator* will carry out the tests and submit the test results to Inmarsat.

This phase of testing also includes extensive validation of the protocols implemented in the AES. Inmarsat is developing an access approval test system (AATS) with the objective of expediting the protocol tests. Figures 1, 2 and 3 show block diagrams of the concept of this test system. It uses ISO-9646 conformance test methodology [3] and the test suite logic is written in ISO-9646 specified 'TTCN' language (Tree & Tabular Combined Notation). One requirement for the application of the test system is the implementation (on the AES under test) of the 'Delayed Echo Application' (which is an optional requirement). Design details, including the necessary software, of the test system will be made available free of charge to manufacturers.

The phase 1 of the approval process represents almost 95% of the approval effort.

Phase 2 Tests

Phase 2 testing is intended as a final validation of the performance of the installed AES over the satellite against an operational GES. The phase 2 tests are scheduled only after successful completion of the phase 1 tests. It should take as little time as possible to minimize use of satellite and aircraft time for tests. Annex 2 to Module 6 [2] provides the phase 2 test procedures. The exact contents and duration of the phase 2 tests will depend on the type of services that the AES will support.

For AES installations using a set of antenna and avionics that have not been part of a previously access approved installation, it includes ground and flight tests. In other situations, the requirement for a flight test, is reviewed on a case by case basis.

Inmarsat Test Witnessing

An Inmarsat representative will witness a selected number of the approval tests. The selection is made after the phase 1 test results have been submitted to Inmarsat. In some cases, an Inmarsat representative will also witness the phase 2 tests.

Access Approval Status

Inmarsat has already access approved several AES installation types. These include Data-1 AESs for ACARS and AIRCOM services and Voice-1 AESs for public telephone services. There are a number of other AES installations that are under approval. The following aircrafts have already been fitted with access approved AES installations: Boeing 727, 737 and 747, L1011, Gulfstream GIV and GIII , Canadair Challenger and Falcon 900.

RTCA MOPS

It has been an Inmarsat aim to develop test requirements that are compatible with those for the fulfilment of other national and international testing requirements (e.g., Minimum Operational Performance Standards for AMSS, under development by RTCA SC 165). This aim has the objective of minimizing of the amount of tests that may need to be carried out by *AES Integrators* to satisfy Inmarsat test requirement and those test requirements of aviation authorities. For this reason, Inmarsat has been very active in the relevant aviation forums in the pursuit of a high degree of commonality, where possible, in the test requirements.

It is clear that there is a need to avoid the duplication of testing, i.e., access approval, certification, etc. To achieve this goal, a working group has been created by Inmarsat to study possible streamlining and delegation of responsibility of access approval activities. Members of this group include representatives of the aviation industry and Inmarsat signatories.

INMARSAT COMMISSIONING

Before an AES can be authorised to operate via the Inmarsat space segment, Inmarsat must be satisfied that:

- it is of an access approved type,
- it has been installed properly,
- the user is legally authorised to operate it, and
- proper arrangements have been made for the payment of satellite service usage charges.

The above is verified during the commissioning of the AES installation. Only access approved AES installation types are considered for commissioning. An application for commissioning, using the relevant forms, has to be submitted to Inmarsat via the national *routing organisation* (RO). A copy of the notification, from the relevant aviation authority, of the aircraft's 24-bit technical address must be attached to the commissioning application. The RO will work with the applicant to ensure that the application form is completed correctly and will act as a link between Inmarsat and the applicant. The RO is responsible for ensuring that the user complies with all applicable national and international regulations concerning its licensing, installation, operation and use.

The commissioning tests will take place after the application has been approved by Inmarsat. These consist of a series of simple end-to-end tests that are needed to verify that the new AES installation functions properly. For SATCOM ADS applications, the Inmarsat commissioning test should comprise of EIRP and frequency tests measured at the ground earth station plus the reporting of its position. In addition to these tests, aviation authorities may introduce additional tests in consideration of the safety related aspects of the satellite service.

The "Commissioning Procedures for an Inmarsat Aircraft Earth Stations" document (Module 7 of the Inmarsat Aeronautical System Definition Manual) [4] describes the formalities and testing required to obtain Inmarsat access approval.

REFERENCES

[1] Inmarsat Basic Documents, Edited by the Inmarsat General Counsel, Fourth Edition (1989).

[2] Access Approval Procedures for Inmarsat Aircraft Earth Station, Module 6 of the Inmarsat Aeronautical System Definition Manual (Version 1.1).

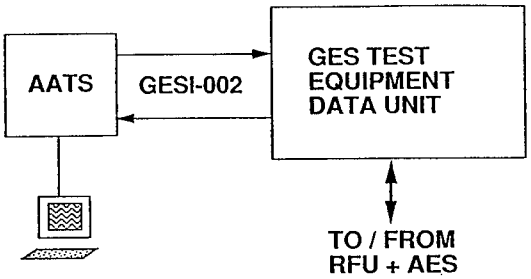
[3] ISO/IEC DP9646, Information Processing Systems - OSI conformance Testing Methodology and Framework.

[4] Commissioning Procedures for Inmarsat Aircraft Earth Station (AES), Module 7 of the Inmarsat Aeronautical System Definition Manual (Version 1.0).

ACCESS APPROVAL TEST SYSTEM

Hardware : MicroVAX II (5 Mb)

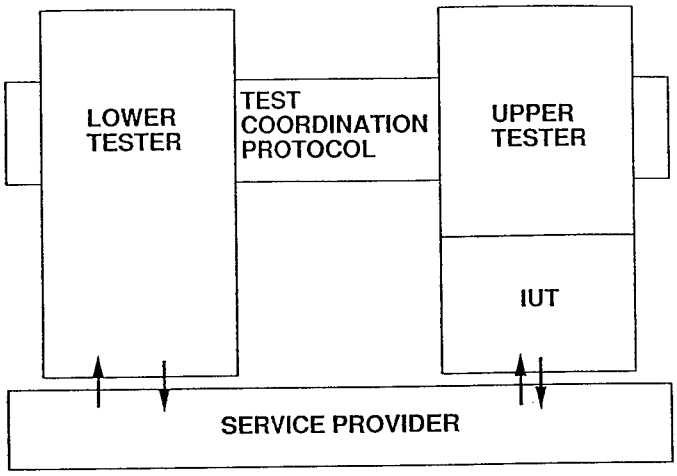
Software : VAX/VMS, C



INPUT: TTCN.MP format test suite held in ASCII files on the MicroVAX

Figure 1

TEST ARCHITECTURES (i)

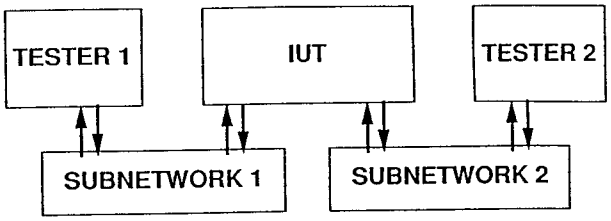


IUT - Implementation Under Test

Co-ordinated Single Layer e.g Data Link

Figure 2

TEST ARCHITECTURES (ii)



IUT - Implementation Under Test

Transverse Test Method e.g Circuit Mode

Figure 3

SESSION THREE: LINK ENVIRONMENT/AVIONICS INTEGRATION

David W. Lipke
Director of Government Aviation
COMSAT

David W. Lipke is Director, Government Aviation Marketing/Technical Services. He is responsible for activities leading to the introduction and development of aeronautical mobile satellite services via the INMARSAT system and their application to government requirements.

Mr. Lipke has thirty years of experience in the field of satellite communications ranging from engineering design of commercial and experimental systems to management of a major U.S. satellite program. He directed the technical efforts for the design of the world's first commercial maritime satellite communications system; many of his concepts which were used in the MARISAT system are now included in the INMARSAT system. Later he was responsible for the day-to-day management of the MARISAT program.

Mr. Lipke has been heavily involved in INMARSAT activities. He participated on behalf of the U.S. in early technical work leading to the establishment of the INMARSAT system, served as Chairman of the INMARSAT Advisory Committee on Technical and Operational Matters and served as alternate U.S. representative to the Council, INMARSAT's main governing body.

Mr. Lipke has authored more than 30 publications, mostly on satellite communications, holds several patents, served as Chairman of major professional groups and has been a U.S. delegate to international meetings associated with satellite communications. He holds Master of Science and Bachelor of Sciences degrees from the Massachusetts Institute of Technology.

OPERATIONAL SATCOM: MOVING FROM TRIALS TO SERVICE

by David Lipke and Elizabeth Young
COMSAT Aeronautical Services

FAA ADS/SATCOM Symposium
September 24-26, 1991

The civil aviation community first began using communication satellites on an operational basis in late 1990. The satellite system inaugurating this service and in use today is owned and operated by Inmarsat, an international cooperative of 65 countries. Both the Inmarsat Directorate in London and a number of Signatories who are owners, including COMSAT, have devoted considerable time and money to create an aeronautical communications system that will meet the expressed needs of the aviation community.

The first ground earth station in the Inmarsat system to offer data communications to commercial aircraft was COMSAT's station in Santa Paula, California, serving the Pacific Ocean region, followed shortly thereafter by COMSAT's Southbury, Connecticut, station. Through a service agreement with ARINC, COMSAT began providing ground and space segment, initially, to three United 747-400's outfitted with low-gain AES's. These AES's were comprised of a Ball Aerospace low-gain antenna and Collins avionics specified as "Data Level 0" in the Inmarsat lexicon. The low-gain system operates with an effective rate of 300 bits per second. To provide this initial service, COMSAT installed Collins-built interim ground earth station equipment capable of offering the initial data services with the Inmarsat system.

During late 1990 and early 1991, other Inmarsat Signatories, including KDD in Japan, OTC in Australia, and Teleglobe in Canada, also activated interim ground earth stations capable of working with the initial low-gain AES's. By the end of the first quarter of 1991, United had made a decision to upgrade their existing AES's to the newly introduced Data Level 1 configuration, and by June, 1991, United, Quantas, and JAL, Cathay Pacific and Canadian Airlines all had aircraft installed with the Data Level 1 capability. Formal FAA trials of ADS services using the satellite system began in the Pacific Ocean region on June 1 of this year. To date, the preponderant use of the low-speed data service has been in the Pacific Ocean region.

Meanwhile, COMSAT has further expanded its ground station capabilities to add voice at both locations and to incorporate higher speed data capabilities into the full service stations, retiring the initial equipment used to establish the early data service. Today, COMSAT's ground earth stations serve aircraft equipped for voice and

for Data Levels 1 and 2. Our users during the past nine months have included more than a dozen corporate jets (equipped for voice), the FAA's own 727 (for data) and aircraft owned by United, Quantas and Japan Airlines.

Initial satcom use in the cockpit has shown that position reports, engine monitoring, equipment status and other operational communications can be easily accommodated via satellite. Message lengths have varied, with a typical position report requiring less than a kilobit of data (including overhead) but with some operational messages requiring as many as 50+ kilobits. Since COMSAT does not have any visibility into the messages, we cannot speculate as to the precise nature of each communication, but it seems clear from the early traffic that on the order of 75 to 85% of the messages are for position reports.

We are continuing to upgrade our ground earth station facilities to add Data Level 3 capability by early 1992 and to add service in the Atlantic Ocean East region, complementing our AOR-W and POR services. With regard to numbers of aircraft served, while using the Collins-built interim Data Level 1 ground earth station equipment, COMSAT's ground earth stations could accommodate a single interface. With the newer Data Level 1 and Data Level 2 equipment, we are able to expand our ability to interface to more aircraft as the need arises.

Voice interfaces at the ground earth stations are relatively straight forward. At the time this paper was written, COMSAT interfaced with AT&T, while discussions have been on-going with other terrestrial carriers. COMSAT's stations permit direct connection with other carriers and private lines. The latter could be of use in initial ATC services.

While we will begin a number of new services in early 1992, including high-speed data (10.5 kbps), facsimile and broadcasts such as FlightNews, our focus here today is the discussion of position reporting and ADS. On that topic, I would like to introduce some ideas about how satellite-based ADS can transition from a demonstration into an operational service.

A key question is, of course, how the entire message network can or should be configured. In other words, assuming aircraft are equipped both to check their positions (increasingly, perhaps, with GPS) and to relay this information via the Inmarsat space segment and operators' ground stations, what is the most efficient and practical pathway for this position information to take from the aircraft to its final destination?

The Inmarsat system is well suited to assist in the provision of oceanic air traffic control (ATC) services. The satellites, as a result of serving the international aeronautical and maritime communities, are ideally positioned over ocean regions

where improved communications can benefit air traffic management the most. Global coverage, except for the polar caps, is now provided by a constellation of four primary satellites as shown in Figure 1, with redundancy in each ocean region.

The use of the satellite network for periodic delivery of aircraft generated position reports can be made straight forward and there are several approaches for doing this using the P, R, and T data channels in the Inmarsat system (see Table 1). The early POR ADS trials used an operational procedure whereby the aircraft, each time a position report was ready to be sent, requested a T-channel assignment, the request being sent on the R-channel. Upon receipt of the request, the GES would assign a T-channel frequency to the AES and the burst message would be sent. In actuality, the GES, while equipped with the interim equipment, used the same data modem to receive both R and T channels. Different frequencies are used for the R and T channels so that both cannot be received simultaneously at the GES. The new GES data equipment contains both R and T channel receivers so that simultaneous reception is possible. Following receipt of the ADS message, the GES sends an acknowledgement to the AES on the P-channel.

The same procedure used in the trials is one of several operational procedures that can be used in the provision of a fully operational worldwide service. The T channel can be used regardless of whether the message is short or long but it will be required for messages in excess of 264 bits. For shorter length messages, the R-channel could be used; the Inmarsat system permits the transmission of messages comprising up to three signal units on that channel. The advantage of using the T-channel method is that it ensures avoidance of collisions which might occur, albeit infrequently, when the complete messages is transmitted via several R-channel signal units.

While the POR trial program has verified the ability of the satellite system to deliver reliably reports from air to ground, the establishment of an improved worldwide Air Traffic Control system requires a communications architecture that connects all GES's and ACC's in the Flight Information Regions of interest. This ground-ground communications capability has as its core requirement the need to assure that ADS reports reach the correct Area Control Centers. The same ADS report will have to be delivered to multiple ACC's to insure smooth FIR-FIR handover. It should be noted that satellites offer an alternative means to terrestrial systems for accomplishing this function. It is easy to envision, for example, a simple time division multiple access VSAT system with all ADS reports received at each GES being multiplexed on a single carrier that is relayed through a communications satellite in the fixed satellite service and received simultaneously by small antennas located at every ACC. Each ACC would merely process the information of

concern to its responsibility and discard the rest. In this way, multiple ACC's would receive the ADS reports from aircraft in their individual FIR's as well as from those in adjacent areas, and the ACC's could track these aircraft, thus assuring a seamless transition at the time of handover.

The INTELSAT system offers the capability for a network that could link ACC's and a host Inmarsat aeronautical ground earth station. INTELSAT's Intelnet service can provide international data communications between a large INTELSAT station (connected to the Inmarsat host station) and microterminals at ACC locations. Intelnet data service is offered as a leased transponder service with space segment units as low as 100 kHz.

One further note regarding ocean air traffic management: The era of aeronautical satellite communications is opening with a rapid take-up by the corporate aviation community. The number of aircraft now equipped for voice service is growing steadily and greatly exceeds the number that have data capability. Since all of corporate aircraft are capable of international/oceanic flight, either equipment upgrade or use of satellite voice communications for ATC will be needed.

In summary, satellites and ground earth stations to assist in the provision of improved ocean Air Traffic Control are in place and procedures for using the satellite network for delivering messages are well understood. Consideration should be given to supplementing terrestrial GES-ACC interconnect with a satellite broadcast mode type of signal for the dissemination of ADS reports to multiple ACC's.

INMARSAT FOUR OCEAN REGION COVERAGE

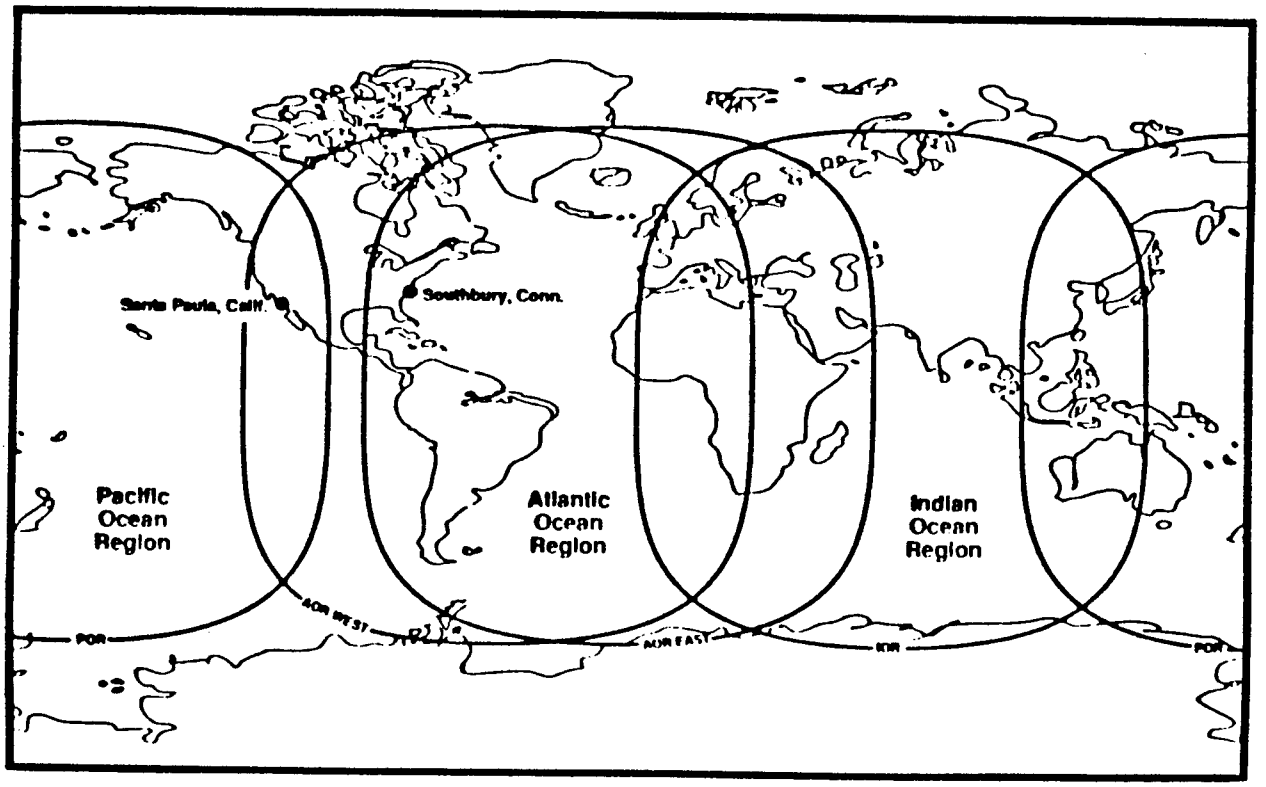


FIGURE 1

TABLE 1

DATA SYSTEM CHARACTERISTICS

THREE DIFFERENT TYPES OF CHANNELS ARE USED TO CARRY PACKET DATA TRAFFIC:

P-CHANNEL: A PACKET MODE TIME DIVISION MULTIPLEX (TDM) CHANNEL, USED IN THE FORWARD (GROUND-TO-AIR) DIRECTION.

R-CHANNEL: A RANDOM-ACCESS (SLOTTED ALOHA) CHANNEL, USED IN THE RETURN (AIR-TO-GROUND) DIRECTION.

T-CHANNEL: A RESERVATION TIME DIVISION MULTIPLE ACCESS CHANNEL (TDMA) CHANNEL USED IN THE RETURN DIRECTION ONLY. THE RECEIVING GES RESERVES TIME SLOTS FOR TRANSMISSIONS REQUESTED BY THE AIRCRAFT EARTH STATIONS (AES) ACCORDING TO MESSAGE LENGTH. THE SENDING AES TRANSMITS THE MESSAGES IN THE RESERVED TIME SLOTS ACCORDING TO PRIORITY.

SESSION THREE: LINK ENVIRONMENT/AVIONICS INTEGRATION

Angus D. McEachen, III
Senior Director
Civil Aviation Services
Aeronautical Radio, Inc. (ARINC)

Angus D. McEachen serves as the Senior Director of Civil Aviation Services/Marketing and Strategic Planning at Aeronautical Radio, Inc. In that capacity, he has responsibility for ARINC Services provided to civil aviation authorities including the Federal Aviation Administration. In addition, aviation communication services furnished by ARINC to other civil agencies as well as military customers are within Mr. McEachen's responsibilities at ARINC. Included in these services are ARINC Communications Addressing and Reporting System (ACARS); ARINC's International Gateway Service which furnishes Air/Ground International High Frequency Radio and Satellite Services in all oceanic areas for which the Federal Aviation Administration has Air Traffic Control responsibilities; and a variety of other flight operations and weather communication services.

Mr. McEachen served as a Captain in the U.S. Navy before he joined Aeronautical Radio. He served in the Navy Command, Control, Communications and Intelligence community for over twenty years.

The FAA/ARINC Initial Implementation of AMSS

Angus D. McEachen III, Senior Director

Aeronautical Radio, Inc.

Abstract

The application of satellite-based Communication Navigation and Surveillance (CNS) as defined by ICAO will provide significant cost benefits to the global air transport industry. This paper traces the evolution of Aeronautical Mobile-Satellite Service (AMSS), identifies the primary applications that are now targeted for use of AMSS and describes the series of phases of worldwide system transition from the current analog voice service to the future digital satellite communication service. Key implementation events that should take place for orderly transition to the future AMSS are also identified. A brief description of the current status of various trials and demonstrations of AMSS applications are also described. The improvements in Air Traffic Management (ATM) through the application of digital satellite based communication links offers the most cost efficient means to increase the quality and level of services offered and improve safety of operations while simultaneously lowering the overall system-wide costs.

1.0 Introduction

During the 10th Air Navigation Conference (ANC) recently held in Montreal, full-scale development and implementation of ICAO's Future Air Navigation System (FANS) concept was a key issue. The principles that define this concept will serve as the basis for evolution and implementation of future Air Traffic Services (ATS) into the next century. The FAA's active participation and sponsorship of the ICAO position, particularly its applicability to Air Traffic Management (ATM) are noteworthy. Implementation of the Communication Navigation and Surveillance (CNS) systems as defined under the FANS concept allows ATM to evolve on an orderly global basis and to become progressively more responsive to the users' needs. Specifically, these CNS systems will provide for:

a) global communications, navigation, and surveillance block to block coverage embracing remote, off-shore, and oceanic areas;

b) digital data and voice interchange between air and ground systems to fully exploit the automated capabilities of both;

c) navigation/approach service for runways and other landing areas which need not be equipped with precision landing aids.

1.1 CNS Applicability to AMSS

The features of CNS which relate to Aeronautical Mobile-Satellite Service (AMSS) are:

COMMUNICATIONS

- Satellite data and voice communication capability will be developed to cover most of the world. HF will be maintained during the transition period and over polar regions until such time as other data communication means are available.

- The Aeronautical Telecommunication Network (ATN) will provide for the interchange of digital packet data between end users over dissimilar air-ground and ground-ground communication links.

NAVIGATION

- Global Navigation Satellite System(s) will provide worldwide coverage and will be used for aircraft navigation and for non-precision type approaches.

SURVEILLANCE

- Automatic Dependent Surveillance (ADS) will be used in oceanic and other airspace where the use of primary or secondary radar for surveillance is impractical.

1.2 Air Traffic Management Improvements and Associated Benefits

As new CNS systems provide for closer interaction between the ground system and airspace users before and during flight, improvements to air traffic management will permit a more flexible and efficient use of airspace and enhance safety and regularity of flight. ATM may be viewed as the principal beneficiary of the CNS improvements; *i.e.*, it is the resultant benefits to ATM which constitute the rationale for incurring the costs of CNS improvements. In turn, improvements in ATM will ultimately benefit all airspace users.

By their nature, satellite systems demonstrate their full advantage when exploited on a global scale with a complementary ATM infrastructure in place. Satellite CNS systems are the key to system improvements and will provide significant benefits. The cost/benefit analysis performed by FANS Phase I indicated a very favorable ratio of benefits to costs for satellite CNS systems. Sensitivity analysis indicated that highly conservative benefit levels would still show favorable benefit-to-cost ratios. The consolidated results show the annual cost of satellite CNS systems to be, in 1987 US dollars, about $1.0 billion against annual benefits ranging from $5.2 billion to $6.6 billion. The benefit category of avoided cost alone roughly equals the total cost while the efficiency benefits are much greater. In appreciating this validation it needs to be noted that, in order to realize the benefits, especially in terms of avoided costs and efficiency improvements, implementation must be carried out on a global scale and a suitable matching ATC infrastructure should be available. Otherwise maximum benefits will not be achieved.[1]

The last FANS Phase II Committee meeting

(FANS II/1 22 May - 8 June 1990) developed a draft Global Transition Plan that documents the institutional and operational issues relevant to the migration of the current ATS to the FANS CNS concept. This draft plan was approved at the 10th ANC and represents the planning framework within which all ICAO member States are to transition to FANS. A key ingredient for the successful implementation of the communications segment of the CNS concept is the need for an effective data link between the air traffic control center and aircraft in controlled airspace. As recommended within the Global Transition Plan, the first guideline urges States to use data link systems as soon as they become available. The second guideline recommends that oceanic airspace and "in continental" en-route airspace with low density traffic be the initial application areas for transition to the AMSS. The Pacific Engineering Trials (PET) of ADS, using selected suitably equipped commercial aircraft, have proven the feasibility of using ADS messages as the basis for position reporting and for the implementation of two-way data link for Air Traffic Control (ATC) communications.

ICAO has developed and analyzed four scenarios that describe possible institutional arrangements among Provider States, as the means for implementation of the FANS concept. These scenarios represent varying levels of State Ownership and control of the satellite and ground communication networks to be used for aeronautical communication services. ATS activities within the U.S. can best be described as conforming to scenario 3 of the four scenarios defined within the institutional arrangements recommended by ICAO. This paper describes the status of satellite based communications, as they are being implemented by the commercial airline community, its representative, ARINC, and the FAA, for deployment in the Pacific Ocean region. The paper identifies the certification and other approval steps being accomplished within the near term to enable operational use of satellite communication-based ADS as the primary means of automated position reporting and other flight control information reporting to the oceanic control center sector(s) within the appropriate FAA Air Route Traffic Control Center (ARTCC). Current operational HF voice communications equipment serves as the back-up for ATC and Airline Operational Control (AOC) for SATCOM-equipped aircraft. The system being implemented provides a migration path that allows for parallel development of automated air/ground communications and the Oceanic Automation System that ensures end-to-end inter-operability between the controller and the flight deck. In the final FANS CNS system, communications will be conducted via transparent information exchange that allows operation from the traditional high frequency voice system through the newer satellite, VHF, Mode S data links and the Aeronautical Telecommunications Network (ATN).

In the near term benefits will also be available with the introduction of automation to Air Traffic Control procedures. These include:

- Improved safety,
- Two-way ATC data link (voice back-up),
- Reduced message delivery time,
- Substantial economic advantage to air carriers,
- Reduce workload,
- Reduced HF communication congestion.

2.0 Background

2.1 ATC and AOC Message Handling via ARINC's Communication Centers

Current oceanic communications systems utilize HF voice communications for both ATC and AOC message exchanges. The ATC system in U.S. controlled oceanic airspace is based upon aircraft position reports being transmitted at prescribed intervals by the flight crews using HF voice communications. These messages are transcribed by ARINC radio operators into data messages and delivered to the specific oceanic control center sector(s) within the FAA ARTCC. When an oceanic air traffic controller needs to send a message to an aircraft, he calls the appropriate ARINC communications center via a dedicated voice circuit and provides the specific text of the message to be transmitted to the aircraft. At the ARINC communications center, the desired uplink message is transcribed into the ARINC data network (for message tracking and control purposes as well as to maintain a record of the transaction) and then relayed verbatim to the aircraft via an HF voice transmission. (Only the Anchorage ARTCC oceanic controllers have the capability of sending messages to the ARINC communication center via a data link rather than dedicated voice circuits).

2.2 Automated Message Routing Exists in the VHF Continental Environment

For operational control communication in the U.S. domestic airspace, a majority of the message exchanges between aircraft and ground systems are conducted via the Aircraft Communications Addressing and Reporting System (ACARS). Many oceanic aircraft are also equipped with VHF ACARS capabilities. This form of flight deck data link allows for the creation and transmission of data messages for AOC and ATC applications and is currently being enhanced to include oceanic data link via satellite communications. Use of this system allows background message exchanges between the flight deck and the oceanic controller with little human intervention, thus improving the integrity of the messages transmitted. Ground processors such as the ARINC Air Traffic Services Message Processor (ATSMP) will accept these automated reports and appropriately reformat them to interface with the FAA and other end systems such as the Oceanic Display and Planning System (ODAPS).

3.0 Intermediate Services (Transition Phases)

To further facilitate the initiation of data link message exchanges for Air Traffic Control, the acceptance and integration of flight deck data for aeronautical operations is being promoted by several U.S. and foreign carriers. The existing system will be used during the transition period from a totally voice-based system to a fully automated data link-based system. The migration path is via a two-step process. The first step automates the flight deck with no changes introduced to the ground controller procedures. The second step introduces changes in the ground controller's environment and permits direct two-way data links to be established between the oceanic controller and the aircraft in flight. These processes are described in the following sections.

3.1 Flight Deck Data Link

In aircraft equipped with ACARS, operating in oceanic areas beyond the VHF line-of-sight range, data link services will be provided by adding SATCOM to the ACARS avionics. To assure a smooth transition of ATC and AOC communications from the manual voice HF environment to that of oceanic data link service, initially, data link communications will be routed to and from aircraft to its destination via the ARINC communications center. Routing all communications traffic through an ARINC communications center will permit relays to ARTCCs of HF voice and SATCOM data link messages transparently, with no change in procedures required at the oceanic center. Near instantaneous fall back to manual HF voice procedures takes place should any service interruption occur on the satellite data channel. ATC data up-linked to the aircraft, from the oceanic controller will also be delivered to the appropriate ARINC communications center via the dedicated voice circuits, employing current procedures used.

3.2 Oceanic Controller Data Link

The next stage in the transition to an all digital data link communications system is to provide oceanic ATC controllers with the capability of origination of data messages for transmission via the satellite channel directly to the aircraft. In the U.S. this requirement is directly linked to the FAA's implementation plans for the oceanic controller work stations. This direct uplink process will automatically detect failure of the aeronautical data link (end-system to end-system) and alert the appropriate controller, aircrew, and ARINC, who will immediately revert to either SATCOM voice or the manual HF voice procedures pending restoration of the data link services.

4.0 SATCOM Voice and ATN Services

4.1 Handling of Satellite Based Switched Circuit Mode Voice

Aircraft equipped with flight deck SATCOM voice capabilities will be supported using procedures similar to those used for HF voice reporting. Under this procedure, the voice call will be placed from the flight deck to the ARINC communications center, where the message will be transcribed and routed to the appropriate ATC sector using the same procedures as those currently in place for the HF voice transmission today. The availability of "toll quality" satellite-based voice communications will provide a significant advantage over the current HF channel. SATCOM voice will be used for non-standard communications and as a backup to SATCOM data link.

4.2 Link Independent Data Communications Can Be Expected from ATN Services

Over the longer term, as implementation of full ATN services are available on ground networks, and avionics within the aircraft are suitably upgraded, the data link utilized by any specific message exchange will be dependent upon the performance requirements of the communication session, and could be conducted over any of the compatible modes of VHF, satellite and Mode S data link. The implementation of ATN will, however, require inter-operability of the new networks and those of the existing operational systems.

Current designs will support the handling of messages originated by the character oriented avionics as well as the new bit transparent systems. This will ensure that the oceanic controller can function within a single set of operational procedures for all data communications equipped aircraft as well as those with only HF systems.

4.3 ATC/AOC Message Handling

Figure 1 shows the internetworking of ATC/AOC messages in the ARINC communications system reflecting interoperability with analog and digital air/ground systems.

5.0 Initial Operational Tasks

After many years of intense industry planning, commercial satellite data communications was inaugurated in September 1990 on a United Airlines Boeing 747-400 aircraft. The first aircraft that are suitably equipped and certified for operational use of Air Traffic Control (ATC) messages in lieu of the existing manual HF position reporting procedures will be in operational service shortly. Initially, these services, in keeping with the FANS Global Transition Plan Guidelines, are expected to be implemented over the Pacific Ocean. The SATCOM data link system will connect aircraft in flight with the appropriate oceanic controller at the FAA's ARTCC through the ARINC communications center under the scenario described in this paper for downlink messages. United Airlines (UA) has undertaken a program to upgrade their Boeing 747-400 SATCOM equipment to meet the certification requirements being developed among the FAA Certification Office in Long Beach, California, avionics manufacturers, United Airlines and ARINC. A certification plan and an equipment upgrade schedule has been approved by the FAA.

Conversion from today's HF based operations to a fully automated all digital service for aircraft operations over the Pacific has been defined under a five-step program. A brief description of the salient features of each step follows:

STEP 1 <u>Satellite Data Link Between Aircraft and ARINC Communications Center</u>

Satellite based communications will be conducted on a two-way data link between aircraft and the ARINC communications center. The data will be received continuously at the communications center and will serve as the basis for pre-operational evaluation and implementation of two-way ATC SATCOM data communications. No procedural changes are necessary at the ARTCC and the controllers will receive and send information to all aircraft in flight using the current procedures. The ARINC communications center responsible for converting controller-provided voice information to the digital communication for relay over data link via satellite to the aircraft. Similarly, the aircraft will undertake to maintain all air ground communication, while in the Oakland and Anchorage FIRs, via the digital satellite link which will be directed to the ARINC communications center. The communications center will transmit the downlinked information to the ARTCC in the manner currently operational at each site.

STEP 2 Satellite Voice Between Aircraft and ARINC Communications Center

Upon the completion of certification and implementation of digital voice equipment within the aircraft, the FAA and ARINC communication center will conduct pre-operational tests of voice communication to the cockpit via the satellite link in lieu of the HF radio link. The purpose of this trial will be to demonstrate the link connectivity, capability, capacity and quality, and to establish performance criteria while gaining field experience in the use of the satellite voice as a back-up to the data link service defined and developed under Step 1. Once again, implementation of this step will require no changes in current controller procedures at the ARTCC. The ARINC communications center is currently responsible for maintaining the air ground voice connection over the Oakland and Anchorage FIRs and will continue to assume this responsibility. Both FAA and air carrier aircraft with participate in these trials. As the aircrews develop familiarity with the communications equipment, they will use it during the trials and rely upon the HF equipment as a back-up. This phase will evaluate the voice quality as well as all other operational parameters such as set-up times and any delays experienced to determine their impact in an operational environment.

STEP 3 Data Link and Voice Between Aircraft and ARINC Communications Center

When sufficient operational experience has been gained in Step 1 and Step 2 , a trial operational cutover with the use of all digital satellite based communications will be undertaken. Step 3 will result in the operational implementation of two-way data link between the aircraft and the ARINC communication center, and a one-way data link from the communication center to individual sectors. Digital data will be received on aircraft flight deck displays. Voice communications with the communication centers will be conducted utilizing the satellite links when available with HF voice as a backup to SATCOM data link and voice service.

STEP 4 Prototype Workstation Development for Two-way Data Link Between Aircraft and ARTCC

This phase of the transition will consist of the development of appropriate software for the RS-6000 controller workstation. Specifically, it will include the development of controller workstations that permit direct two-way digital communications between the aircraft and the controller. Data traffic transferred in both directions will be treated under pre-operational procedures and will necessitate the maintenance of existing (or Step 3) data communication procedures. It will be utilized to conduct in-depth analysis and evaluation of the controller workstation and verification of the various interfaces to ODAPS. Development of the requirements for procedures for operational implementation of this data link will also be included.

STEP 5 Operational Two-way Data Link Between the Aircraft and the ARTCC Workstation

The program will result in the establishment of operational two-way data traffic between the ARTCC and the aircraft utilizing the RS-6000 workstation. It is anticipated that a trial

period for operational cut-over will be required for each ARTCC to demonstrate the validity of the functionality developed during Step 4. Oceanic clearance processing and full communications of data and voice are expected to be handled via the satellite data link for routine and non-routine communication requirements. HF voice capability will be maintained as a back-up facility. Step 5 will result in the pre-operational verification and subsequent full implementation of end-to-end two way data link via SATCOM.

5.1 Oceanic ATC Automation Concept.

Figure 2 shows the connectivity and migration capabilities involved in the implementation of the five-step plan.

6.0 Key Implementation Events

There is a need to establish a priority structure of system elements and areas of applicability with regard to implementation. Transitioning the current air ground communication system to that proposed in the five phase process described earlier requires the establishment of milestones that should take into account the following parameters relative to each system and/or region:[2]

a) end-to-end integration of airborne and ground system elements on phased basis;
b) pertinent tasks by relevant ICAO groups:
c) adoption of relevant avionics standards;
d) completion of relevant research and development and applications developments;
e) management of satellite capacity;
f) availability of avionics;
g) completion of pre-operational trials/validation;
h) availability of suitable requirements and procedures;
i) availability of ground infrastructure;
j) completion of training;

Ideally, the transition to new CNS systems will be based on improvements in ATM and accompanied by procedural and structural changes that will provide benefits to ATM and to users. The transition a highly complex process that requires the active cooperation and participation of the FAA, airlines, equipment manufacturers, standards organizations and a host of other groups, for successful implementation. Requirements and procedures will be developed with the participation of all parties in a Computer Human Interface (CHI) emulation of the operational system. They should increase simulation of the end-to-end systems. See Figure 3.

7.0 Current Status

ARINC Air/Ground Data Link SATCOM Service for Airline Operational Control Communications has been in place since the availability of the first SATCOM-equipped United Airlines 747-400 aircraft initiated passenger service in late September 1990. Since then, the infrastructure for data communications on oceanic flights has been demonstrated in the Pacific Engineering Trials (PET). Some communications traffic statistics from these trials are given in Table 1. The Automatic Dependent Surveillance (ADS) reports replace manual reports with an increase in accuracy and reliability.

During the Pacific Engineering Trials, ARINC developed tools and techniques for analyzing position reports and generating plots of flight paths. Three types of position reports were used.

1) The Automatic Dependent Surveillance (ADS) reports were originated by the Aircraft Condition Monitoring System (ACMS).

2) Data link position reports keyed in by the aircraft crew in conjunction with the voice waypoint reports and delivered via satcom.

3) Waypoint reports delivered at ten degree crossings by voice over HF radio to one of the ARINC comm centers, and transcribed to data messages by the ARINC radio operators.

Figure 4 is the plot of data from UAL 90 on December 22, 1990 which illustrates all of the PET air/ground communications modes. The flight heads northeast from Narita airport toward the Aleutian islands. Near Alaska, the flight turns southeast and follows the Pacific coastline of the United States to Los Angeles. The ADS data indicates that the flight jogged to the east coming over land at San Francisco.

8.0 FAA Certification

FAA certification for use of SATCOM-equipped aircraft for ATC data link communications has resulted in early implementation of this capability between appropriately equipped aircraft and ARINC communications centers. No changes to operational procedures need be immediately undertaken within the ARTCC. Key components of the FAA certification plan include the following:

- Detailed description of the data communications system including FMS diagrams, end-to-end message flows, and appropriate documentation describing the internal handling of all classes of data traffic.
- Complete procedures for downlink and uplink message flows. (Procedures for assurance of positive receipt and end-to-end verification).
- Ground-to-ground integrity compliance and assurance.
- Annunciation of SATCOM inoperative and relevant procedures to be undertaken.
- Message logging and lost message procedures.
- Procedures implementation and training plan for all personnel impacted.
- Avionics qualification test plan and results.
- Operational trials and subsequent data analysis of results.
- Advisory Circular exceptions.

9.0 Conclusion

Thoughout the aviation industry, the rapidly increasing need for communications and information transfer as a means to improve safety of operations while simultaneously lowering the overall system-wide costs, results in a substantial economic and administrative challenge. Improvements in ATM through the application of digital satellite based communication links offers the most cost efficient means to achieve these objectives. ARINC's strong support and active participation in delivering digital communications from the flight deck to ground systems, whether they are for ATC or AOC, assures the FAA and the airline

community that the pace at which implementation of air ground services is achieved will not be delayed by the lack of ground based facilities to support aircraft in flight.

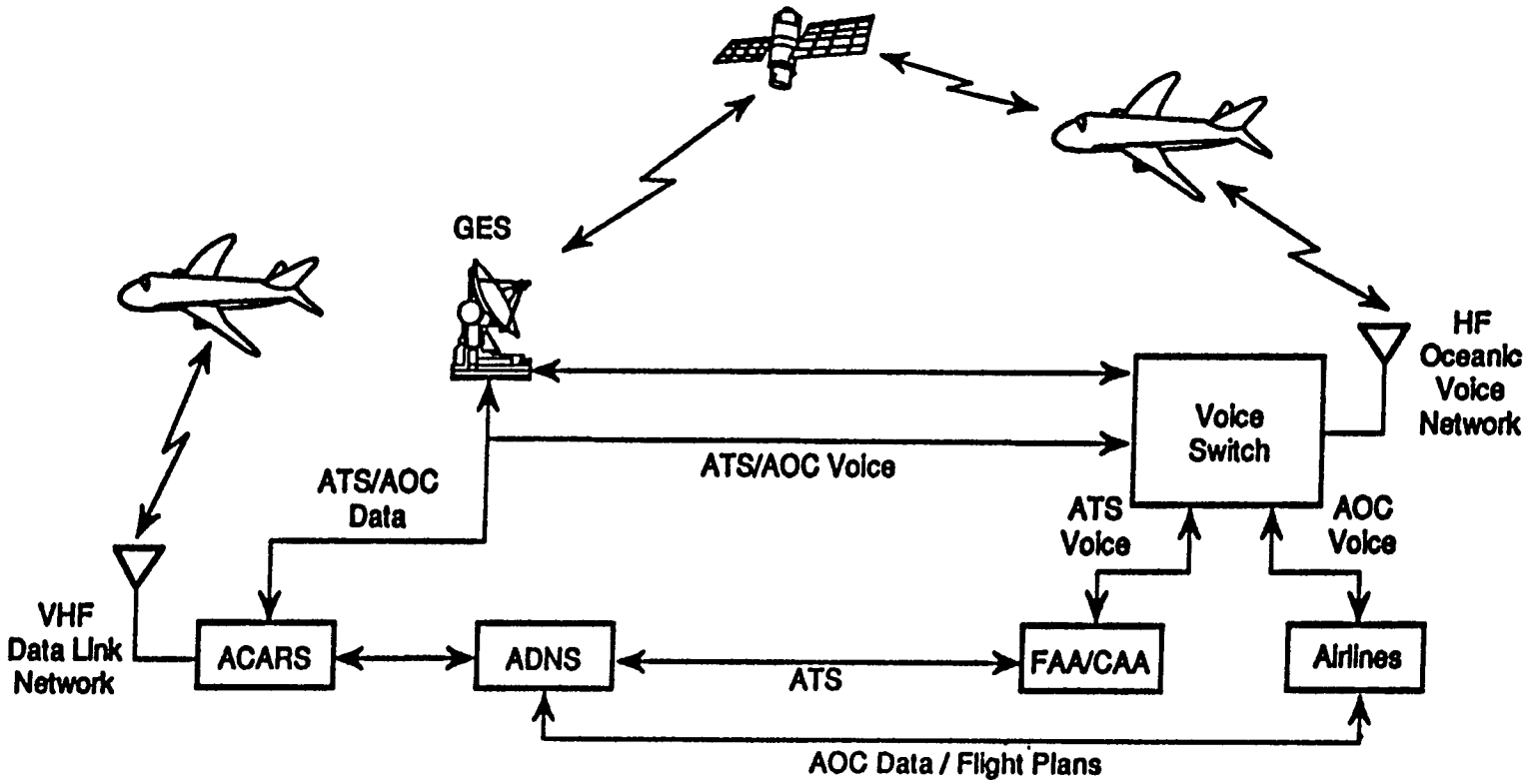
1. FANS (II)/2-WP/94 15/5/91 Special Committee for the Monitoring and Coordination of Development and Transition Planning for the Future Air Navigation System (FANS Phase II) Second Meeting, Montreal 29 April to 17 May 1991 - Report on Agenda Item 5 - Development of a Global Transition Plan. Page 5A-10

2. Ibid p. 5A-22

			Blocks		Messages				HF Voice
Month	Year	Flights	D/L	U/L	D/L	U/L	POS	ADS	Reports
SEP	90	14	1273	1375	865	306	5	504	0
OCT	90	2	0	6	0	3	0	0	0
NOV	90	51	1380	1881	908	869	65	120	0
DEC	90	57	1712	1872	1063	524	68	330	12
JAN	91	61	1435	1512	826	337	42	288	23
FEB	91	41	146	215	73	91	8	0	141
TOTALS		226	5946	6861	3735	2130	188	1242	176

Table 1 Pacific Engineering Trials Traffic Statistics

ATC AND AOC INTERACTIONS AT ARINC COMMUNICATION CENTERS



Legend:
ATS - Air Traffic Services
AOC - Airline Operational Control
GES - Ground Earth Station

Figure 1

File: FAA\NETWORKS\06-15-01\W

OCEANIC ATC AUTOMATION CONCEPT

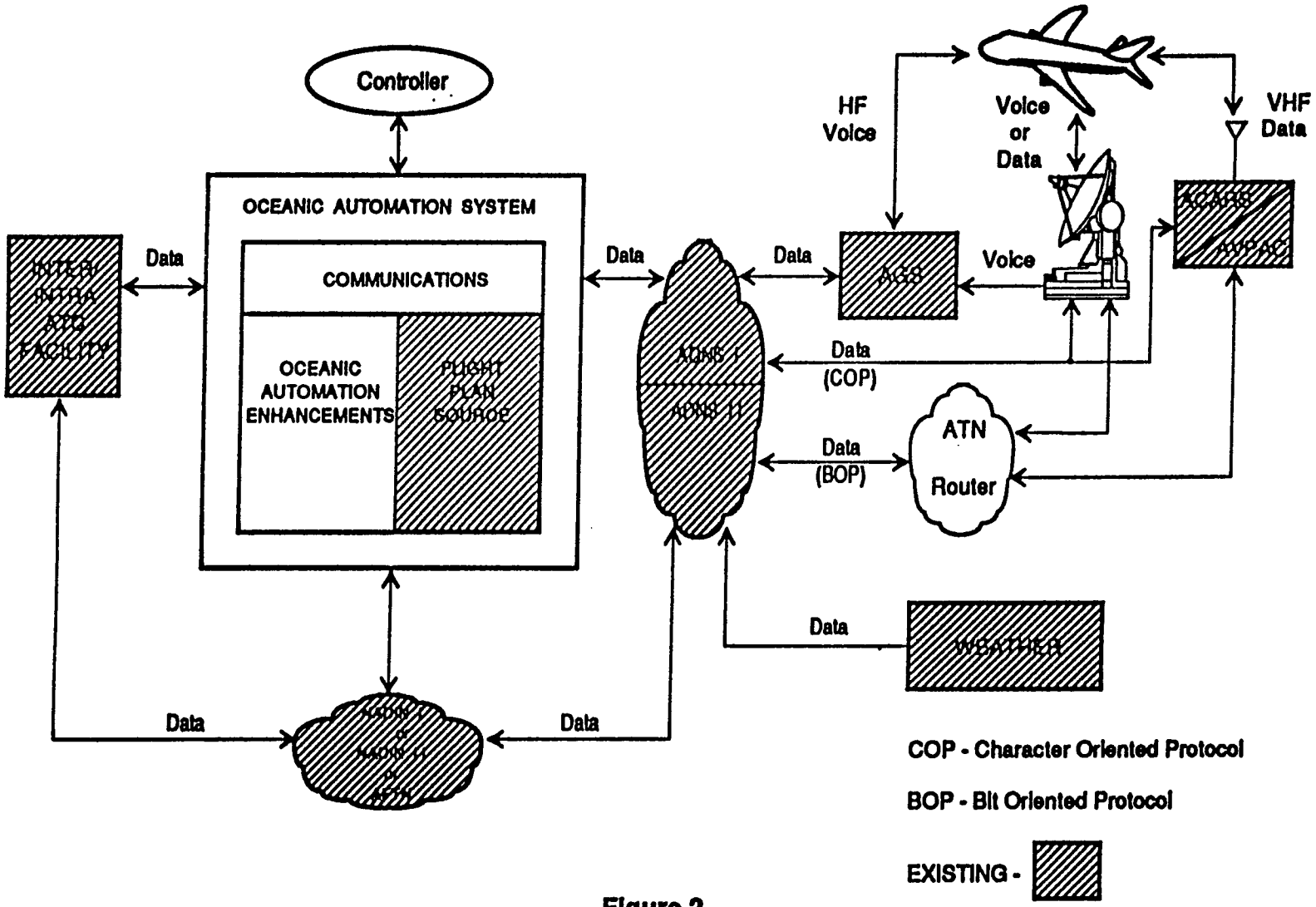


Figure 2

File: EOS / EOSCIR 7-16-91-T

OCEANIC ATC AUTOMATION
OCEANIC SYSTEMS DEVELOPMENT TEST BED

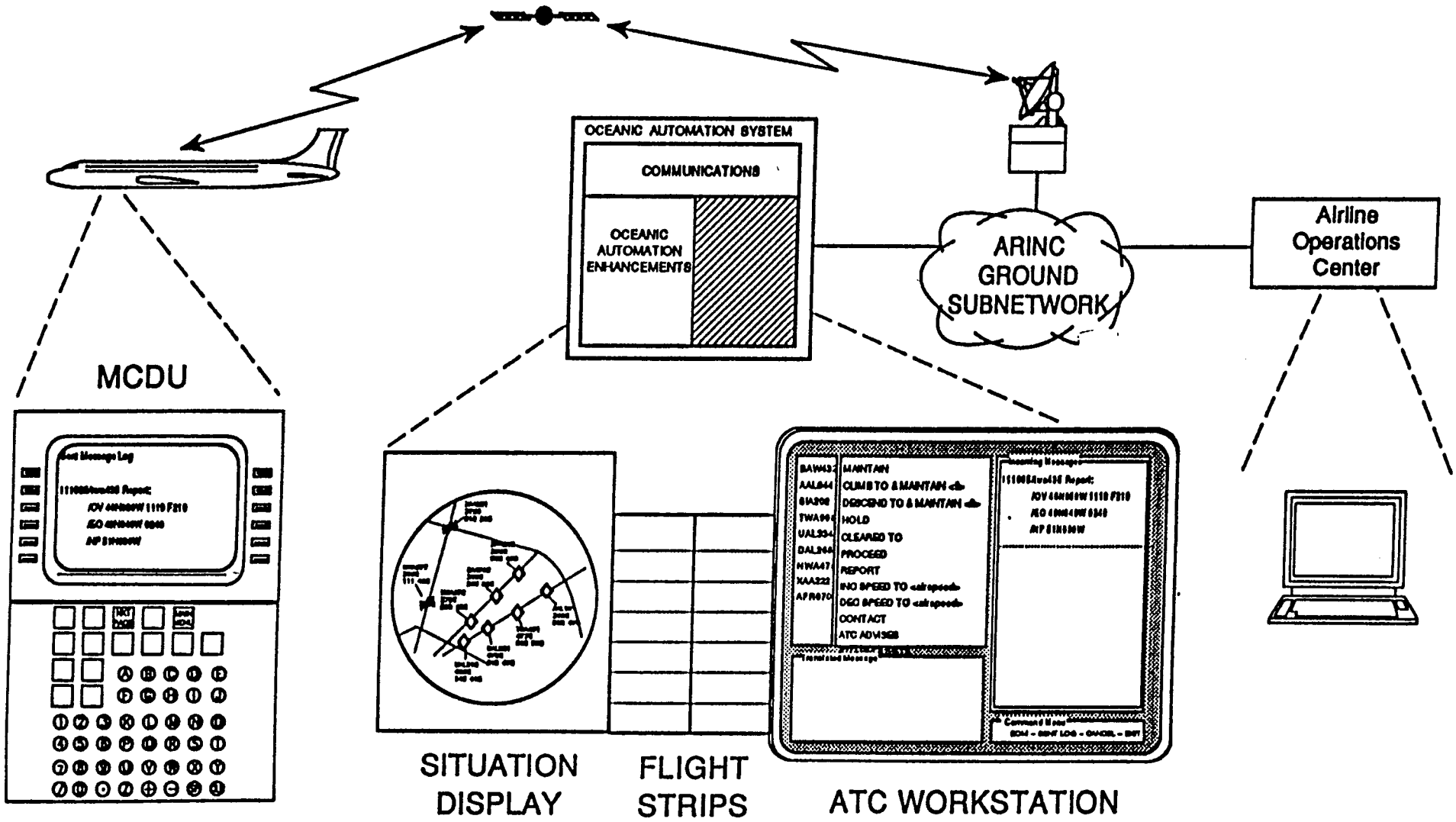
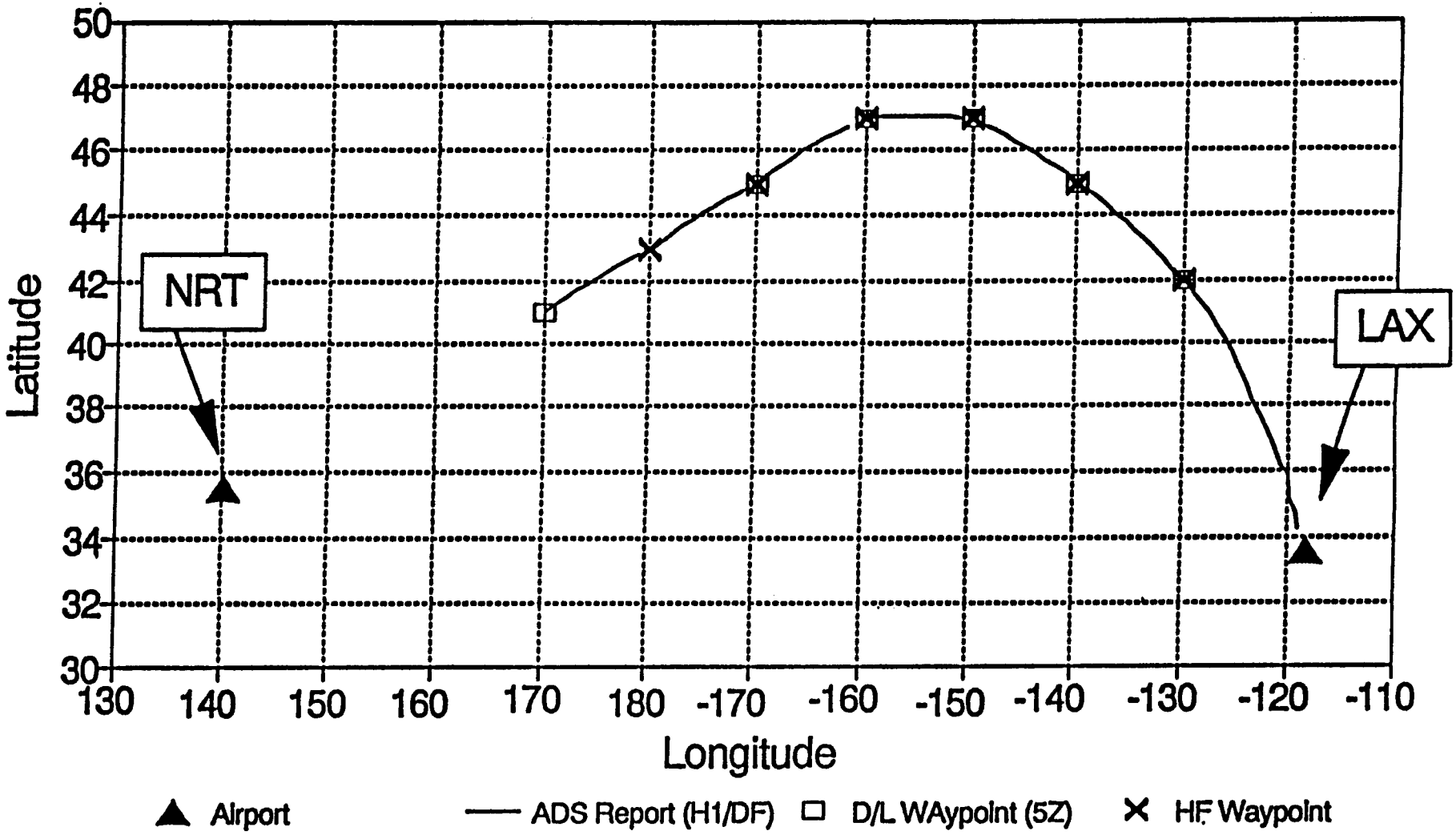


Figure 3

UAL 90 NRT to LAX

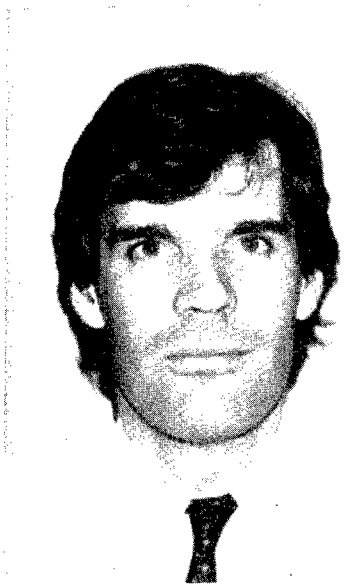
12/22/90



Source: UnitedD1.TXT

Figure 4

SESSION THREE: LINK ENVIRONMENT/AVIONICS INTEGRATION



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Graham C. Lake is Deputy Director, International Relations responsible for directing all SITA relations with Civil Aviation Administration world-wide. He is responsible for SITA development and implementation of the Air Traffic Control data link trial programs in which SITA is involved.

Mr. Lake is a British national and graduated from the U.K. College of Air Traffic Control in 1976. He worked as an operational Air Traffic Controller in the British Isles until 1986 when he moved into ATC management and administration.

Mr. Lake joined SITA at the beginning of 1988 and is based at their Northern Europe regional office in London.

SITA SATELLITE AIRCOM IMPLEMENTATION

Graham Lake

Dep. Director International Relations, SITA
London
England

SYNOPSIS

This paper introduces SITA as a global aeronautical communications service provider. SITA operates the world's largest private telecommunications network, serving over 400 airlines in 190 countries.

SITA provides VHF datalink services in some 45 countries and a world-wide voice and data Aeronautical Mobile Satellite Service.

The status and evolution of SITA AMSS is discussed, together with a review of Air Traffic Control use of SITA datalink facilities.

INTRODUCTION

SITA is a highly specialised organisation that provides telecommunications and data processing services for the air transport industry world-wide.

SITA is a not-for-profit cooperative and is owned by over 400 airlines. SITA operates in 190 countries and territories and carries around 100 million messages across the network each day.

The main component of SITA network services is the DATA TRANSPORT NETWORK (DTN), which is a meshed system of 34 nodes. Host systems interface directly into the DTN.

A new network architecture is currently in implementation to meet the needs of the air transport industry into the 1990's and beyond. A major component of this new architecture is the Mega Transport Network (MTN).

The MTN is an X25 based network supporting 1.5 M bps (T1) and 2 M bps trunk speeds with X25 and SNA protocols.

SITA is currently migrating the backbone network from the DTN to the MTN. About 30% of DTN traffic will be transferred to the MTN this year. The remainder of the migration will take place progressively over the next 3 years.

The MTN will enable SITA to support the networking requirements for the Aeronautical Telecommunications Network (ATN).

AIR/GROUND SERVICE EVOLUTION

In 1984 SITA introduced the VHF AIRCOM digital datalink service in Australia, using the ACARS protocol and compatible with the ARINC service in the United States. VHF AIRCOM is now available in some 45 countries around the world including both China and the Soviet Union as well as at strategic locations around the Pacific and Atlantic oceans.

The limitations of VHF datalink for airline communications were identified at an early stage and SITA began planning for the implementation of AMSS.

The Committee for Aeronautical Mobile Satellite Service (CAMSS) was formed to enable airlines to participate in the development of a satellite service requirement and implementation. Over 30 airlines regularly participate in CAMSS meetings.

The Prodat experiments, which have been the subject of another paper given earlier at this symposium, were one of the first practical results of the work of the CAMSS.

Prodat proved the viability of the satellite based datalink concept and provided an excellent foundation from which SITA was able to launch the SATELLITE AIRCOM service.

SATELLITE AIRCOM

In 1989 SITA signed a quadripartite agreement with FRANCE TELECOM, OTC AUSTRALIA and TELEGLOBE CANADA. Each of these Inmarsat signatories operate aeronautical ground earth stations (GES) and have enabled SITA to develop a consistent plan for service introduction meeting the various levels defined by INMARSAT on a fully redundant world-wide and seamless basis.

Figure I illustrates the standard INMARSAT coverage chart with the SATELLITE AIRCOM GES.

SITA SATELLITE AIRCOM IMPLEMENTATION

1) Data communications

Data communications are available to all aircraft equipped with either low gain (O dB) or high gain (12 dB) satellite communications antennae.

Aircraft equipped with low gain antennas are capable of low speed data communications. Aircraft equipped with high gain antennas are capable of low and high speed data communications.

Data communications are fully compatible with the SITA VHF AIRCOM Service, so as to maintain the same interface with airline ground systems.

2) Communications

Voice communications for cockpit crew and cabin crew are available to aircraft equipped with a high gain antenna. Both air-initiated calls and ground initiated calls are possible.

Terrestrial extensions between the ground earth stations and ground airline personnel are by means of the public switched telephone network (PSTN) or be means of dedicated leased voice-grade lines.

TECHNICAL DESCRIPTION

1) System Architecture

System architecture conforms to the Industry Standards such as AEEC 741 characteristic.

2) Space Segment and Earth Stations

The Inmarsat space segment is used. This choice may be reviewed periodically.

The initial implementation of six earth stations and their relationship to the current Inmarsat space segment is described as follows:

Operator	Location	Coverage Region
France Telecom	Aussaguel*	Atlantic (East) & Indian
OTC Australia	Perth*	Indian & Pacific
Teleglobe Canada	Weir	Atlantic (West)
IDB Aeronautical	Niles Canyon**	Pacific

* two stations

** IDB Aeronautical Communications, Inc, a Joint Venture between Teleglobe International (US) Inc and IDB Communications Group.

To ensure a coherent, world-wide Service with highest availability, the various ground earth stations are operated in a coordinated fashion: in geographical areas where satellite communications can be established with two or more ground earth stations, these stations provide mutual back up and the possibility for load sharing.

3) Associated Ground Functions

A supervision centre maintains a centralised data base of all user aircraft registered for service, monitor the status of the system components of on-going connections between aircraft and ground earth stations.

CONTRACTED USERS

To date ten airlines have taken the major step of committing to satellite communications and have contracted for SATELLITE AIRCOM service.

These airlines are: AUSTRIAN AIRLINES, CATHAY PACIFIC, CHINA AIRLINES, FINNAIR, LAUDA AIR, QANTAS, SWISSAIR, AIR NEW ZEALAND, JAPAN AIRLINES AND UTA.

SERVICE STATUS

SATELLITE AIRCOM is available world-wide for data ('Data 1'), and has already been introduced in commercial service for voice communications.

On the data side, SATELLITE AIRCOM remains the only Service available with Data 1 world-wide, including coverage of the Indian Ocean Region (IOR). Data 2 will

	AUSSAGEL		PERTH	WEIR	NILES C.		WORLDWIDE	
	IOR	AOR-E	IOR/POR	ADR-W	POR	SGL	RDD	4-0
	F.T.		OTC	TLG	IDB			
D1	NP	NP	AVBL	AVBL	NP	AVBL	NP	NP
D2	2Q92	4Q91	1Q92	4Q91	4Q91	4Q91	2Q92	2Q92
D3	3Q92	3Q92	2Q92	2Q92	3Q92	2Q92	3Q92	3Q92
V1	2Q92	AVBL	AVBL	AVBL	3Q91	AVBL	2Q92	2Q92
V2	2Q92	4Q91	1Q92	4Q91	4Q91	4Q91	2Q92	2Q92'

KEY : D1 - DATA 1
NP - NOT PLANNED
SGL - SINGLE GES/OCEAN REGION
RDD - MORE THAN 1 GES/OCEAN REGION (REDUNDANT)

Figure II SATELLITE AIRCOM IMPLEMENTATION STATUS

be introduced, again world-wide, during the 4th Quarter of this year. Five B757-400's of QANTAS (Collins SAT 900 and ACARS avionics) and three B747-400's of CATHAY PACIFIC (Collins SAT 900 with Bendix ACARS) now use the Service in daily flight operations. Several other B747-400's of both QANTAS and CATHAY PACIFIC will be introduced into service before end 91. Japan Airlines is also using the service.

By end 91 around 12 aircraft, operated by five airlines ,will be using SATELLITE AIRCOM in commercial service.

The first Data 2 use is expected early in 1992. Voice service is currently used by several corporate aircraft.

See figure II above.

AVIONICS PROCUREMENT

One of the prime issues delaying the implementation of AMSS by airlines has been the non-availability of suitable avionics. As a consequence, on the 3rd June 1991 CHINA AIRLINES, FINNAIR, SWISSAIR and SITA jointly issued a request for proposal (RFP) for satellite communications avionics to potential providers. This RFP calls for the provision of several LRU's: HPA, RFU, SDU and STIU, to progressively equip the long/medium haul fleets of the above customers of SATELLITE AIRCOM Service

The RFP has enabled the parties to define an advanced multi channel system intended to optimise and expedite AMSS implementation.

With respect to the MD11 aircraft, McDonnel Douglas has also formerly joined the activity, further expanding the benefits of the endeavour. A number of other airlines have also expressed their wish to participate.Several manufacturers have now submitted detailed proposals.

A number of benefits are also expected by the participating airlines:

- cost saving to procure said avionics through a scale effect
- sharing of aircraft engineering and retrofit tasks among the airlines
- minimum certification costs and minimum tasks to obtain the required authorisation from Inmarsat.
- increased support from the concerned aircraft manufacturers.

ARINC/SITA JOINT VENTURE

SITA, together with its American counterpart organisation ARINC, have established a joint venture

company to provide Aeronautical Mobile Satellite Services for Air Traffic Services (ATS) communications.

The Joint Venture provides a uniform, standard, single supplier access between aircraft and Civil Aviation Administrations. The Joint Venture also ensures consistent uninterrupted delivery of ATS messages irrespective of location, equipment and regardless of the AMSS provider used by the aircraft operator.

Further ARINC and SITA have charged the Joint Venture with the task of building an AMSS qualification facility, said AVIONICS TEST BED. This facility will avoid redundant effort and capital expenditure that would otherwise be associated with aircraft equipment certification. It is expected that this facility will be used by airlines, airframe manufacturers, avionics suppliers, space segment providers and air traffic service providers.

Air Traffic Control interest in datalink communications continues to grow. The activities of various ICAO groups and the North Atlantic Systems Planning Group (NATSPG), have included discussion of VHF and satellite datalink applications in ATC.

SITA is co-operating with a number of administrations around the world by supporting various air/ground datalink trials. Given that some 3000 air transport aircraft are equipped with VHF datalink compared with only a handful of satellite equipped aircraft, it is not surprising to note that most of the trials activity has centred on the use of VHF datalink.

OCEANIC CLEARANCE DELIVERY

Authority for an aircraft to cross oceanic airspace - Oceanic Clearance Delivery by VHF Datalink was first implemented by Transport Canada in Gander Airspace, in cooperation with Air Canada as a user airline and datalink service provided. SITA became involved with the introduction of trials in Shanwick airspace, in cooperation with the U.K CAA.

The Portuguese and Icelandic CAA are also developing trial programs. The Icelandic trials began in July 1991, commencing with uplink of oceanic clearance to aircraft entering oceanic airspace at or above 61 degrees north. The Portuguese trials will involve aircraft entering Santa Maria oceanic airspace.

AIR TRAFFIC CONTROL ACTIVITIES

VHF

ATLANTIC OCEAN
Oceanic Clearance Delivery

Shanwick	:	
Santa Maria	:	
Iceland	:	
Gander	:	available in cooperation with Air Canada

PRE-DEPARTURE CLEARANCE(PDC)

France
Germany
United Kingdom
Portugal
Iceland

DIRECT CONTROLLER PILOT COMMUNICATION(DCPC)

Iceland
Germany
France
Australia
Norway

ATIS

SATELLITE

South Pacific ADS and DCPC

French CAA Program

NORTH ATLANTIC ADS PROGRAM

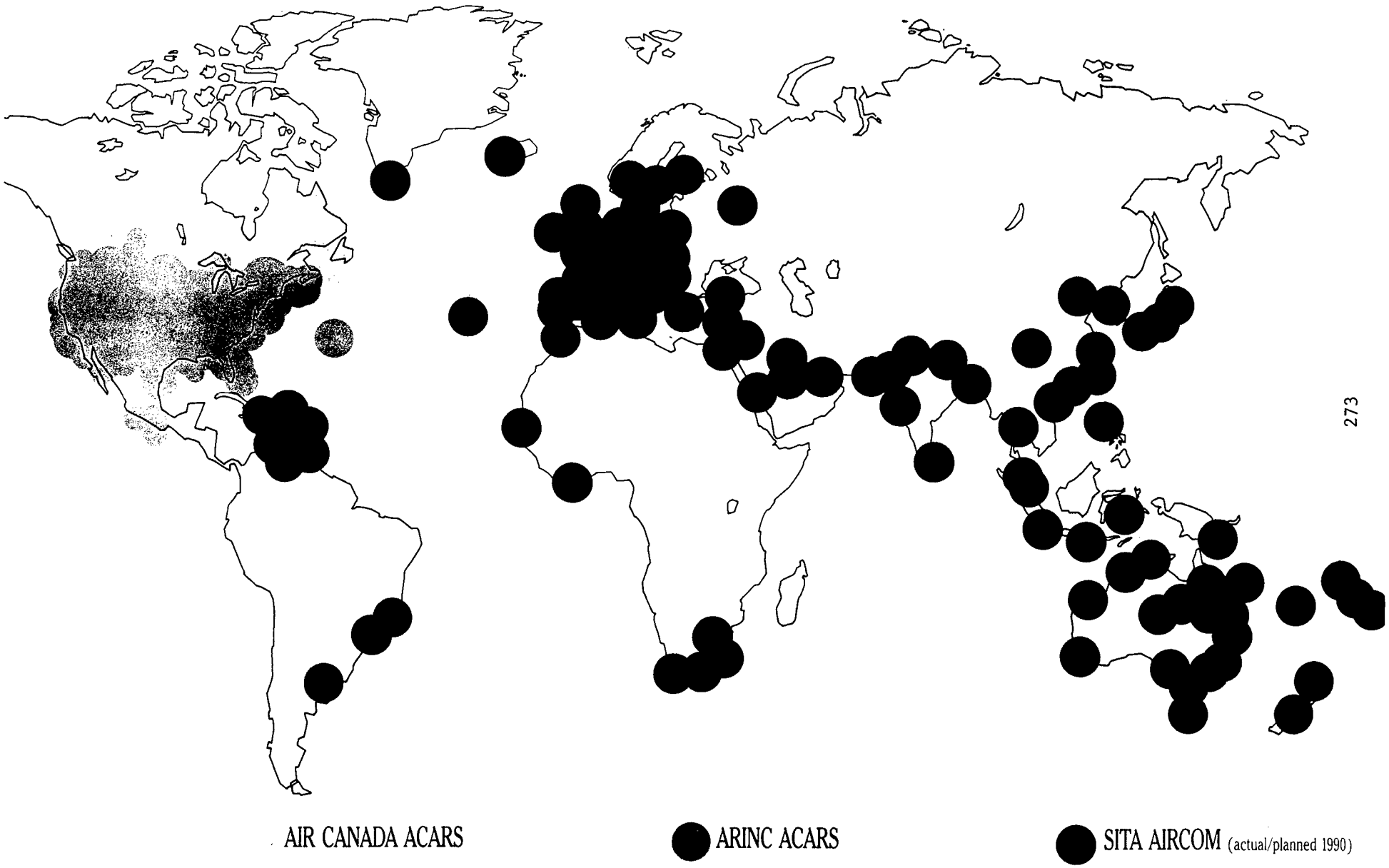
In cooperation with the North Atlantic systems planning Group

Pacific Engineering Trials (PET) ADS Program

SITA is keen to facilitate these trials in order to expedite ATC implementation of AMSS to obtain improvements in efficiency and capacity.

Participation will be free of charge to SITA customer airlines. Any space segment costs will be recovered from the CAA by the XA/XS Joint Venture.

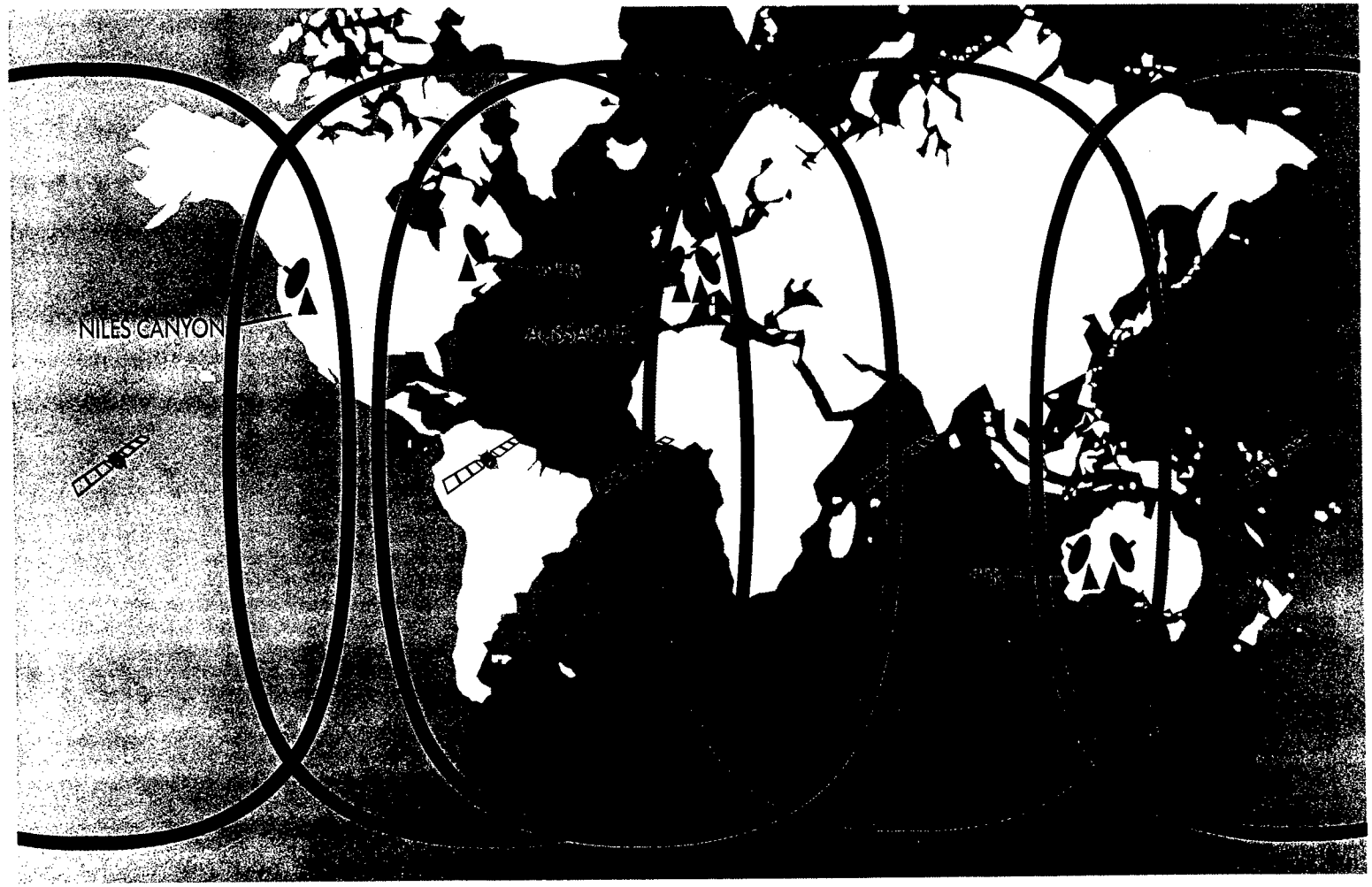
DATA-LINK COVERAGE



SATELLITE AIRCOM

Approximate geographical coverage

(5° minimum elevation)



SITA

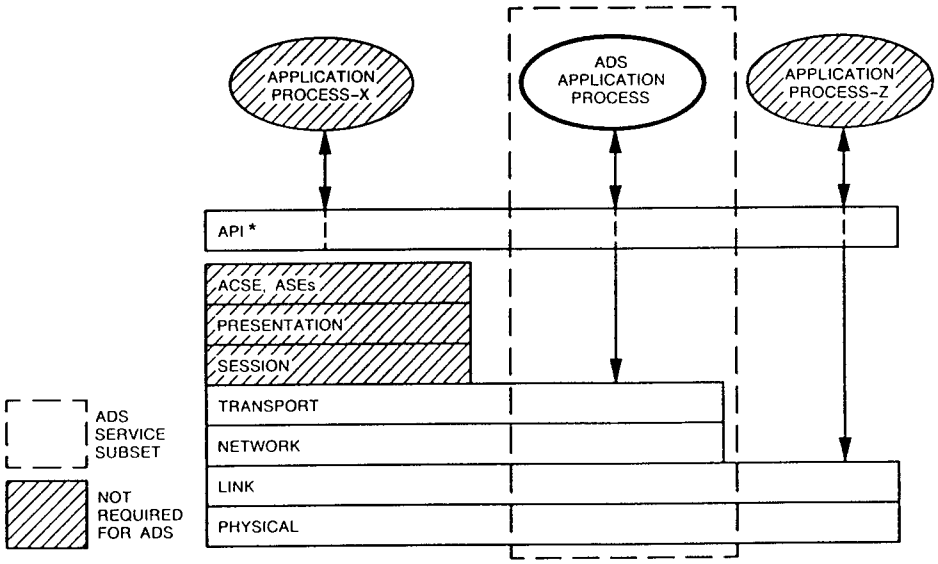
ACMS. Test programs have been developed (such as the Pacific Engineering Trials, PET) with existing ACARS-based satellite air/ground subnetworks, and are being used to gain valuable on-line experience with automatic position reporting. Also, there are some provisions for pilot-controller two-way data link in this test environment, but this capability is still very limited, due in part to the character-oriented nature of existing systems.

A problem with the current ACARS automatic position reporting system is that it is based on proprietary protocols, which do not allow adequate international growth. What is needed is a standard international suite of protocols for an interoperable, data transparent system... which brings us to ADS and the ATN.

BIT-ORIENTED ADS MESSAGES USING ATN (OSI) COMMUNICATIONS PROTOCOLS

Since the future ADS system will be used globally, the supporting communications system must provide a compatible communications network which provides universal aeronautical interoperability, as well as the capability to handle the new bit-oriented ADS messages. The communications network should not be constrained by ACARS character-based message, block size, or protocol encoding limitations, but should allow for total byte and code independence. The advent of other subnetworks (Mode S, AVPAC VHF, etc.) has further prompted the need to standardize data link, allowing all systems in the aeronautical environment to communicate interoperably. A suite of bit-oriented Open Systems Interconnect (OSI) communications protocols, selected for reasonable adaptation to the aeronautical environment, can provide this capability.

For ADS messages in particular, the industry is recognizing the need to use only those OSI communications protocols which are required for the application, eliminating unnecessary protocol complexity wherever possible. The OSI services up through the transport layer (layer four) are the only services needed to satisfy the requirements of the ADS application process (i.e., the session, presentation, and application layers, are not needed for ADS). This protocol specification for ADS is in accordance with industry development for AEEC ADS Characteristic 745, RTCA SC-170 ADS MOPS development, and the AEEC upper layer architectural model. This upper layer model allows the flexibility of direct access (through an Application Program Interface, API) to the appropriate protocol subset of the OSI architecture for those applications which do not require the services of all seven layers, such as ADS (see Figure 1).



* THE APPLICATION PROCESS INTERFACE (API) SELECTS THE APPROPRIATE SERVICE SET FOR A PARTICULAR APPLICATION TRANSACTION BASED ON SERVICE REQUIREMENTS PRESENTED BY THE APPLICATION PROCESS.

Figure 1 — OSI Architecture for ADS Application

The ADS message set is bit-oriented, as opposed to the character-oriented automatic position reporting used in test programs today. Bit-oriented composition allows an initial data compression of at least 8 to 1 over standard ASCII character-based messages. Therefore, the ADS message data (reports) are relatively short, generally on the order of 10 to 20 bytes.

Ground-based requests for ADS reports may be simple or complex, and operate in contract or polled/demand mode. For contract mode, the ground-based request specifies the time interval between reports to the aircraft ADS server. Polled/demand mode consists of a single request from the ground, followed by a single report response from the aircraft. Complex reports contain optional extended data. In the contract mode, ADS reports are nominally generated by the aircraft at 5-minute intervals, but can be varied to a period of 10 seconds to 42 minutes.

The basic ADS report contains general position information of latitude, longitude, altitude, time stamp, and figure of merit (an indicator of the aircraft's navigational capabilities). Additional ADS reporting capability includes: the vector information group, providing track (or true heading), ground speed (or calibrated air speed), and vertical rate; the meteorological group, providing wind speed, wind direction, and temperature; an emergency report (same information as basic ADS); the Flight ID group; the 24-bit aircraft ID group; and a predicted route group, providing latitude, longitude, and altitude for the next and next + 1 waypoints of the active flight plan. We will see shortly that the FMC provides the majority of this information.

THE FLIGHT MANAGEMENT COMPUTER – AN OVERVIEW

The function of the FMC (in conjunction with other interfacing equipment) is to form an integrated control and information system which provides automatic navigation, guidance, map display, and inflight performance optimization. The FMC reduces cockpit workload by eliminating many routine tasks and computations normally performed by the flight crew. The additional capability of data link to the FMC further reduces workload, expedites aircraft ground turnarounds and communications, and eliminates potential human data entry errors. One of the more tedious, and potentially error-prone entries, is the position report entry, especially for lat-lon waypoints. ADS eliminates this human link in the transfer of this data.

ADS INTEGRATION INTO THE FMC

For the package B 747-400 FMC data link program, the FMC will function as an OSI End System (ES) and provide the ADS function (in addition to airline AOC messaging) as a participant of United Airline's Team Dutch in the ATN Project. Some FMC programs have already begun the transition to OSI through the implementation of the OSI-compatible Williamsburg link layer protocol for the avionics ACARS MU/FMC interface (e.g., 757/767 PIP data link). This initial link layer implementation is being expanded to include the OSI network and transport layers required for the ADS service subset, as illustrated in Figure 1.

Formatting of the data into bit-oriented messages allows the FMC to send binary data in a computer-resident format, instead of undergoing a translation to ASCII character representations, as is required for character-oriented data link. One of the reasons the FMC provides an optimum host environment for Step One of the ADS Air Traffic Services implementation is the availability of data as part of routine flight management operation. In particular, data for the ADS predicted route group which requires next and next + 1 waypoint position information are routinely calculated dynamically along the flight path in conjunction with performance and route progress updates.

Of special interest within an FMC-hosted ADS function is the latest ADS "aircraft intent" report recently proposed by United Airlines. This new message could be used by ATC to improve the accuracy of ADS to provide conflict detection and correction for changes in high altitude flight paths outside of radar coverage. The format of the new intent message is currently being investigated as an alternative to the ADS predicted route group. The message provides present aircraft position plus short-term (20 minutes or less) intermediate "intent" projections of aircraft range, bearing, altitude, and projected time, allowing ATC to more accurately provide conflict resolution.

FUTURE ATM INTEGRATION INTO THE FMC

Step Two of the Air Traffic Services program, the capability for two-way ATC data link, is the first step in the Air Traffic Management system. As initial host of the ADS function, the FMC realizes even greater potential in the expanding ATM arena where air traffic controllers can begin to make use of advanced flight management functions by integrating these operations with ATM automation via data link. One of these potential advantages is the automatic uplink of flight plan clearances directly from ATC to the FMC. Thus, full route or amended clearances can easily be integrated into the active flight plan, after pilot acceptance. Other relevant ATC tasks can include time navigation and optimal 4D descent path calculations, FMC approach transitions, FMC computed approaches, and self-spacing clearances. The overall transition philosophy is expected to be directed toward ATC-monitored systems, instead of ATC-controlled systems, which should better accommodate airline user-preferred flight paths.

CONCLUSIONS

The need for automatic and error-free position reports in non-radar environments has driven the development of ADS. An interim automatic position reporting system is currently being used to gather test data for evaluation. This system however, is not representative of the full ADS system and is limited to ACARS character-oriented protocols and messages.

The fully operational ADS system will employ bit-oriented messages and OSI protocols, as part of the ATN environment, and therefore will provide end-to-end interoperability over various subnetworks from different aircraft to Air Traffic Control.

The Flight Management Computer, as the primary management system for generating and calculating flight data, provides an optimum host environment for current ADS applications, as well as providing for the future needs of Air Traffic Management.

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SESSION THREE: LINK ENVIRONMENT/AVIONICS INTEGRATION

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Stephen P. Van Trees is employed by Stanford Telecommunications (STEL) on the SEIC contract at FAA Headquarters, Washington, D.C. He provides ATN systems engineering and ISO data communications protocol expertise. His recent work has been in the requirements analysis for upper-layer protocols over the ATN. He has represented the FAA at AEEC Datalink, 637, 638, 745; RTCA SC-162, SC-170; and SICASP TULIP committees.

He has over 13 years of industry experience in data communications including participation in US Navy, US Air Force, and federal government network implementation.

He holds master's degrees in Computer Science (George Mason University, 1990) and Slavic Languages and Literatures (U.C. Berkeley, 1978). He is pursuing his Ph.D at George Mason. His research interest is in parallel-processor protocol verification.

Use of ISO protocols in the ADS Environment

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The work described in this paper is being performed under the aegis of the Federal Aviation Administration, FAA/ASE-111 for Radio Technical Commission for Aeronautics (RTCA) SC-170 [1] and Airlines Electronic Engineering Committee (AEEC) Project Paper 745 [2]. This work will also be forwarded to the International Civil Aviation Organization (ICAO) Automatic Dependent Surveillance Panel (ADSP). It should be noted that some work, especially the Application Layer definition is still under current study in committee.

Mr. Hal F. Ludwig is the responsible project officer. Any errors of interpretation are due solely to the author.

Introduction

As depicted in [3-4] the Automatic Dependent Surveillance (ADS) system has been developed to improve surveillance in the oceanic environment, thereby leading to improvement in Air Traffic Control (ATC). Improvements in communications, navigation, and surveillance (CNS) have the potential to result in lessening in separation requirements. This may allow airlines more fuel-efficient routes and more frequent flights.

ADS is the implementation of an onboard navigation system with an air-ground communications system to relay aircraft position data to a ground-based command and control system. The implementation of pilot-controller data link is also be supported by this system. The physical layer is a satellite communications channel. The actual end systems (ESs) are ADS Functions (ADSFs) on the ground and in the aircraft. The communications infrastructure is the topic of this paper.

Use of the ISO protocol suite

The use of the International Organization for Standardization (ISO) Open Systems Interconnection (OSI) model [5] is the guiding principle of the communications system design. The OSI model and the ISO protocols have been used since the ADS program is under the auspices of the ICAO and international communications interface and ATC handoff procedures must follow an internationally recognized standard. The ISO protocols provide interoperability and portability. These advantages of the ISO protocols are critical. The advantage of interoperability is important in today's environment where FAA equipment must communicate with vendor airborne equipment, as well as with other national civil aviation authorities (CAAs). Adherence to an international standard allows a well-understood interface. The advantage of portability allows for the potential usage of commercial off the shelf software (COTS) rather than a recoding of entire communications stacks. Each of the peer implementations can be run against the test suite allowing assurance

that the communications function will perform per the standard. The use of the ISO protocols obviates the need for custom in-house software, with its attendant protocol design, specification, verification, and implementation. For, in the words of two protocol verification authorities [6], "We have been amazed at the errors we have made in informal arguments. Programs that seemed so obviously correct at one time are, in retrospect, so obviously wrong". The ISO protocols have been developed with formal specification and verification as a goal, so there is a greater probability that what was meant was what was specified, and what was specified was what was implemented. Standardized test suites may allow certification of what was implemented.

Concept of Operations

The description of the concept of operations of the system is derived from [3-4] and [7], the Data Link Architecture Study. In [7], the ground system is the data link processor (DLP). The DLP in each area control facility (ACF) provides the means for accessing air/ground data link communications. The routing for data-linked ADS, ATC and weather messages is through the DLP router for dissemination to the aircraft or ACF weather application processes (APs).

The aircraft, in this concept of operations, is generally in the oceanic flight information region (FIR). This is a fundamental element of the architecture. There are then derived requirements for supporting logical connections past an air route traffic control center (ARTCC) boundary. Operation takes place in an environment with longer delays and different media than in the domestic ATC environment. This imposes requirements for end-to-end accountability (positive acknowledgement) and reliability that are met by the use of the ISO transport protocol. The interoperability requirement that is entailed by the aircraft's transitioning FIRs is met with the ISO internetworking protocol and the interdomain routing protocol (IDRP). The process of aircraft annunciation to the ATC system, logon, contract negotiation, and ground-controlled handoff as the aircraft transitions FIRs is a requirement that is met by the application-layer processes and ADS application process as well as by ground-based procedures. Connection management is an area of intensive recent study. It will be presented below in the discussion of the application layer.

The remainder of the paper discusses the specific ISO protocols used to support ADS. Topics of interest covered during the protocol discussions include aircraft initiation into the ADS system, network routing, end-to-end acknowledgement strategies, and application layer requirements.

The OSI model for ADS

The OSI model [5] is used to characterize the subsystems and protocols required for the ADSF implementation. The ADSF functions as an OSI end system with a complete seven-layer stack (with null presentation and session layers). The layers and the specific protocols implemented at each layer are defined below. An overview of the ADS protocol architecture is shown in Figure 1. An overview of the ADS system is presented in Figure 2.
We give a one-sentence characterization of each layer, then discuss relevant ISO protocols at that layer.

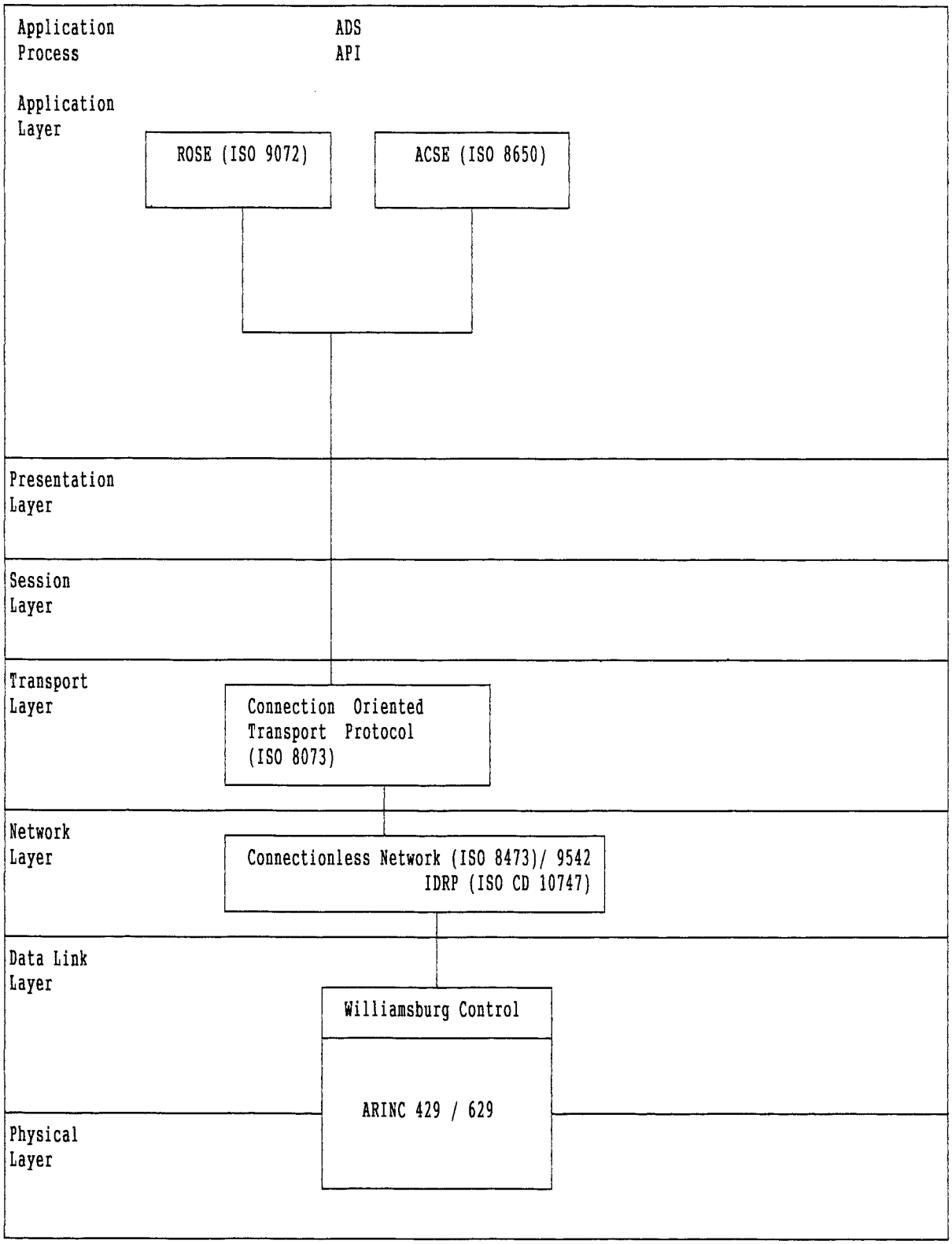

Figure 1 ADS ISO Protocol Architecture

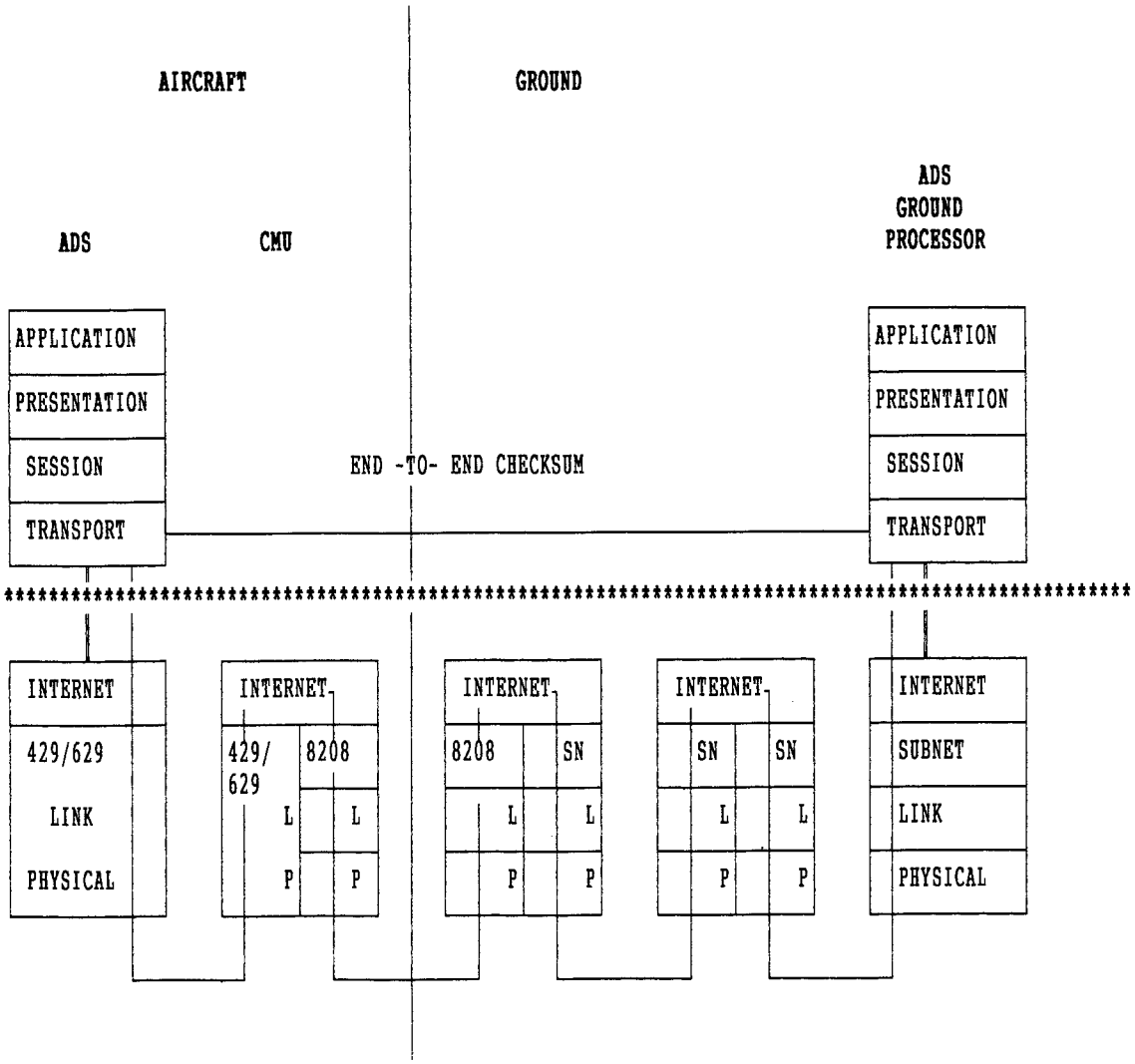

Figure 2 End to End Protocol Architecture

Physical Layer

The physical layer is devoted to the transmission of electrical signals to the end system. All electrical interface requirements are as specified in [8]. As pointed out in [3] the satellite forward channel (in the ground-satellite-aircraft direction) employs the P-channel, a continuous mode, time division multiple access (TDMA) channel. The P-channel transmits prioritized messages on assigned time slots. The cost of the P-channel is expensive when a routine acknowledgement procedure for every ADS report is used. Thus, every effort has been made to minimize the use of forward channel traffic, such that only the minimum number of acknowledgements (at every protocol layer) is generated.

Data Link Layer

The data link layer is responsible for the framing and error detection of the bits transmitted to the end system. The data link layer provides data reliability, a virtual channel interface, and data flow control as specified in [8]. As seen in figure 2, the link layer in the ES employs the Williamsburg 429 protocol.

Network Layer

The network layer provides sequence checking, error checking, and routing of packets. The ADSF operates in an internetwork environment, per figure 2. The ADSF conforms to the standards of ISO 8348 [9] (Connectionless Network Service Definition) and supports ISO 8473 [10] (Connectionless Network Protocol). As an End System, ADSF also supports ISO 9542 [11] (End System to Intermediate System Routing) between the ADSF and the ATN router. ISO CD 10747 [12] (Interdomain Routing Protocol (IDRP)) is also supported.

The question of communication initiation has been a complex issue. Recent discussions [13] have begun to achieve consensus. For Mode S, the subnetwork event function must be ground-initiated. In the case of interest to us, the satellite initiation, the subnetwork event function is aircraft-initiated, though it may be a ground-initiated operation for redundancy and reliability, particularly in areas of continuous coverage. Thus, at the initiation of ADSF air/ground communication, the aircraft will initiate the process. This may be logon through predeparture clearance, 'pop-up' discovery to ATC, or reinitiation of communications after an outage.

The aeronautical telecommunications network (ATN) is the basis for next-generation ATC communications support. The ATN is the largest OSI implementation to date -- and its end systems move! The critical issue of the network layer is that of mobile network service access points (NSAPs); how is routing information conveyed? Per [13], the subnetwork event function leads to the establishment of a subnetwork connection between peer routers. Next, network entity titles (NETs) are exchanged between peer routers via the ISO 9542 ES-IS [11] intermediate system hello (ISH) protocol data unit (PDU). Finally, NSAP address prefixes and associated path and route information between peer routers via ISO CD 10747 [12] IDRP Boundary Intermediate System (BIS) BIS-BIS Open PDU and subsequent Update PDUs. The IDRP, as is evident from its designation is still in development as an ISO standard. It was chosen as the routing protocol because it allows a model wherein each aircraft is its own routing domain (RD), it allows policy routing to be enforced, and it allows efficient update of routing tables as topology changes in the aeronautical

mobile environment. Policy in the oceanic environment is currently simple - cost is the only criterion; if very high frequency (VHF) radio is available, that is used, otherwise satellite is used.

After initial aircraft logon, the ATC system is responsible for transitioning the ATC system from one ATC authority to another.

Transport Layer

The transport layer provides end-to-end data sequencing and end-to-end error detection.

The provision of a end-to-end connection assumes greater importance in an aeronautical mobile environment. As the aircraft transitions from one FIR to another, the ATC connection is established to the new ATC authority. However, the transport connection which supports the ADS association must persist across FIR boundaries.

The first question, then, is the choice of a connection-oriented transport protocol (ISO 8073 [13-16]) or a connectionless transport protocol (ISO 8602 [17]). For the reasons cited above, especially the desire to have a positive connection status and the requirement for transport-layer acknowledgement, the decision has been made to field the connection-oriented ISO 8073 [14] as the transport protocol for ADS. Overhead analyses also bear this out since the ADS transport connection is a long-duration connection that amortizes the cost of the connection setup. ISO 8073/AD 2 [15] requires that ISO 8073 Class 4 be used if ISO 8073 is implemented over a connectionless network.

Examples of specific engineering studies of the ADSF transport layer are presented below. As stated, the desire is to conserve bandwidth by limiting the number of acknowledgement (AK) transport PDUs (TPDUs). This is done in two ways: be exchange of peer acknowledgment timers and by dynamic request for acknowledgment update.

First, in acknowledgement timer exchange, the peer transport entities calculate the expected acknowledgement timers. If an implementation is operating any policy which delays the transmission of AK TPDUs, the maximum amount of time by which a single AK TPDU may be delayed shall be indicated to the peer Transport service provider using the acknowledgement time parameter. The value transmitted should be expressed in milliseconds and rounded up to the nearest whole millisecond.

The implementation will infer from the negotiated contract the expected ADS message rate. Low-update-rate traffic (defined as five minutes or greater between messages) will be acknowledged on a one-for-one basis. High-update-rate traffic (less than five minutes between messages) will rotate the credit window several units at a time.

The initial flow control credit window is negotiated to a value determined by the expected traffic. The flow control window is set to its maximum for frequent update traffic, and set to one for sporadic update traffic.

All timers used in data transfer must be coded to encompass expected air/ground delays. These delays are longer than those contemplated in ISO 8073.

Second, in the dynamic acknowledgement scenario, as depicted in figure 3, the transport

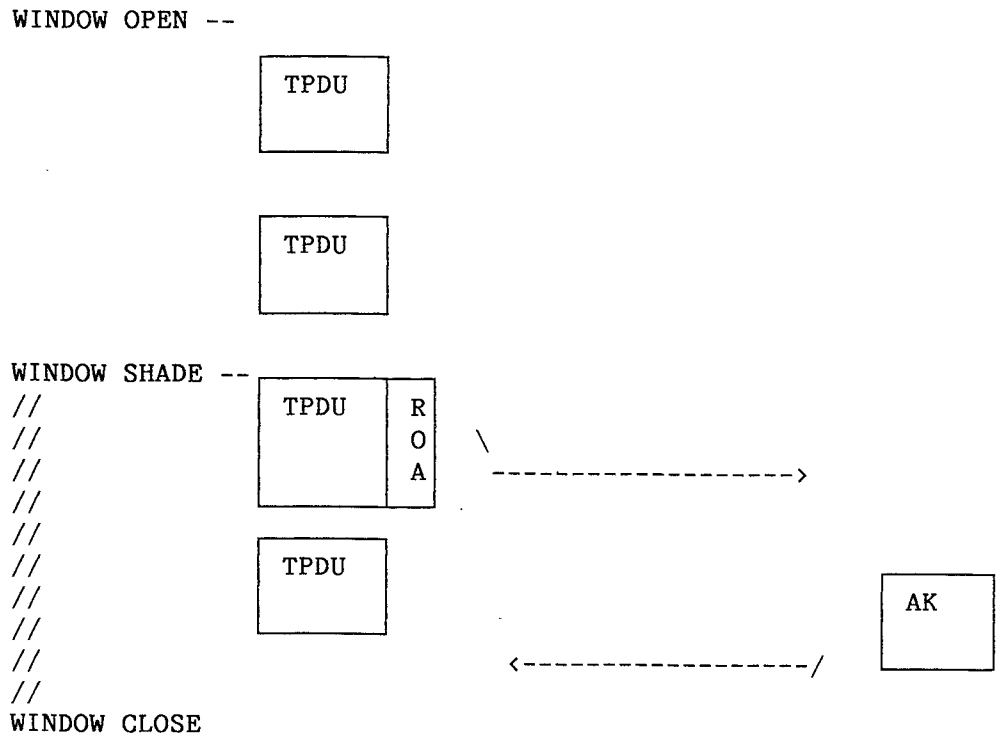

Figure 3 Use of Request Acknowledge in ADS

protocol calculates when an acknowledgement is required based on recent traffic pattern and the space remaining in the flow control window. This design is based on ISO 8073/PDAD 4 [16]. The goal is to minimize the number of AK TPDUs. This is achieved by the AK TPDU arriving just as the transmission window would have closed. The procedure inquires, on sending each DT TPDU, 'is the time left in the window less than or equal the round-trip delay (RTD)?' (i.e., (Local Idle Time) x (Window Size - Outstanding DT TPDUs) <= RTD). If so, we are in the 'closing' region of the window, and should set the ROA (Request of Acknowledgement) bit. If the ROA bit has been asserted within the closing region, then we do not send it again. If the DT TPDU with ROA is lost, recovery procedures are in place. If the ROA has been asserted for longer than twice the RTD, we assume it lost, and reassert ROA in DT TPDU. The request acknowledgement strategy works with both go-back-N acknowledgement and selective acknowledgement strategies.

Session Layer

The session layer handles session establishment, session management, and session termination between session entities. There are no requirements currently identified for the session layer. This layer is null in the current protocol architecture.

Presentation Layer

The presentation layer is responsible for the encoding of application protocol data units. This layer is null in the current protocol architecture.

Application Layer

The application layer provides the means for association control and the application to communicate using an application program interface (API) to other application service elements

(ASEs). This layer is null in the current protocol architecture, however, active consideration is being given to the application service control element (ACSE) [18] and the remote operations service element (ROSE) [19-20].

The use of ACSE has arisen from discussions of connection management as a sublayer above that specified by the transport service specification [21]. That is, there are aspects of connection management which exist above the transport layer such as when a connection is established, how connection errors are recovered, and when connections are torn down. This last must be provided by connection management, because the transport layer itself will endlessly exchange AK TPDUs as a keep alive measure. Connection management must decide when a connection is idle, i.e., it has been too long without supporting a contract. It is our preliminary conclusion that this requirement is fulfilled by use of ACSE.

The ISO reference model provides a compact method of managing application entity-application entity relationships. These relationships are referred to as associations. Thus, the association control service element (ACSE) manages associations between application service elements (ASEs)

The important feature of the ISO ACSE is its extensibility. In addition to application layer naming, other features are easily added within the ACSE syntax. These features include authentication, charging, and user security features. Only authentication is presently an ATN requirement.
It is also important to note that ACSE does not require an ASN.1 compiler.
The operation of the protocol is described in ISO 8650 [18]. The protocol is straightforward. It comprises two operational phases: association establishment and establishment release. Association establishment begins with an A-ASSOCIATE.REQUEST from the caller which is transmuted into an A-ASSOCIATE.INDICATION at the calling end. The called application entity (AE) then returns an A-ASSOCIATE.RESPONSE which appears as an A-ASSOCIATE.CONFIRMATION at the calling AE. This process allows the negotiation of supported application protocols (such as ROSE), it also allows exchange of protocol context initialization information.

Association release, the second phase of the protocol, is likewise straightforward. There are three possible terminations: A-RELEASE, A-ABORT, and A-P-ABORT. The A-RELEASE is the familiar orderly termination which ensures that all data in transit are successfully delivered. The A-ABORT allows a unilateral termination of the association. The A-P-ABORT allows the ACSE service provider to inform the communicating application entities that the service has been terminated.

Many of the more than 20 parameters in ACSE PDUs derive from presentation and session-layer context information. The use of ACSE over a short stack may obviate use of much of this information.
Processing and bandwidth overhead calculations are now under way. At first calculation, the mappings indicate that the overhead imposed by the ACSE in the authentication dialogue is equal to one round-trip delay of one TPDU.

The ROSE is used to manage request/reply interactions such as contract negotiations. The ROSE uses lower-layer services for data transfer. The primitives used in ROSE are straightforward. The RO-INVOKE.REQUEST is called by the invoking AE, and the RO-

INVOKE.INDICATION is given to the requested AE. If the operation succeeds, the RO-RESULT service is used. The RO-RESULT.REQUEST and RO-RESULT.INDICATION are used to implement the service. If the operation fails, the RO-ERROR service is used. Both the ACSE and the ROSE are described in [22].

The ROSE is also useful when an application-layer acknowledgement is required. This requirement is called out in [23]. The support requirements for these ASEs is still under study; the results will be brought to the AEEC, RTCA, and ICAO forums.

Conclusion

The paper has presented the ISO protocols currently used and envisioned for ADS communications support. The OSI seven-layer model as used in ADS was presented. The network layer protocols ISO 8473, ISO 9542, and ISO CD 10747 were presented. The transport layer protocol ISO 8073 was presented. The application layer protocols ISO 8650 and ISO 9072 were presented for information purposes. The benefit of ISO protocols in terms of interoperability and portability is important to the ADS program. The selection, profiling, implementation and fielding of these protocols is an important ongoing effort.

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SESSION THREE: LINK ENVIRONMENT/AVIONICS INTEGRATION

PANEL DISCUSSION:

"Evolutionary Implementation of Satellite Communications"

PANEL MEMBERS

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SESSION THREE: LINK ENVIRONMENT/AVIONICS INTEGRATION

PANEL BIOGRAPHIES

ONLY THOSE BIOGRAPHIES ARE LISTED THAT DO NOT APPEAR ELSEWHERE.

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SESSION FOUR: AIR TRAFFIC CONTROL ENVIRONMENT/ CERTIFICATION

Thursday, September 26, 1991

Master of Ceremonies - Robert D. Till, Communications, Satellite Navigation and Oceanic Systems Senior Program Manager, Federal Aviation Administration Technical Center

Session Chairperson - Jerald M. Davis, Manager for Technical Programs Division, Flight Standards Service, Federal Aviation Administration

8:30 **Opening Remarks** - Robert D. Till, Master of Ceremonies

8:30 **Near-Term Satellite-Based Oceanic Air Traffic Control: Ground System Description** - Elbert J. Henry, Air Traffic Control Specialist, Federal Aviation Administration. (Co-author, Mary A. Minnix, Member of the Technical Staff, the MITRE Corporation)

8:50 **Impace of Automation and Data Link Enhancements on Oceanic Air Traffic Control** - Sabrina F. Saunders-Hodge, Member of the Technical Staff, The MITRE Corporation (Co-author - Mark H. Runnels, Member of the Technical Staff, The MITRE Corporation)

9:10 **U.S. Air Traffic Control: Past, Present and Future** - Amado Colberg, International Procedures Specialist, Federal Aviation Administration

9:30 **Preliminary Evaluation of ADS/Radar Correlation** - Christopher N. Andrews, Member of the Technical Staff, The MITRE Corporation (Co-author - Dr. Leonard A. Wojcik, Member of the Technical Staff, The MITRE Corporation)

9:50 **BREAK** sponsored by **IBM**

10:20 **Cooperative ADS/AAS Integration** - Sherman G. Francisco, Senior Technical Staff Member, Air Traffic Control Programs, IBM . (Co-author Charles A. Kengla, Manager Logistics Support, Advanced Automation System Program, IBM).

10:40 **Operational Oceanic Air Traffic Control Using Satellite Data Link - Initial Implementation** - Donald Armstrong, Manager, Flight Test Branch, Aircraft Certification Office, Federal Aviation Administration

11:00 **Panel Discussion: Operational Approval and Implementation of Satellite Data Link into the Oceanic ATC Environment**

Panel Members:

Howard E. Hess, FAA
William L. Umbaugh, FAA
W. Frank Price, FAA
Donald Armstrong, FAA
James C. Crowling, FAA
John A. Scardina, FAA

SESSION FOUR: AIR TRAFFIC CONTROL ENVIRONMENT/CERTIFICATION

SESSION CHAIRPERSON

Jerald M. Davis
Manager, Technical Programs Division
Flight Standards Service
Federal Aviation Administration

Jerald M. Davis, Manager for the Technical Programs Division, Flight Standards Service, is responsible for the direction of the numerous technical Flight Standards programs that include various weather, human factors and related R&D programs. Prior to joining the FAA, the experience and background of Mr. Davis covers over 20 years of extensive military transport aircraft service with over 9000 hours flying time logged in various aircraft. In the commercial field, Mr. Davis holds an Airline Transport Pilots Certificate with over 3500 hours recorded with the airlines.

Mr. Davis has acquired a vast experience record with the FAA that has included positions as FAA's Principle Operations Inspector for Pan Am, responsibility for the authorship of numerous Aircraft Circulars (ACs), operations specifications, handbooks, and an FAA Order. Additionally, Mr. Davis has been deeply involved in various Category III research programs, several aircraft design approval certification programs, the management of various flight standards technical programs, and has been the final approval authority on a variety of landing system operations. Mr. Davis has also participated on several ICAO activities. Mr. Davis received his BSEE in 1964.

SESSION FOUR: AIR TRAFFIC CONTROL ENVIRONMENT/CERTIFICATION

Elbert J. Henry
Air Traffic Control Specialist
Federal Aviation Administration

Elbert J. Henry joined the FAA in 1970 as a controller at the Atlantic ARTCC. He held a variety of staff positions while at Atlantic ARTCC including Evaluation and Proficiency Specialist.

Mr. Henry came to FAA headquarters in Washington as a Air Traffic Requirements Specialist. He presently is responsible for Air Traffic Requirements for all Oceanic Automation Programs under development including ADS and DOTS.

Mr. Henry is Chairman of the Oceanic Air Traffic System Requirements Team (SRT).

Mr. Henry has been a practicing attorney since 1979 and member of the Georgia Bar Association and a member of the Aviation Section of the State Bar.

NEAR-TERM SATELLITE-BASED OCEANIC AIR TRAFFIC CONTROL: GROUND SYSTEM DESCRIPTION

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ABSTRACT

This paper presents a functional description of the next generation U.S. oceanic air traffic control ground automation system. The system will be based on the use of automatic dependent surveillance and data link communications between pilot and controller. A number of automation features will be provided to the controller to take advantage of the surveillance and communications capabilities. This paper describes the significant aspects of the surveillance, communications, and automation capabilities, and illustrates how the air traffic controller will operate in the new environment. In addition, some background is given on the work of the Federal Aviation Administration's Oceanic System Requirements Team of active oceanic controllers.

INTRODUCTION

With the advent of aeronautical mobile satellite communications, the oceanic air traffic control (ATC) environment is undergoing revolutionary changes. The manual, time-consuming processing of pilot position reports sent via high frequency (HF) radio is being replaced by automatic dependent surveillance (ADS), in which frequent position reports are transmitted automatically via a communications satellite to ground ATC automation systems. The current ATC communications process is a complex one, in which voice messages are transmitted from the cockpit to a radio operator via HF radio and then transcribed and sent as digital data to the ATC position. This process is being replaced by direct satellite data link communications between pilot and controller. These new surveillance and communication capabilities offer many possibilities for improving oceanic ATC services, both for pilots and for air traffic controllers.

Background

International oceanic ATC services have been based for over thirty years on manual, HF radio surveillance and communications processes as described above. Using these methods of surveillance and communication, the ATC job primarily consists of monitoring oceanic flights by ordering paper flight strips in columns according to route of flight. Changes and updates to flight information are recorded by the controller manually marking the flight strips. Very little attention has historically been given to oceanic ATC, and as a result, oceanic controllers have had few automated tools with which to do their jobs.

The U.S. Federal Aviation Administration (FAA) has begun the evolution of oceanic ATC from a largely manual process to an automated process. The Oceanic Display and Planning System (ODAPS) has recently been introduced into a U.S. Oceanic ATC Center to help

controllers monitor air traffic and to perform many of the routine bookkeeping tasks that are required. A Plan View Display (PVD) provides the oceanic controller with a simple graphical display of the traffic situation. Flight plan data processing helps the controller with maintenance of pertinent data as each flight progresses through the airspace. A flight plan-based conflict probe will soon provide an automated mechanism for alerting controllers to potential air traffic problems. The conflict probe will also be able to determine whether or not proposed flight plan amendments may safely be granted.

Satellite-based surveillance and communications will allow the automation capabilities to be expanded significantly. Along with ODAPS' existing capabilities, the automation will provide the controller with a rich repertoire of data messages and many additional automation aids to allow the controller to manage expected increases in traffic for the next several years. The FAA plans to enhance the ODAPS with the necessary hardware and software upgrades to allow the controller to function effectively in this future environment.

Purpose

The purpose of this paper is to provide a functional description of the expected oceanic ATC ground automation system during the mid-1990s. It focuses primarily on the oceanic controller's tasks and how these will be affected by new surveillance, communications, and automation capabilities.

Scope

This paper is a high level description of the future oceanic ATC automation system. Because of space limitations, the level of detail is not very deep. In addition, this paper does not attempt to describe overall oceanic ATC operations beyond general issues that have been raised during the development of the functional requirements for the automation. A detailed operational concept is currently being developed by the FAA to fully address ATC operations in the new oceanic environment.

THE OCEANIC SYSTEM REQUIREMENTS TEAM

Since early 1988, the FAA has had a group of active oceanic air traffic controllers working together to establish the functional requirements for future oceanic ATC automation systems. The main incentive behind including active controllers is to maximize the probability that the system developed for the ocean is operationally acceptable. Active field personnel, people who will actually use the systems being developed, help to focus development plans so that the final system will be operationally effective.

Along with the five oceanic controllers (one from Anchorage, two from New York, and two from Oakland Oceanic ATC Centers), the Oceanic System Requirements Team (SRT) includes a group of ATC supervisors and other FAA ATC representatives who make up the SRT Oversight Committee. The members of this committee are more involved with the policy and rulemaking aspects of future ATC concepts than with the fine details of using the systems; however, the Oversight Committee monitors all recommendations generated by the SRT. Along with representatives from the FAA, there have been SRT meetings in which foreign governments have sent ATC representatives. International paritcipants in the SRT have been from Canada, U.K., Japan, Iceland, and Portugal. In addition, the SRT has close ties with representatives from the International Civil Aviation

Organization (ICAO) and the Air Transport Association (ATA).

The SRT began its work in developing functional requirements for oceanic ATC automation systems by participating in brainstorming sessions and reviewing demonstrations of increasingly refined prototypes of these systems. Early work by the SRT led to a refinement of the functional requirements previously defined for the initial phase of the ADS program, in which ADS reports are brought into the ODAPS. The SRT then went on to define a broad set of requirements that is being used as the basis of design for the oceanic ATC automation system phases being planned for use well into the next century.

The SRT has focused primarily on the ATC automation systems that will be based on ADS and satellite data link communications, but their responsibilities have also included verification of the functional descriptions of the Dynamic Ocean Tracking System (DOTS) for oceanic traffic management. In addition, the SRT has looked at operational issues and requirements for procedural modifications in the new automation environment. They are heavily involved in the FAA's work in developing operational concepts for current and future states of the oceanic ATC environment.

FUNCTIONAL DESCRIPTION OF THE SATELLITE-BASED ATC AUTOMATION SYSTEM

ADS Report Processing

The full ADS report consists of five parts, as currently defined by the ICAO ADS Panel. These are position, ground vector, air vector, projected profile, and weather, with each part containing a number of individual data fields. The near-term oceanic ATC automation system will control report rate and content in ADS "agreements" (previously called "contracts") by automatically generating and transmitting ADS agreement messages, based on certain events. For example, prior to accepting control of a given aircraft, the ground automation will send a message establishing a nominal ADS agreement with the aircraft, whereupon the aircraft will begin to send a predefined set of data (presumably, aircraft identification, three-dimensional position and time, and figure of merit) at a predefined message rate (currently on the order of five minutes). ADS report content and rate will be automatically modified through new ADS agreement messages upon automatic detection of an alert situation and upon transfer of control; in addition, the controller will be able to manually send an ADS agreement message to change report content and rate.

In addition to providing an ability to establish and modify ADS agreements, the ATC automation will be able to process all data transmitted in the ADS report. All position-relevant data will be automatically processed and used to update the flight plan data base, as well as to check for any discrepancies in current or planned position. Weather data contained in the ADS report will be used to keep an on-line weather data base, used in calculating future aircraft times and positions, up to date.

Data Link Message Processing

The ATC automation will be able to generate, receive, process, and display both fixed format and free format data link messages. Aside from checks for standard communications protocol requirements, free format messages will not have any automatic verification processing upon receipt or any automatic message generation. Free format messages will be manually created by the controller for transmission and simply displayed to the controller upon receipt. Any errors in free

format messages must be handled by the controller. The use of free format messages is to be minimized and generally limited to non-routine situations. For critical situations, free format data link communications will not usually be adequate, so the HF voice back-up system is identified as the initial communications link for critical situations. Digital voice using the satellite data link is planned for future use in critical situations; this function will be addressed later in this paper.

Routine ATC operations can be almost completely encompassed by a small set of fixed-format ground-to-air and air-to-ground messages. Most messages sent to the pilot/airborne automation fall into the categories of clearance, advisory, response, and request; most messages received from the pilot/airborne automation, aside from ADS reports, fall into the categories of request, response, advisory, and onboard flight plan. There will be a very small set of fixed format messages to be used for critical situations; these will relay from the aircraft the existence of problems such as hijack, loss of fuel, or emergency descent, and from the ground a standard emergency request for aircraft and situation information. As noted above, most critical situation communications will use voice.

To accommodate the expected mixed traffic environment (including both aircraft equipped for ADS and satellite communications, and aircraft not so equipped), a data link exchange capability will be provided between the oceanic ATC centers and the high frequency (HF) radio service provider. With this data link interface, routine text ATC messages to non-ADS-equipped aircraft can be created and processed in the same manner as for ADS-equipped aircraft. Messages created using the standard data link message creation tools are sent to the radio service provider instead of directly to the aircraft. The radio service provider then transmits messages to the non-equipped aircraft using HF radio. Routine messages received through HF radio are similarly sent via data link from the radio service provider to the ATC ground automation and processed as normal text messages.

Format, logic, and reasonableness checks will be performed automatically on all incoming and outgoing fixed format messages.

Ground-to-Air Fixed Format Messages

Ground-to-air fixed format messages will be generated using any of a variety of access methods, such as programmable function keys, message alias names (two or three letter message identifiers), and menus. In addition, some types of fixed format messages will be automatically generated as a result of processing done by the system. For example, when a fixed format request for a flight plan change is received from the pilot and processed, the controller will simply touch a button to initiate a conflict probe trial amendment. Based on the outcome of the conflict probe, a clearance message will be automatically generated by the system and presented to the controller. With the touch of another button, the clearance can be transmitted to the aircraft, and when a technical acknowledgement of the message has been received from the aircraft, the ATC flight plan data base is automatically updated. The same sort of automatic generation of messages will also be available for a small set of alert situations, such as aircraft out of conformance. When an out of conformance position report is received, the system will generate a message instructing the pilot to return to his cleared flight plan. The controller can then touch a

button and the message is sent to the pilot.

Another type of ground-to-air fixed format message that can be generated either automatically or manually is the ADS agreement message referred to earlier.

Air-to-Ground Fixed Format Messages

All air-to-ground fixed format messages will be received, processed, and displayed to the controller. The processing done on these messages depends upon the type of message received. All incoming fixed format messages will be checked for format, logic, and reasonableness. Processing done on ADS reports will also include conformance checking and time updating of the ATC flight plan data base. More extensive processing will be done on certain types of incoming fixed format messages. Simple request processing, for example, will include conflict probe trial execution and clearance message generation, as mentioned above.

Automatic processing will be performed also for incoming fixed format flight plan messages transmitted from the aircraft for flight plan verification purposes. When aircraft enter a flight information region, or flight plan amendment clearances are granted, the ground automation will send a request to the airborne automation for a flight plan check. When the flight plan data is transmitted down, the ground automation will compare the onboard flight plan to the ATC flight plan data base. This is all transparent to the controller unless there is a discrepancy, in which case the controller will be notified of the problem.

Automation Enhancements

A wide variety of automation tools will be available to the controller in the ADS environment. Dynamic flight data processing and a flight plan-based conflict probe will form the base of the ATC automation. Incorporating ADS reports into the automation will allow aircraft conformance monitoring and alerting of missing ADS reports. Similar processing is currently done in ODAPS to identify discrepant position reports and overdue position reports for non-ADS-equipped aircraft.

Automation associated with fixed format data link messages, beyond the message generation tools, includes outgoing message status monitoring. This function assigns certain attributes to each type of ground-to-air message, such as the type of pilot response required and the time limit for the response to be received. For example, when a clearance is sent to an aircraft, if a response is not received within the specified time parameter, the controller will get a "pilot timeout" alert.

The ground automation minimizes the amount of data entry required by the controller. One way in which it does this is to integrate the function of transmitting an uplink data message containing an ATC instruction with the function of updating the ground data base to account for that ATC instruction. Another is to use the data directly from any downlinked ATC request from the pilot, rather than having the controller enter data from scratch. The following two examples illustrate how automation reduces controller entry.

Suppose that one aircraft has been flying at a slower speed than planned. After the latest ADS report for that aircraft, the ADS report processing function of the ground automation system determines that times of arrival for future points on the trajectory of the aircraft need to be updated, and it carries out this update. This causes the

conflict probe function to be automatically initiated. As a result of the update, the aircraft for the first time is predicted to have less than the required separation from another aircraft two hours in the future. The controller must analyze the situation and determine a tentative course of action that will involve an ATC instruction to one of the aircraft. He will enter this as a trial flight plan amendment and will submit it for trial probe processing by the conflict probe. If the probe indicates no conflict, a complete data link message will be created and presented to the controller for approval for uplink. All of the content of the uplink message can be obtained from the controller's original entry of the trial flight plan amendment. The controller approves the message for uplink, and in the normal situation, this completes his actions for this situation. When the pilot receives the instruction, he is required to downlink an acknowledgement, indicating either that he accepts the instruction and will comply, or that he is unable to comply. The ground automation system will process the downlinked will-comply acknowledgement message and automatically update the flight plan data base for the affected aircraft.

The following is the sequence of events for a pilot-initiated ATC request. The pilot prepares a fixed-format ATC request message using whatever automation tools are provided to him. After the pilot has reviewed this message, he releases it for downlink. When received on the ground, the message is presented to the controller. With only one command, the controller releases the request for trial probe processing. The ground automation has all the data necessary from the downlinked ATC request to create the trial flight plan amendment for the trial probe. If the requested flight plan is conflict free, a complete uplink ATC instruction message will be created and presented to the controller for approval for uplink. The message will be uplinked, and, if the aircraft is suitably equipped and the pilot accepts the instruction, will be entered automatically into the aircraft's flight management system.

There are several significant benefits that derive from this fundamental principle applied in the development of the oceanic automation system: only one person (either the pilot or the controller) should have to do original data entry of an ATC instruction and that person should not have to duplicate that data entry. Data entry workload is minimized and the workload effort of voice readback is eliminated. With the approach described here it is very likely that all four of the relevant versions of an aircraft's flight plan are the same. Those four versions are the version understood by the controller, the version understood by the pilot, the version in the ground automation, and the version in the cockpit automation.

In order to help the controller monitor previous ATC interactions with each aircraft, there will be a message recall feature available in the ADS ATC automation. This tool will allow the controller to search electronically through all text messages exchanged with all aircraft in the flight information region and text messages exchanged with other ATC facilities (all those with available on-line interfaces) over a four hour period.

A tool to help the controller monitor pilot preferences is the deferred request list function. When a flight plan amendment request cannot be granted because of a potential conflict, the request will be placed on file in the deferred request list. When subsequent changes are made to flight plans in

the surrounding area, the deferred request list will be reviewed by the automation to determine whether or not any of the conflicts have been eliminated by the change. If a deferred request becomes conflict free, the automation reminds the controller that the clearance can be granted.

The controller will be able to create lists of aircraft addresses using the common denominator function. This tool allows the controller to identify a common parameter, such as altitude, geographical region, aircraft type, or destination, and the system will generate a list of all aircraft under his/her control that fit the parameter. This list can then be used in conjunction with a related tool, called the multicast function, which is used to transmit a message to groups of aircraft. When the multicast function is given a message and a list of addresses, it sends the message to each address in the list, eliminating the need for the controller to perform many repetitive actions.

A limited amount of processing will be associated with the expected transfer of control of aircraft into the flight information region. Upon initiation of transfer of control, an ADS agreement will be established by the receiving flight information region's ground automation, and ADS report processing begins. At the same time, a request for the onboard flight plan will be transmitted automatically to the aircraft, and flight plan verification is then performed by the ground automation.

Hardware Enhancements

The basic hardware components used by the controller will include an enhanced replacement to the ODAPS Flight Data Input-Output (FDIO), an enhanced replacement to the ODAPS Plan View Display (PVD), and a flight strip printer. The FDIO replacement will be used to perform most controller-machine interface and communications tasks, including data link message generation, receipt, processing, and display. The PVD replacement will be used primarily for graphical display of air traffic, but will have the capability to display most of the text data normally shown on the FDIO replacement. The controller interface tools, namely keyboard and trackball, will be identical for both the FDIO replacement and the PVD replacement, and both systems will be capable of running from the same keyboard/trackball.

The display hardware available to the controller will be based on current workstation technology, with standard open systems architectures and network interfaces among the various ATC hardware components. The displays themselves will have flexible computer-human interface features such as sizable and moveable windows; scrolling, sorting, searching, and filtering of data; data emphasis capabilities including color, phasing, and selectable font size; and standard editing tools such as cut, paste, copy, move, and insert.

BENEFITS OF THE FUTURE OCEANIC ATC ENVIRONMENT

As stated in the final report of the International Civil Aviation Organization (ICAO) Future Air Navigation Systems Committee, 1988, "satellite-based communication, navigation, and surveillance systems will be the key to world-wide improvements" in ATC. Use of satellite-based systems will provide the greatest immediate impact in oceanic airspace, which for the U.S. is the area most in need of improvements in ATC surveillance and communications.

Use of satellites for automatic dependent surveillance and two-way data communications will allow many new tools to be developed for oceanic controllers. The higher frequency of surveillance reports from ADS will support aircraft conformance monitoring and missing report detection. These can enhance safety by increasing controller confidence in the aircraft's position. The ability of the controller to have immediate communication with the pilot will facilitate the incorporation of a number of automation tools, such as Message Recall, Deferred Request Processing, and Message Multicast. Such tools will eliminate many of the mundane tasks currently performed by the controller.

The use of fixed format data link communications will allow messages to be automatically transmitted, received, and processed, and data bases (both ground and airborne) to be updated automatically, with the touch of one or two buttons. Safety and efficiency will be enhanced by the use of fixed format data link communications because of the reduced probability of incorrect relaying or misinterpretation of messages. With fixed format messages and maximum use of automation processing in the aircraft and on the ground, there is greater likelihood that the expected future flight path of an aircraft will be the same in both locations.

The addition of satellite-based surveillance and communications with automation enhancements for oceanic ATC will also provide pilots with a number of benefits. The speed and reliability of communications combined with automation aids to process and generate data messages and maintain the flight plan data base will permit ATC operations to be much more flexible. Flight plan amendment requests will be granted more often, and pilots will be allowed more flexible clearances such as step climbs. Ultimately, with the increased safety provided by ADS and data link communications, separation standards between aircraft will be able to be reduced, and more aircraft will be permitted to fly on the most desirable routes and flight levels.

FUTURE ENHANCEMENTS TO OCEANIC ATC AUTOMATION

A number of other automation features are planned to be available to oceanic air traffic controllers in the near future beyond the phase described above. These are capabilities that, either because of technical complexity or difficulty in determining functional and operational requirements, have been postponed to avoid slowing down the immediate development process. Some of the more significant features are described in this section.

Digital voice communications via satellite is a feature that will be important in the near future for use primarily in emergency and non-routine situations. The use of voice is necessary when immediate and unpredictable messages must be sent in a time-critical manner. For the immediate future, HF voice communications will still be available for such situations. However, once the ground and airborne equipment are capable of digital satellite voice communications, this will be the preferred mode of emergency communications because satellite voice is quicker and more reliable than HF voice. Data communications will remain the preferred mode of communications for routine situations primarily because of the reduced probability of misunderstandings and automated recordkeeping capabilities associated with data messages.

The use of electronic flight strips to reduce the amount of paper currently required in the ATC

environment is a popular idea. However, there still remains a great deal of work to do before it is clear how to most effectively and efficiently automate flight strip data. After more research has been done in this area and the necessary operational and procedural changes have been implemented, electronic flight strips will be incorporated into the oceanic ATC automation system.

An electronic library will be available in future phases that allows controllers immediate, on-line access to required reference documents, such as FAA ATC Handbooks, ICAO Rules documents, Standard Operating Procedures manuals, and pertinent military guides. Because of the large amount of data storage required, this capability is being postponed until after the initial oceanic ATC automation phase.

An out of conformance conflict probe function will be developed to determine whether or not potential conflicts exist for aircraft that have strayed off course. The conflict probe normally used for oceanic ATC operations uses flight plan information to identify potential conflicts; when an aircraft is out of conformance with its flight plan, a flight plan-based conflict probe is no longer sufficient. The out of conformance conflict probe will incorporate the available data on current and expected position of the aircraft to form a region of space that will be protected around the airspace. This protected airspace is then probed for conflicts with other aircraft in the area. This function is important to allow the controller to determine the urgency associated with an aircraft out of conformance situation; however, because the algorithms have not yet been developed for this function, it will be postponed beyond the initial oceanic ATC automation phase.

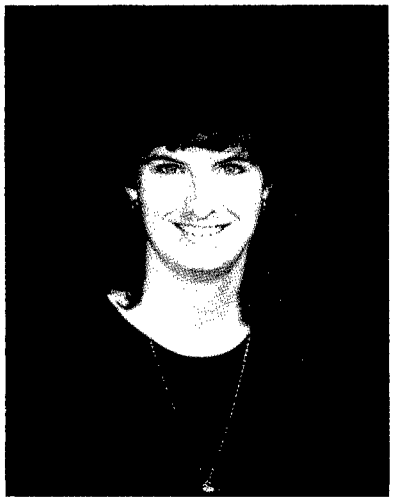
A limited conflict resolution aid, whereby alternative conflict-free routes (altitudes, tracks) are suggested to the controller, may be available in the next automation phase. This tool may be used when a trial amendment is run and a conflict is detected; in such a case, the automation can perform conflict probes on altitudes immediately above and below the requested altitude or on tracks to the right and left of the requested track. Any such alternative routes that are found to be conflict free would then be displayed to the controller for information and selection (if desired). Full conflict resolution capabilities, however, are considered to be too complex to incorporate in the near term.

CONCLUSIONS

With the capabilities being provided by satellite-based surveillance and communications in the future oceanic environment, controllers will soon be able to take advantage of many new automation tools that will reduce the number of tedious tasks required and help make the oceanic ATC environment more efficient. In order to take full advantage of these technological tools, however, a great deal of work must be done in the areas of operational and international coordination and standardization. Within the FAA and ICAO, operational adjustments must be made and rules must be changed both to allow the new capabilities to be used fully and efficiently and in order for the expected increases in oceanic capacity demands to be met. In addition, by the very nature of oceanic ATC and satellite communications, international coordination, especially among countries with adjacent flight information regions, is imperative. In order to attain the full benefits of ADS and satellite data link

communications, countries must have common technical standards, a common base of operational requirements, and a coordinated plan for transition and evolution of their systems. This is the area where the real challenges lie.

CO-AUTHOR



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SESSION FOUR: AIR TRAFFIC CONTROL ENVIRONMENT/CERTIFICATION

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IMPACT OF AUTOMATION AND DATA LINK ENHANCEMENTS ON OCEANIC AIR TRAFFIC CONTROL

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ABSTRACT

Among other anticipated benefits, the implementation of Automatic Dependent Surveillance (ADS) is expected to facilitate significant improvements in the overall efficiency of oceanic air traffic control (ATC). This paper presents the findings of an analysis conducted to evaluate the potential impact of ADS on current oceanic ATC operations and procedures.

INTRODUCTION

The current oceanic ATC environment is characterized by very conservative aircraft separation standards, infrequent flight progress reporting, indirect controller-pilot HF voice communication, and manual controller operations. As a direct result, controllers often have limited flexibility in accommodating aircraft that desire to alter their flight profiles in an attempt to achieve maximum efficiency.

ADS will provide automatic aircraft position reporting and direct two-way digital data link. ADS, in conjunction with ATC ground automation, is expected to provide air traffic controllers with additional capabilities, increased flexibility and allow the reduction of aircraft separations. As a result, airspace users are expected to realize increased acceptance of preferred routes of flight and increased responsiveness to in-flight requests.

Recently, an analysis of actual flight progress reports, along with associated pilot requests and corresponding controller responses, was performed. The goal of this analysis was to identify situations where an aircraft was constrained from altering its flight profile within the current oceanic ATC environment, but more than likely would not have been constrained if ADS were available. The following information documents the analysis approach and findings which are represented in the form of reconstructed scenarios that highlight such situations.

APPROACH

For this study, three key assumptions have been made. First, it was assumed that ARINC text data messages are sufficient to reconstruct enroute aircraft flight histories. Second, it was assumed that the ADS system comprises three parts, a two-way satellite communications capability, an ATC ground automation system with a conflict probe, and ADS equipped aircraft. Third, it was assumed that the implementation of ADS will be coupled with changes to present ICAO and FAA rules and procedures governing separation criteria.

The first assumption can be supported by reviewing how the current oceanic ATC system operates. Today all oceanic aircraft communications are via high frequency radio to an ARINC operations center. The ARINC center serves as an intermediary between pilots and ATC. At the center, pilot voice conversations are transcribed into ARINC messages which are delivered, via text data messages, to oceanic ATC controllers. Conversely, the ARINC operators send a read-back text data message to the controllers for every ATC instruction issued to pilots. Thus, all routine substantive communications between pilots and controllers are reflected in the ARINC text data messages.

Although the ADS system is still under development, the assumption that ADS comprises the three stated parts is taken as given. The third

assumption is required since many of the benefits that can accrue from ADS will not be possible without some changes to separation standards and existing ATC rules and procedures. For the purpose of this study, these assumptions are required if meaningful comparisons between the existing oceanic ATC system and one using ADS are to be made.

METHODOLOGY

An approach to analyzing the current oceanic environment was adopted that took into account the stated assumptions. Specifically, ARINC messages would be used to reconstruct actual flight scenarios in which pilots were unable to fly their desired flight paths. This approach was expected to identify situations where there was congested airspace, thus revealing opportunities for automation to help the controllers handle heavy traffic. At the same time, the analysis would illustrate situations where the responsiveness of the current ATC system, from the pilots perspective, could be improved through automation.

The study was initiated by selecting two days at random for review. They were April 2, 1991 for flight operations in the Oakland FIR and March 6, 1991 for operations in the New York FIR. ARINC messages for these days were collected and stored on computer tape in real time. The data was then parsed and formatted for use in a database program. Once formatted, the data files could be downloaded and manipulated in the database program as required.

The database program was an efficient tool for sorting and collecting aircraft scenarios. For example, it was quite easy to search for all aircraft that had passed through one or more oceanic waypoints. This data subset could then be sorted by time to establish the order in which the aircraft had passed the waypoints. The most instructive sorts were those specifying key words used in ARINC messages. Using the key words UNA for unable and REQ for request, many interesting situations were uncovered.

FINDINGS and ANALYSIS

From the two days reviewed, four scenarios were selected that highlight situations where it is likely that ADS would have been beneficial. These scenarios are described below. The analysis is based solely on the scenario circumstances. Speculation about events that led to each scenario is not discussed since the ARINC message data can only be used to reconstruct history not pilot and controller intentions or desires. Additionally, this data does not provide the information required to measure the influence of inter- and intrafacility coordination on the timeliness of controller responses to flight requests.

The New York and Oakland Oceanic FIR data collected and analyzed comprised 1556 ARINC messages representing 221 separate aircraft flights and 2503 ARINC messages representing 391 separate aircraft flights, respectively. For comparison, Table 1 and Table 2 list the breakdown of those messages by type and list the same data for the preceding and/or following days. Although not a statistical sample, it should be clear that March 6 and April 2 do not appear to be unusual days for traffic.

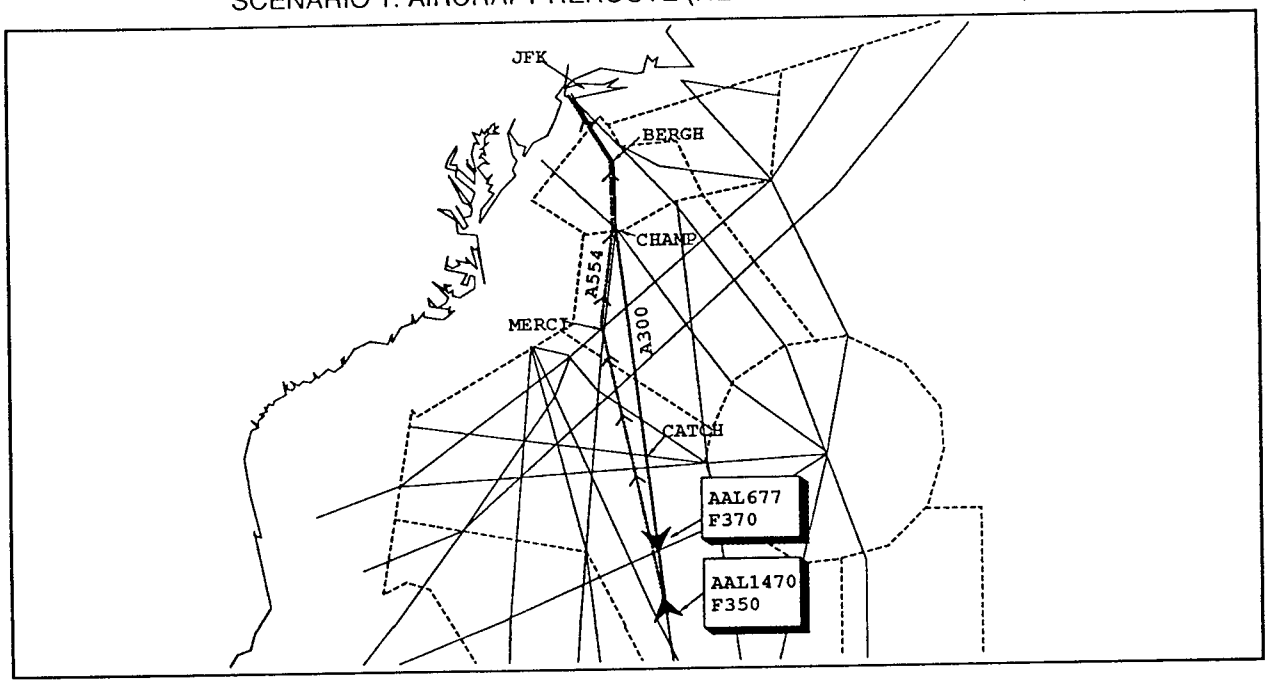
New York Oceanic FIR

Daily Flight Events and ARINC Message Summary

	Wednesday March 6, 1991	Thursday March 7, 1991	Friday March 8, 1991
Total Aircraft Flights	221	229	284
Total ARINC Messages by Message Type	1556	1615	1793
Air Ground	730	847	827
Position Report	678	584	812
Meteorological Position Report	144	167	148
Departure Report	4	5	4
Arrival Report	0	1	2
Errors - Unknown Type	0	11	0

Table 1

SCENARIO 1: AIRCRAFT REROUTE (NEW YORK OCEANIC FIR)



PILOT-CONTROLLER COMMUNICATIONS

Controller:
ATCC AAL1470 TO THE JFK ARPT VIA PSNT POSN DRCT MERCI A554 CHAMP THEN AS PREV CLRD MAINT F350

REROUTE IS DUE TO TRAFFIC *** ADVISE DELIVERY

Pilot:
AAL1470 RF F370 TO AVOID REROUTE

Controller:
ATCA AAL1470 UNAB F370 DUE OPPOSITE DRCTN TRAFFIC

COMPLY WITH REROUTE

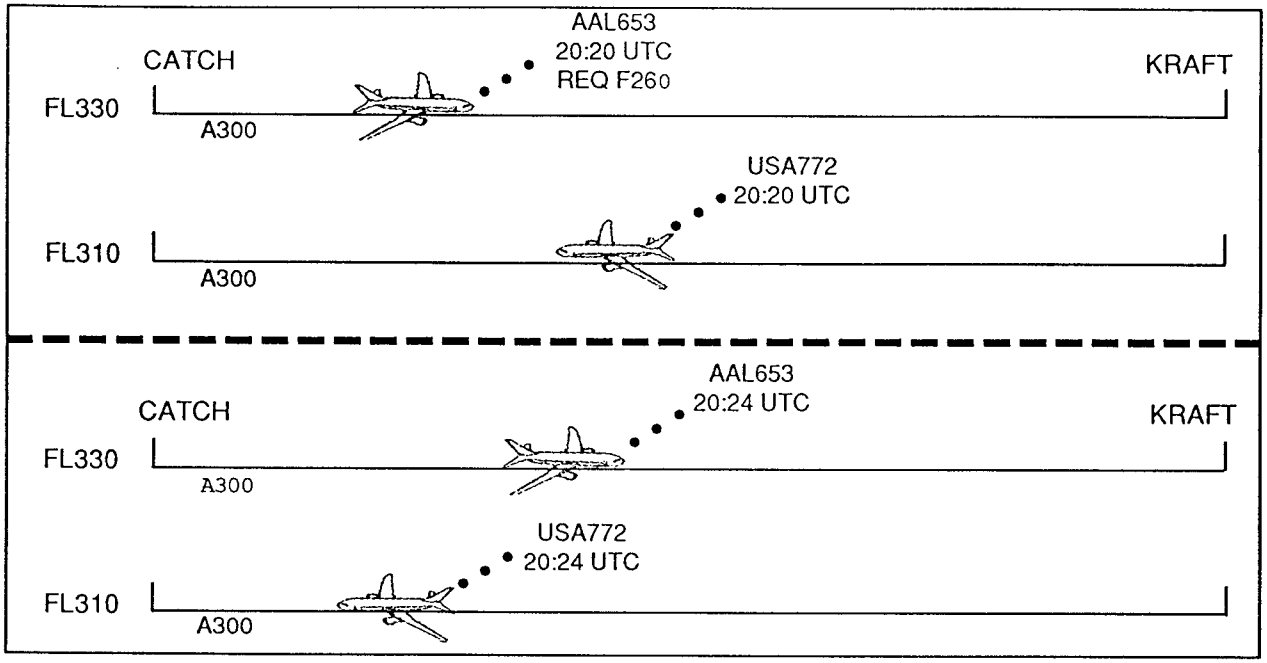
SCENARIO EVALUATION

As depicted in the above aircraft situation display, flight AAL1470 was initially headed for JFK airport via the route A300 containing waypoints:CATCH and CHAMP. Upon AAL1470's approach to CATCH, the pilot was directed by the controller to reroute and head direct to MERCI, which lies on route A554, and then to adhere to his previously cleared flight plan after reaching CHAMP.

In an attempt to maintain his preferred route of flight, the pilot requested to climb from flight level 350 to flight level 370 as a possible alternative to the reroute. His request was denied by the controller due to opposite direction traffic. Flight AAL677 was the only aircraft in the immediate vicinity traveling in the opposite direction on route A300 at flight level 370. The controller's evaluation of the situation was accurate in that there would have been a conflict with AAL677 at the time of the request. However, closer analysis of the situation revealed that in only 5 to 6 minutes from AAL1470's request, AAL677 would have passed AAL1470 making it possible for AAL1470 to climb to flight level 370 without a conflict. In the current ATC environment, the controller would have had no way of knowing this until receiving more information from AAL1470's next progress report approximately 60 minutes later.

ATC ground automation in conjunction with frequent ADS position reports and modified separation standards would have provided the controller with the option to grant AAL1470's flight level request within 5 to 6 minutes and possibly allow AAL1470 to maintain its preferred route.

SCENARIO 2: AIRCRAFT TURBULENCE AVOIDANCE (NEW YORK OCEANIC FIR)



PILOT-CONTROLLER COMMUNICATIONS

Pilot:
AAL653 TB RUFF RIDE/RF F260 IMMED

Controller:
ATCA AAL653 UNA LWR DUE OPPOSITE DIRECTION HEADON AT FL310

MAKE REQ AGAIN AFTER KRAFT..ALSO WHAT KIND OF TURBC ARE U HAVING

Pilot:
TB HAVING SOLID HEAVY LINE OF TB

SCENARIO EVALUATION

Just after crossing the waypoint: CATCH (at 20:11 UTC) and heading for the waypoint: KRAFT on route A300, the pilot for flight AAL653 requested an immediate descent from flight level 330 to flight level 260 due to turbulence (at 20:20 UTC). His request for the lower altitude was denied by the controller due to opposite direction head-on traffic at flight level 310. Flight USA772 was the only aircraft in the immediate vicinity traveling in the opposite direction on route A300 at flight level 310. The controller's evaluation of the situation was accurate in that there would have been a head-on conflict with flight USA772 within a matter of 2 to 3 minutes from the time of the request if flight AAL653 were cleared to descend through flight level 310 down to flight level 260. However, closer analysis of the situation revealed that in only 4 to 5 minutes from AAL653's request (approx. 20:24 UTC), flight USA772 would have passed flight AAL653 making it possible for flight AAL653 to descend through flight level 310 down to flight level 260 without a conflict. In today's oceanic ATC environment, without conflict probe and a situation display, the controller had no way of realizing this.

Another interesting point to note is that the controller suggested that AAL653's pilot make his request again after reaching the next waypoint:KRAFT. The pilot estimated being over KRAFT at 21:13 UTC and actually arrived at 21:09 UTC. Under current ATC separation standards and procedures, this would have been the next allowable time for AAL653 to change altitude because the controller would then have an additional progress report from both USA772 (after reaching CATCH) and AAL653. Hence, flight AAL653 was not eligible to descend to a lower altitude in order to avoid turbulence for at least 49 minutes after its pilot's original request.

This is a clear example of where ADS combined with revised separation standards and procedures would have provided the controller with the option to grant the flight level request within 4 to 5 minutes and thus allow flight AAL653 to escape the turbulence and smooth out its ride in a timely manner.

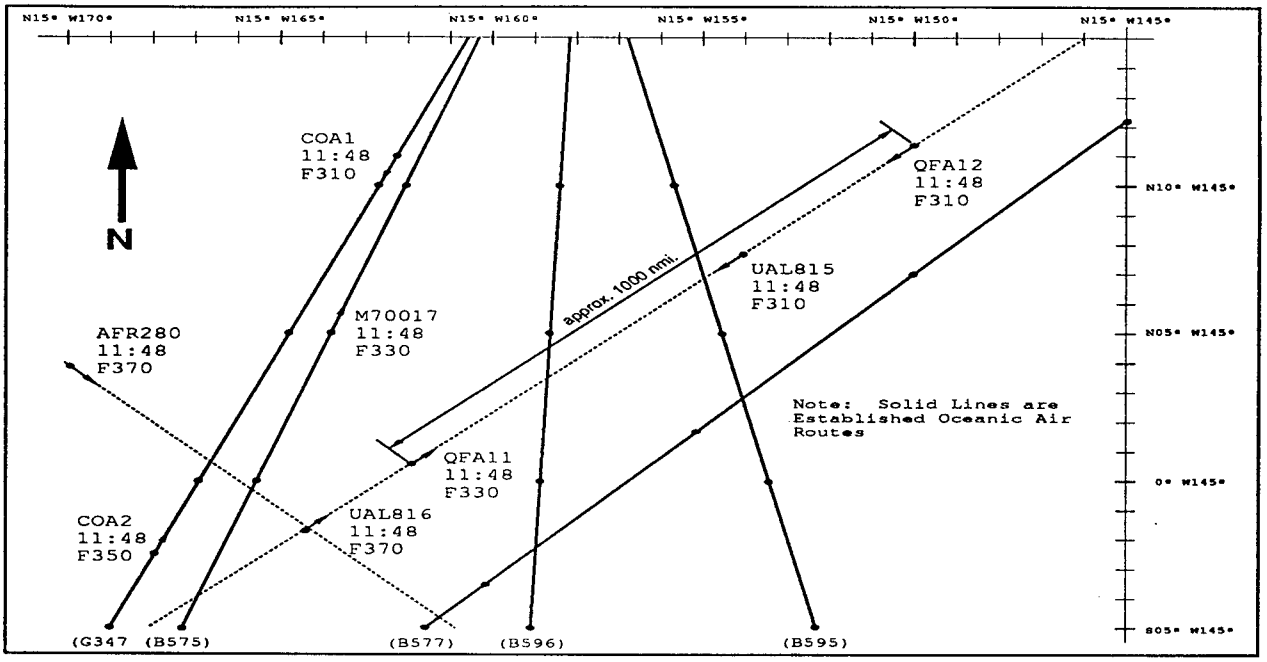
Oakland Oceanic FIR

Daily Flight Events and ARINC Message Summary

	Monday April 1, 1991	Tuesday April 2, 1991	Wednesday April 3, 1991
Total Aircraft Flights	405	391	428
Total ARINC Messages by Message Type	2841	2503	2526
Air Ground	1071	904	945
Position Report	543	468	434
Meteorological Position Report	1024	1089	1072
Departure Report	59	35	47
Arrival Report	14	6	24
Errors - Unknown Type	4	1	4

Table 2

SCENARIO 3: AIRCRAFT CROSSING (OAKLAND OCEANIC FIR)



PILOT-CONTROLLER COMMUNICATIONS

Pilot, QFA12 @ F310 - 11:50 UTC:
REQ F350

Controller to QFA12 - 11:53 UTC:
QFA12 UNA HIER DUE CONVERGING TRAFFIC

Pilot, QFA11 @ F330 - 11:54 UTC:
REQ F370

Controller to QFA11 - 11:58 UTC:
QFA11 CTAM F370

Controller to QFA12 - 12:11 UTC:
QFA12 CTAM F350

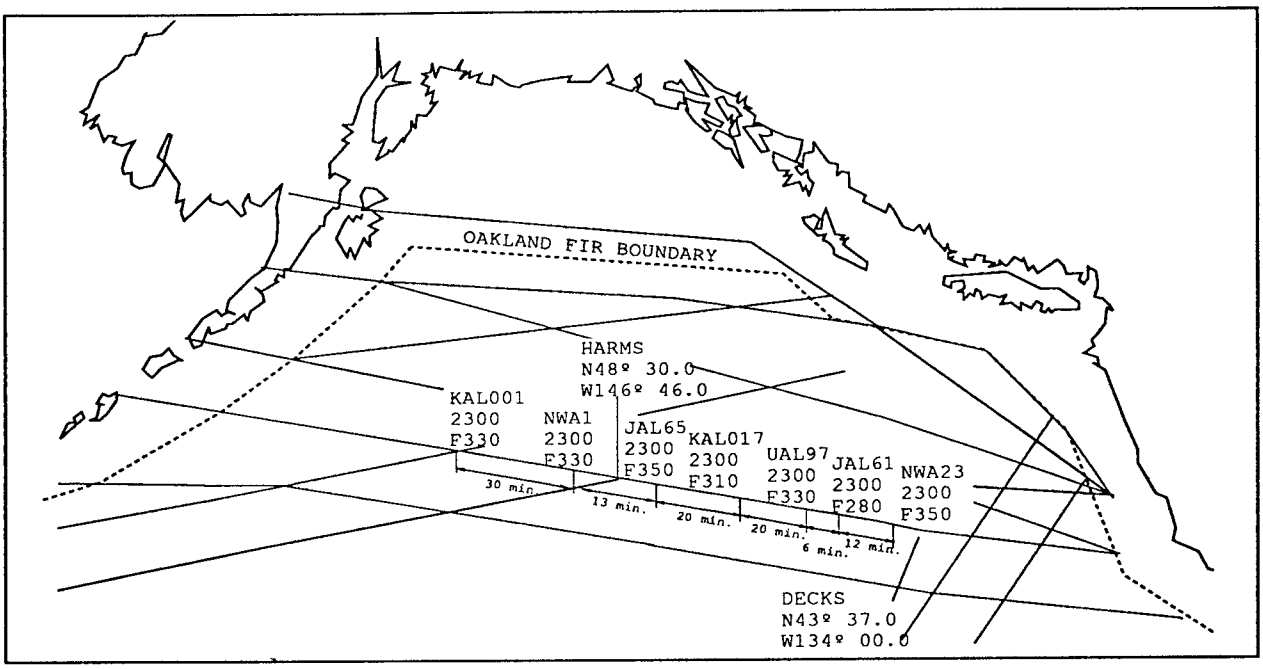
SCENARIO EVALUATION

As depicted above, QFA12 was enroute on a southwesterly course from the west coast of the United States to a destination in the Pacific Ocean. All aircraft in an area bounded by N15", W145" and S05", W170" are plotted above at their positions for 11:48 UTC.

At 11:50 UTC, QFA12 made an altitude request for a climb to flight level 350 from flight level 310. ATC promptly responded to the QFA12 request but denied the change in altitude. Inspection of this scenario reveals that QFA12, while climbing to F350, could have been in conflict with QFA11 flying a reciprocal course at F330 . Since oceanic controllers rely on flight strips to track aircraft, this controller had only a rough estimate of QFA11 and QFA12s position at 11:50 UTC. Current separation standards would require the controller to maintain vertical separation for both crossing aircraft from 20 minutes before the estimated crossing point to 20 minutes after the aircraft had passed. At a ground speed of 500 nmi per hour, the aircraft would have crossed in an hour or less. This would have given the controller 40 minutes or less to perform a mental conflict probe, communicate a clearance to QFA12, verify that QFA12 had reached the cleared altitude, and handle all other traffic in that FIR sector. Given the uncertainty of each aircrafts position and the actual time they would have passed, the controller prudently denied the flight level request. Eventually, QFA12 was able to climb to F350 since QFA11 was granted a climb to F370, eliminating the potential conflict.

This scenario is an excellent example for illustrating how the ADS system could benefit controllers and pilots. If QFA11 had not requested a climb, then QFA12 could have remained at F310 for a extended period of time. With a situation display and frequent ADS position reports, the controller would have known that QFA12 and QFA11 were separated by nearly 1000 nautical miles. Further, a conflict probe could immediately tell the controller if longitudinal separation between the aircraft would be maintained as QFA12 passed through F330. These tools of the ADS system should help controllers in making informed decisions and by default make the ATC system more responsive to pilots.

SCENARIO 4: AIRCRAFT FOLLOWING ENROUTE (OAKLAND OCEANIC FIR)



PILOT-CONTROLLER COMMUNICATIONS

Pilot, JAL61 @ F280 - 21:58 UTC:
REQ F330 (request flight level 330)

Pilot, UAL97 @ F310 - 22:00 UTC:
REQ BLK F330B350 IF UNA REQ F330 (request block altitude from flight level 330 through 350, if unable, request flight level 330)

Controller to JAL61 - 22:03 UTC:
UNA HIER ROF (unable higher request on file)

Controller to UAL97 - 22:09 UTC:
CTAM F330 (climb to and maintain flight level 330)

Pilot, UAL97 @ F330 - 22:13 UTC:
AT LEVEL F330

Pilot, JAL61 @ F280 - 22:51 UTC:
REQ F310 OR F330

Pilot, UAL97 @ F330 - 00:03 UTC:
REQ F350

Controller to UAL97 - 00:12 UTC:
CTAM F350

Controller to JAL61 - 00:22 UTC:
CTAM F330

SCENARIO EVALUATION

Depicted above are seven aircraft flying in single file from the west coast of the United States toward the Anchorage FIR at 2300 UTC. The clustering of aircraft in this manner is quite typical for the Oakland FIR. The first four aircraft in line, KAL001, NWA1, JAL65 and KAL017 are separated by ten or more minutes. Additionally they are all at flight level 310 or higher.

As these four planes progressed down the route, all of them received requested altitudes except KAL017. JAL65, ahead of and higher than KAL017, failed to file a position report for the waypoint HARMS. ATC tried to contact JAL65 but was unsuccessful. At roughly the same time, KAL017 requested flight level 350. ATC denied the request due to traffic. Presumably the request was denied because ATC was uncertain of JAL65s location. This example highlights the unreliable nature of high frequency communications. In an ADS equipped system using satellite communications, ATC would likely not have lost contact with JAL65.

Aircraft five and six, UAL97 and JAL61, enter the FIR at flight levels 310 and 280 respectively and are separated longitudinally by only six minutes. The last plane in this line, NWA23, enters the FIR 12 minutes behind JAL61 at flight level F350 and remains there for the duration.

SCENARIO EVALUATION (CONTINUED)

Listed above are the pilot controller communications for UAL97, JAL61 and ATC. JAL61, at flight level 280 and behind UAL97, requests flight level 330. This request is correctly denied by ATC since UAL97 is at flight level 310 and only slightly ahead in time. However, in an ADS system with a reduced longitudinal separation standard of 5 minutes, this request would have likely been granted.

Immediately after the JAL61 request, UAL97 requests a block altitude from flight level 330 through 350. ATC grants UAL97 only the altitude change to flight level 330. The block altitude request was probably denied because Mach separation technique was not in use. Current separation standards require the use of Mach technique prior to granting a block altitude request. With ADS and modified separation standards, UAL97s block altitude request would likely have been granted since UAL97 was clearly behind KAL017 by roughly 20 minutes and was ahead of NWA23 by 18 minutes.

Roughly an hour after his original request, JAL61, still flying at flight level 280, requests flight level 310 or 330. There was no response from ATC. Clearly JAL61 could have climbed to flight level 310 since UAL97 had been at flight level 330 for more than 30 minutes. At 0003 UTC, UAL97 requested flight level 350. ATC granted this request at 0012 UTC. By this time JAL61 has been at flight level 280 for close to two hours. Finally at 0022 UTC, ATC responds to JAL61 with approval to climb to flight level 330.

Like scenario three, this scenario is a good example of where ADS, with conflict probe, could have immediately identified that the block altitude request by UAL97 was acceptable. Additionally with the ground automation of an ADS system, the controller could have requested an event driven ADS position report from UAL97 upon reaching flight level 330. This report could have automatically triggered an instruction to JAL61 for an altitude change to flight level 310. This would have avoided the two hour flight by JAL61 at flight level 280. With the advent of reduced separation standards, JAL61 could have been cleared to flight level 330 or higher.

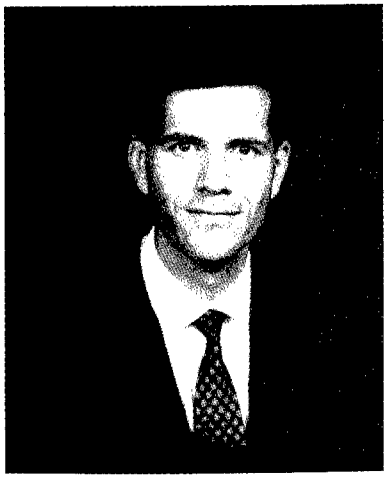
Many of the benefits that can accrue from the ADS system are highlighted in this scenario. Reliable communications coupled with ADS position reports should lessen the impact of unreceived position reports. Additionally, controllers may be more willing to grant clearances that are close to minimum separation standards, if they know they can depend on immediate contact with aircraft should future small variations in flight dynamics cause an erosion of separation. Ground automation coupled with a conflict probe should ease controller workloads by providing decision aids that will quickly assess available options. Finally, the reduction of separation standards will mitigate some of the limitations found in the current oceanic ATC system.

CONCLUSION

In summary, the results of this analysis have indicated that the implementation of ADS, defined in terms of automatic position reports, two-way digital data link, and ATC ground automation, promises to have a positive and significant effect on the efficiency, capacity and responsiveness of oceanic air traffic control operations. This analysis also indicates that there are several benefits to be gained from ADS by both pilots and controllers without a change to current separation standards. However, it should be noted that unless the ADS system is accompanied by a simultaneous change in ICAO and FAA rules governing separation standards, a number of the anticipated improvements to air traffic control and management will not be realized.

Further data analysis in support of studying the operational impact of ADS is planned. Using an ADS prototype equipped with conflict probe and operator interaction capabilities, simulations will be performed to re-enact oceanic air traffic control scenarios. These simulations should serve to uncover additional control situations encountered by controllers which could be handled more efficiently with ADS. In addition, these simulations may serve to uncover benefits that were not originally anticipated as well as additional functionality that should be adopted in ADS implementation specifications.

CO-AUTHOR



Mark H. Runnels
Technical Staff Member
MITRE Corporation

Mark H. Runnels is a member of the MITRE Center for Advanced Aviation System Development in McLean, Virginia. He is currently supporting the development of minimum operational performance standards for ADS avionics and studying the operational impact of ADS on the oceanic ATC system.

From 1985 to 1989, Mr. Runnels served in the U.S. Navy developing advanced intelligence systems. He holds a Bachelor of Science degree in Electrical Engineering from the University of Houston.

SESSION FOUR: AIR TRAFFIC CONTROL ENVIRONMENT/CERTIFICATION

Amado Colberg
International Procedures Specialist
Federal Aviation Administration

Amado Colberg works as an International Procedures Specialist at the Federal Aviation Administration Headquarters in Washington, D.C. He participates in the Automatic Dependent Surveillance Panel and working group meetings held by the International Civil Aviation Organization. Mr. Colberg was a member of the En Route Procedures Branch for two years prior to his present position. During this period he helped establish and became chairman of the Air Traffic Advanced Automation Procedures Team which is developing air traffic procedures for the U.S. computerized air traffic system.

Mr. Colberg came to Washington from San Juan CERAP (Combined En Route and Approach Control). He worked there for 17 years, during which time he participated as an Air Traffic Control Specialist (ATCS), an ATCS instructor, an automation specialist, a team supervisor, and an Assistant Manager for Automation.

Mr. Colberg has a Bachelor of Arts degree from Rutgers University, New Brunswick, New Jersey. He is fluent in Spanish and conversant in French.

U.S. OCEANIC AIR TRAFFIC CONTROL: PAST, PRESENT, AND FUTURE

Amado Colberg
International Procedures Specialist
Federal Aviation Administration

ABSTRACT

This paper provides a brief review of oceanic air traffic control as it has been conducted in the United States. It then describes the system improvements which are planned through the use of satellite communications technology, including air/ground data link and Automatic Dependent Surveillance.

As nearly all of the oceanic airspace is outside of air traffic control (ATC) radar coverage, the oceanic ATC system has been characterized by the use of procedural non-radar separation. Further, most of the oceanic airspace is beyond the coverage of land-based Very High Frequency (VHF) communications, which is subject to line-of-sight limitations. Accordingly, it has bee necessary to use High Frequency (HF) for air/ground/air communications. HF communications are relayed through commercial facilities dedicated to this purpose, which results in an additional delay in the ultimate reception of air traffic control messages.

Looking toward the future, it is anticipated that the use of satellite relays will provide reliable and direct data link communications between controllers and pilots, eliminating the present communications delays. The use of Automatic Dependent Surveillance (ADS) will provide continuous surveillance of oceanic air traffic on displays similar in appearance to ATC radar displays. These improvements will revolutionize future oceanic air traffic control operations by enabling more flexible and efficient control with considerably higher traffic capacity.

PAST

Until recently, oceanic air traffic was controlled by seven U.S. Air Route Traffic Control Centers: Anchorage, Honolulu, Oakland, Houston, Miami, San Juan, and New York, as shown in Figure 1. As most of the oceanic area was outside ATC radar and VHF coverage, procedural non-radar separation was used. ATC communications utilized HF. Messages were relayed by ARINC, as the FAA does not use HF frequencies for air traffic control because HF is characteristically noisy, particularly during periods of sunspot activity, and is subject to fading due to diurnal changes in the ionosphere.

Aircraft oceanic position reports were approximately one hour apart. However, because of communications difficulties and the need for relaying messages to and from the centers, messages could be delayed as much as 20 minutes. These factors severely limited the flexibility of the ATC System to respond to pilot requests and to obtain current information on aircraft position.

Initially, dead reckoning and celestial navigation were the only means of navigation for aircraft crossing oceanic airspace. These methods were not as accurate as the navigation systems now in use. The large navigation errors, combined with communications delays, required the use of large separation standards which severely limited the capacity of the oceanic airspace.

In the vast reaches of oceanic airspace there were little or no surveillance capabilities. The use of radar in oceanic airspace were limited to areas around islands, such has Puerto Rico, or offshore areas. The lack of surveillance capabilities over oceanic airspace makes it necessary for air traffic controllers to use flight progress strips to keep track of aircraft in non-radar airspace. These progress strips have all the necessary aircraft information needed to separate air traffic using non-radar procedures.

PRESENT

With the expansion of the ARINC and FAA communications networks, it has been possible for the FAA to consolidate some of the oceanic ATC Centers and reduce the number from seven to four (Anchorage, Oakland, Houston, and New York). The San Juan Combined En Route/Approach Control (CERAP) and Miami Center oceanic sectors were incorporated into New York Center, and the Honolulu CERAP oceanic sectors were incorporated into Oakland Center.

Further, a variable set of parallel tracks is currently established twice daily for the busiest routes across the North Atlantic and the North Pacific Oceans. These tracks are computer-derived to take advantage of favorable wind circulation around high and low pressure areas. In the North Atlantic Minimum Navigational Performance Standards (MNPS) Airspace the tracks are published for the westbound traffic from Europe and for eastbound traffic from North America. These tracks are organized in one-way flow in the morning and evening and are spaced laterally one degree of latitude (60 NM) apart to be used by aircraft capable of complying with these tolerances. A similar set of tracks using 100 nautical mile lateral separation is in use between the Orient and North American airports.

Currently, the majority of aircraft on oceanic routes use the Inertial Navigation System (INS) or Internal Reference System (IRS) for more accurate area navigation. This has allowed the use of reduced lateral and longitudinal separations between similar aircraft on these tracks.

The procedures used in oceanic Centers are similar to those used in domestic Centers many years ago, in that surveillance and direct communications with aircraft are not available. Communications are still relayed through the ARINC network and are conducted on HF. The oceanic controller's ATC display are still flight progress strips, and the traffic situation is still a controller's mental visualization.

However, as oceanic ATC is a global activity, a number of international organizations have been working to develop the procedures and technology for tomorrow's oceanic system. As it is very important that the developments in the various countries be compatible with each other, these developments are coordinated through the International Civil Aviation Organization (ICAO) to ensure standardization and harmonization. The FAA, particularly through its International Procedures Branch, participates in the work of various international groups, which include, the North Atlantic Systems Planning Group (NAT/SPG), the Informal Pacific ATC Coordination Group (IPACG), the Automatic

Dependent Surveillance Panel (ADSP), and the Caribbean/South America Regional Planning and Implementation Group (GREPECAS).

The International Procedures Branch also participates in the FAA's Oceanic Systems Requirements Team (SRT) and leads the FAA's Air Traffic ODAPS Procedures Team (ATOPT).

FUTURE

North Atlantic air traffic has been forecast to grow 36% between 1990 and 2000; North Pacific Traffic has been forecast to grow at double this rate during the same period. To handle such demands, radical improvements in the system will be necessary.

Although plans vary, it is expected that eventually U.S. Oceanic ATC Centers will be consolidated into two facilities, the Oakland and New York Centers.

The use of satellite communications technology will enable direct communications between pilot and controller. Present communications delays will be eliminated, allowing the ATC system to be more responsive to pilot requests. This technology should allow much greater control flexibility and correspondingly more fuel-efficient flight profiles.

Air-ground satellite data links will be utilized for routine messages and acknowledgements, as data link messages can be completed in a small fraction of the time required for voice messages. However, it is expected that voice capability will be retained for non-routine or emergency messages.

Together, satellite and data link technology will make possible the continuous surveillance of aircraft in oceanic airspace, through the use of ADS, which in the U.S. will use ODAPS technology as a base. In this application, the aircraft will automatically and periodically transmit its identity, latitude, longitude, and altitude via data link to a communications satellite. Latitude and longitude data will originate in the INS, IRS or the Global Positioning System (GPS) equipment in the aircraft. The satellite earth station which will send it to the air traffic control facility. The aircraft position data will then be converted into a target on a cathode ray tube (CRT) display, with aircraft identity and altitude shown on an alphanumeric tag in a manner similar to current ATC radar displays.

Such a display will enable air traffic controllers to separate aircraft, check the progress of each aircraft in relation to its flight plan and to monitor and correct any critical deviations from the planned flight track. Ultimately, automation will be added to the ADS display to alert the controller to any possible traffic conflict far enough in advance for the controller to evaluate various alternative ways to resolve and avoid the conflict. The preferred solution can then be coordinated directly with the pilot via the satellite communications system.

SUMMARY

Up to the present time, ATC procedures for oceanic airspace have changed very slowly. However, the development of direct satellite communications and ADS will revolutionize oceanic air traffic control procedures, by giving the oceanic controller surveillance and communications capabilities which are similar to those currently in use by the domestic air traffic controller. These improvements will enable oceanic separation standards to be reduced, increasing system capacity and efficiency while maintaining the safety of the system.

SESSION FOUR: AIR TRAFFIC CONTROL ENVIRONMENT/CERTIFICATION

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Christopher N. Andrews has been a member of the MITRE Center for Advanced Aviation System Development in McLean, Virginia since 1990. He is currently involved in the development of a real-time simulation of Automatic Dependent Surveillance (ADS).

Prior to joining MITRE, he worked as a Software Engineer for IVAC Corporation. Mr. Andrews graduated with honors form the Georgia Institute of Technology in 1990, with a Bachelors degree in Electrical Engineering.

PRELIMINARY EVALUATION OF ADS/RADAR CORRELATION

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Dr. Leonard A. Wojcik

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ABSTRACT

This paper addresses the potential utility, limitations, and implementation factors associated with use of an Automatic Dependent Surveillance (ADS) /radar correlation function in an operational ADS system. It also evaluates the quality of surveillance data that could be obtained from ADS equipped flights and assesses its suitability for oceanic automation by comparing engineering trials ADS data to radar data.

SECTION 1

INTRODUCTION

1.1 Background

Improvements to oceanic surveillance and communications provided by ADS will enable significant user benefits, increased system safety, and a more efficient use of oceanic airspace. While some of these benefits can be realized immediately upon introduction of ADS progress reports, satellite data link, and oceanic air traffic control (ATC) automation, the most significant benefit will be derived from reductions in oceanic separation standards.

To put reduced separation standards into place, thorough safety studies of the ADS system will be required. These safety studies will need to identify all mechanisms that can lead to errors in navigation and propose tests that can reveal the presence of errors due to each mechanism. These studies are necessary since ADS places a great reliance on the integrity of navigation data and does not use an independent surveillance system that can detect erroneous navigation data.

In September, 1990, the Federal Aviation Administration (FAA), in cooperation with several aviation industry companies, began testing of satellite ADS position reports and datalink. These tests involved in-service airline aircraft recently equipped with satellite data link and ADS capability. These tests, called the Pacific Engineering Trials (PET), generated data that could be used to evaluate various aspects of ADS in an operational environment.

1.2 Purpose

There are two objectives in conducting the analysis of PET data and in preparing this paper:

1. Evaluate the potential utility, limitations, and implementation factors associated with use of an ADS/radar correlation function in an operational ADS system. Such a function would be intended to detect some blunders leading to erroneous navigation data.

2. Evaluate the overall quality of surveillance data that could be obtained by ADS and assess its suitability for oceanic automation by comparing the engineering trials ADS data to radar data. Both raw radar reports and track data were collected from the FAA's enroute automation system during the trials and were correlated with ADS progress reports.

1.3 Study Limitations

This study was performed with data collected from a limited number of ADS-equipped flights involved in the early part of the ADS Pacific Engineering Trials. Such limited data does not provide conclusive evidence on the relative accuracy of ADS. The data collected and

analyzed is limited to the airspace under radar coverage and to the navigation system on the participating aircraft.

SECTION 2

OPERATIONAL ADS/RADAR CORRELATION

ADS/radar correlation could be used in oceanic ATC as a final check on aircraft-reported position and time before outbound ADS-equipped aircraft leave radar coverage. This section briefly discusses potential applications for ADS/radar correlation in actual operations.

2.1 Navigation System Correlation

Maintaining a high level of safety for the oceanic air traffic system requires that human or machine caused blunders that could result in an accident be prevented or corrected through redundancy of independent systems or procedures.

The inertial navigation system (INS) is an example of a redundant system. The INS must be at least a dual system, including navigational computers and reference units, and at least two units must be functioning at takeoff. Cross-checks among the aircraft crew help verify that all data entered into the system are correct, that units are functioning properly, and that system controls and switches are properly configured to provide the desired information.

ADS/radar correlation could add to this set of INS initialization checks and could reduce the initialization blunder rate. This study suggests that ADS/radar correlation is adequate to detect large navigation system initialization errors. This could improve safety at present separation standards or could be part of a justification to reduce separation standards.

2.2 Time Correlation

ADS/radar correlation offers an independent means to validate the clock that provides the contents of the time field sent in ADS progress reports. Accurate aircraft time is a new element required by ADS. Current controls over reported aircraft time are not stringent because of the large existing separation standards. ADS may permit separation standards to be reduced if times of aircraft positions updates are known with enough accuracy to show positions within a few nautical miles on controllers' displays.

Since a subsonic jet travels about 8 nautical miles in one minute, a time inaccuracy of no greater than 20 seconds may be sufficient for aircraft separations on the order of tens of miles. Time inaccuracy on the order of several seconds is equivalent to aircraft position inaccuracies of less than one nautical mile. Separation standards approaching domestic enroute standards would require more stringent time accuracies.

ADS/radar correlation is an attractive candidate to ensure that the aircraft time is accurate because the check could be performed entirely independent of the aircraft and could be accomplished automatically. A mechanism would be needed for pilots to adjust the aircraft clocks if a correction is required. Also, pilots would have to be alerted to a major inaccuracy early enough in the flight to permit clock adjustments and another ADS/radar correlation check to validate the adjustments.

One limitation of ADS/radar correlation for clock correction is that the method cannot distinguish between clock inaccuracies and navigation system inaccuracies along the line of flight.

2.3 Global Positioning System (GPS)

In the future, GPS is expected to provide position and time information to equipped aircraft. ADS/radar correlation may diminish in importance for oceanic operations with widespread GPS use because GPS will meet stringent integrity and reliability requirements and does not require initialization. INS may still be used in aircraft with GPS to complement the weaknesses of GPS (which could appear in conditions as poor satellite geometry), but it is unclear whether ADS/radar correlation would still be justified as an independent means to validate aircraft time and position accuracy.

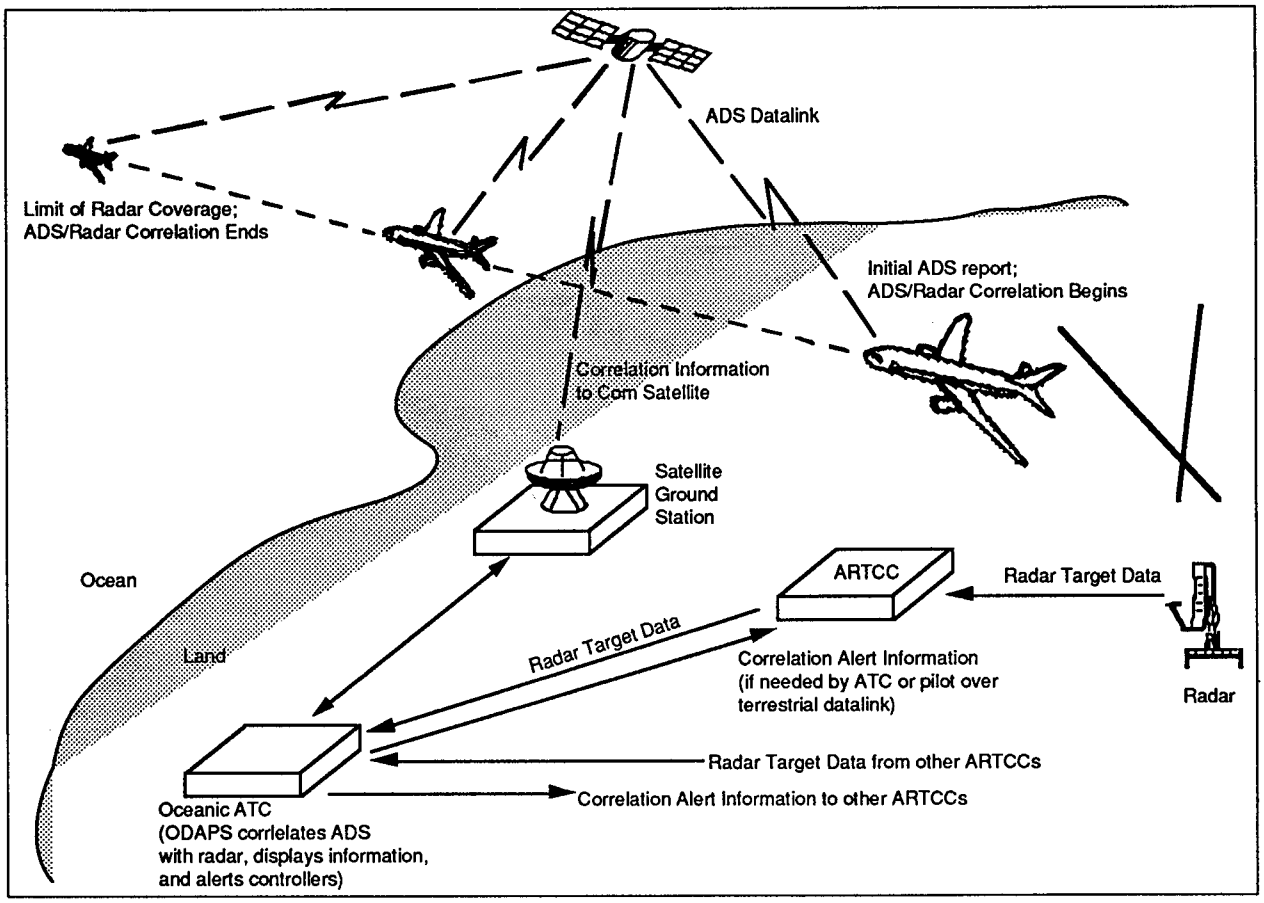

Figure 1--Possible ADS/radar correlation concept

2.4 Operational ADS/Radar Configuration

Figure 1 suggests a possible operational concept for ADS/radar correlation. Since aircraft bound for transoceanic travel may be under coverage of ATC facilities other than the oceanic control facility prior to entering oceanic airspace, inter-facility communication will be needed. Radar position and time information for oceanic aircraft are transmitted from each Air Route Traffic Control Center (ARTCC) to the Oceanic Display and Planning System (ODAPS), where they are correlated with ADS-reported position and time. Depending on the outcome of the correlation, an alert or confirmation message could be sent to the aircraft.

Oceanic controllers would also receive correlation alert messages so they could contact pilots with further instructions if correlation is not achieved. The process begins early in the flight to permit the crew to make any clock or INS position adjustments. Following an alert, ADS/radar correlation continues until satisfactory correlation is achieved.

SECTION 3

SURVEILLANCE DATA

Aircraft position information was collected from three sources: ADS progress reports, radar returns, and track data. Stereographic projection techniques were used to map the data to a common X, Y coordinate system.

3.1 ADS Progress Reports

ADS progress reports, generated by onboard navigation equipment at five minute intervals, were transmitted from an United Airlines aircraft to the Inmarsat Pacific Ocean satellite, received by the COMSAT west coast ground earth station, and routed to several ADS experimental

workstations via the Aeronautical Radio, Incorporated (ARINC) Data Network Service (ADNS). The ADS progress report contains the aircraft's latitude, longitude, and altitude, as well as a time stamp.

The position of the aircraft was determined by converting the latitude and longitude from the ADS report to system coordinates using exact stereographic projection equations [1].

3.2 Radar Returns

Common Digitizer (CD) tapes were collected from the ARTCC in Oakland, California. The data from the CD tapes consist of the range and azimuth of the aircraft from the radar site, the altitude of the aircraft based on Mode C transponder returns, and a time stamp.

The aircraft's location was converted to system coordinates using exact radar data coordinate conversion equations and second order approximations to radar data transformation equations [1].

3.3 Track Data

Track data, generated by the Host Computer System in six second intervals, were obtained from the Oakland ARTCC. These data include the location of the aircraft calculated by the tracking algorithm, based on radar returns.

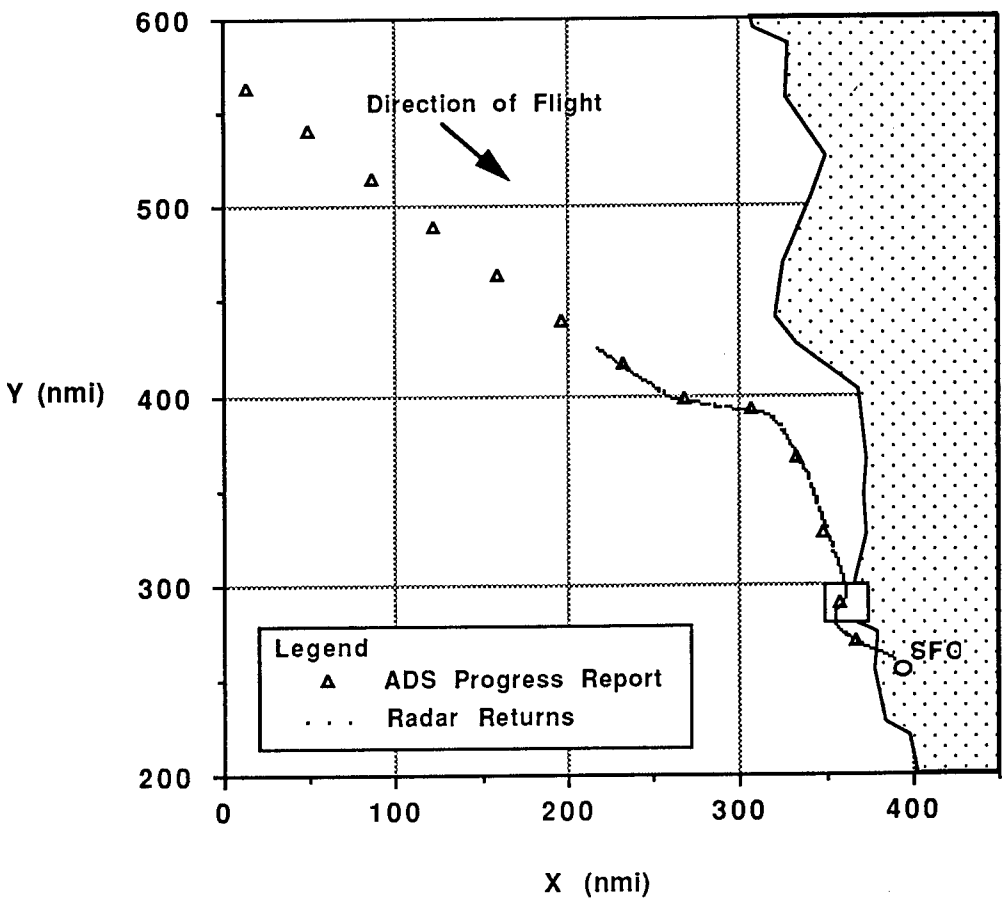

Fig. 2--This illustration shows United Airlines Flight 806 as it approaches San Francisco International Airport on 09-28-90. The area in the small box is shown in Figure 3.

The data are expressed in system coordinates and include a time stamp.

Track data do not always accurately reflect the flight path of the aircraft, especially during turns, as can be seen in Figure 3. On the other hand, when the aircraft is in straight flight at long-range from the radar, the raw radar reports contain random errors. In this situation, a more accurate estimate of aircraft position is obtained from track data. Because the aircraft under study were involved in a series of turns, raw radar reports were used to evaluate the accuracy of ADS progress reports.

SECTION 4

DATA ANALYSIS

4.1 Surveillance Data Plots

The path of United Airlines Flight 806 can be seen as it approaches San Francisco International Airport in Figure 2. This flight departed from Hong Kong and had been airborne for approximately 8 hours when the data shown in Figure 1 were reported. The source for the position data included in the ADS progress reports was the inertial navigation system. It is not known whether the system had been updated during the flight.

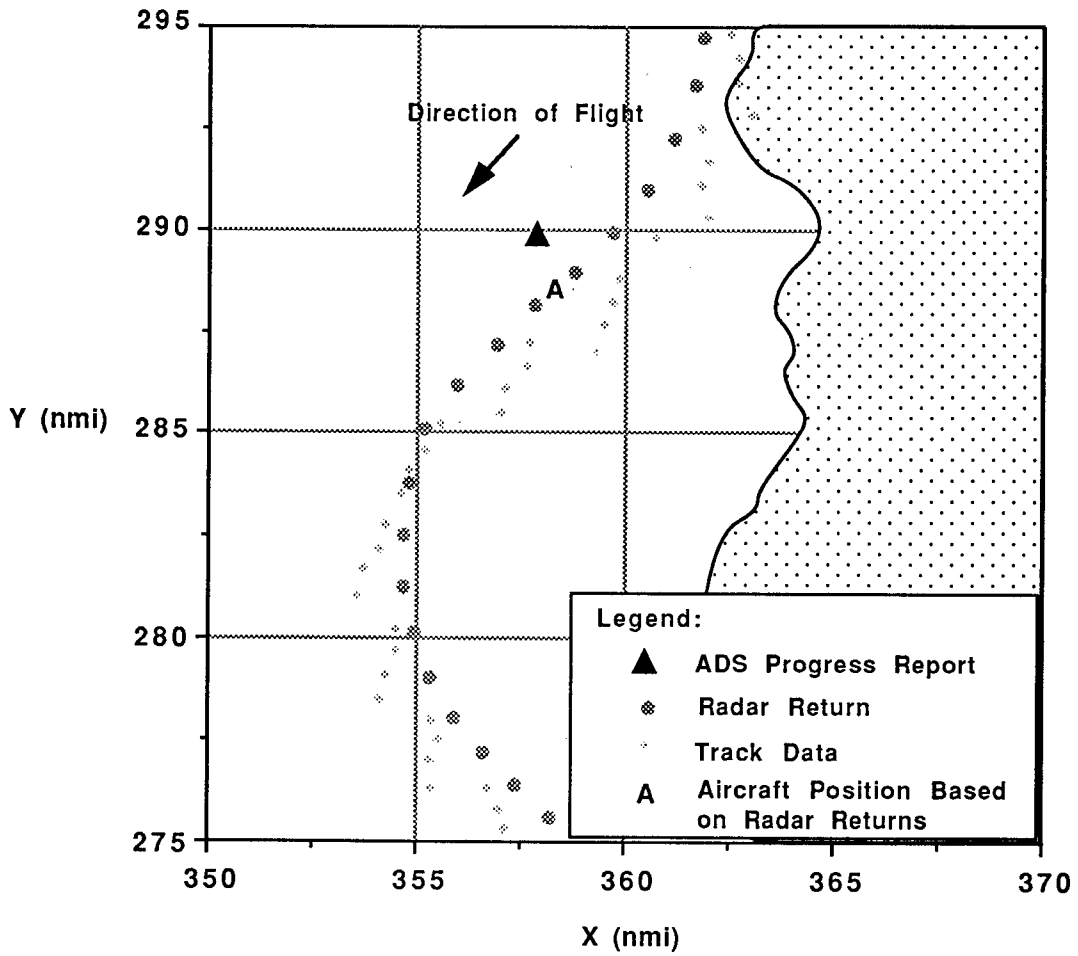

Fig. 3--This illustration shows a detailed view of United Airlines Flight 806 as it approaches San Francisco International Airport. The position of the aircraft based on the radar data is denoted by the A. This position corresponds with the ADS progress report.

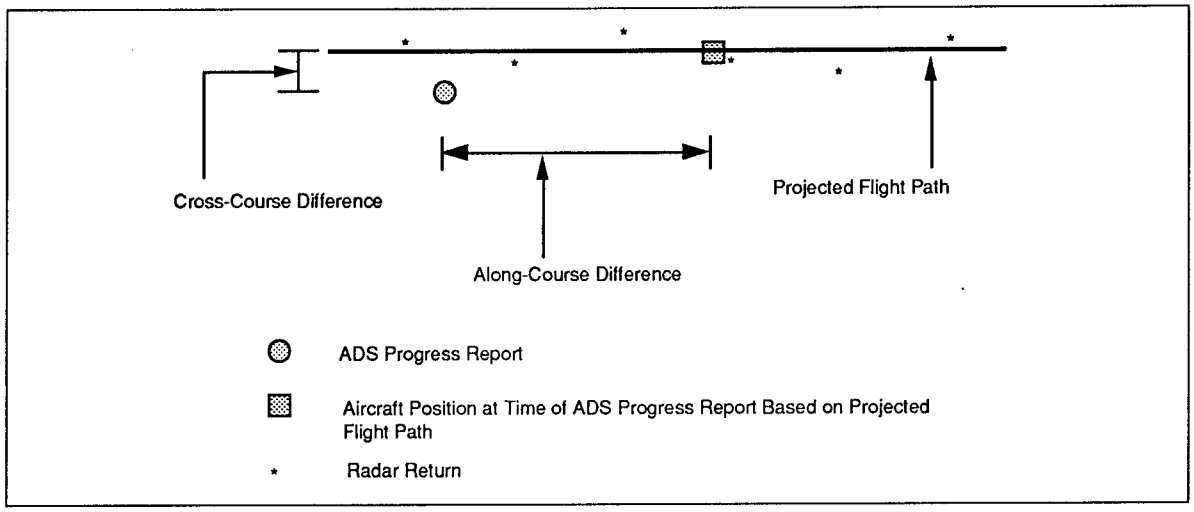

Fig 4--Illustration of cross-course and along-course difference.

Figure 3 shows a detailed view of the surveillance data shown in the box in Figure 2. This illustration shows a variation in time and position between the ADS progress report and the radar returns. The position of the aircraft based on the radar returns is denoted by the A. This position corresponds with the ADS progress report shown in the figure.

This figure also shows the track data for the aircraft. Track data deviates by as much as 1.1 nautical miles from the true path of the aircraft.

4.2 Measurement Methodology

A simple algorithm was used to determine cross-course and along-course difference. Position information from the ADS progress reports and radar reports were converted to system coordinates as described in section 3. Small segments of the flight path of the aircraft were generated by fitting radar reports to first-order polynomial equations. Radar reports used to generate the flight path were selected by their proximity in time and location to the ADS point.

	Flight 806 09-28-90 (Inbound)	Flight 807 09-28-90 (Outbound)	Flight 808 09-30-90 (Inbound)	Flight 805 09-30-90 (Outbound)	Overall
Average Cross-Course Difference	0.5873	0.4134	0.2773	1.0174	0.4829
Average Cross-Course Difference Standard Deviation	0.4104	0.3065	0.2426	0.2712	0.3787
Average Along-Course Difference	0.9042	0.5895	0.9133	0.9006	0.8030
Average Along-Course Difference Standard Deviation	0.5089	0.3871	0.3607	0.4218	0.4428
Average Total Difference	1.2010	0.7816	0.9951	1.3970	1.0241
Average Total Difference Standard Deviation	0.3660	0.3834	0.3247	0.3536	0.4076

All entries in this table have units of nautical miles.

Table 1--ADS/radar correlation statistics

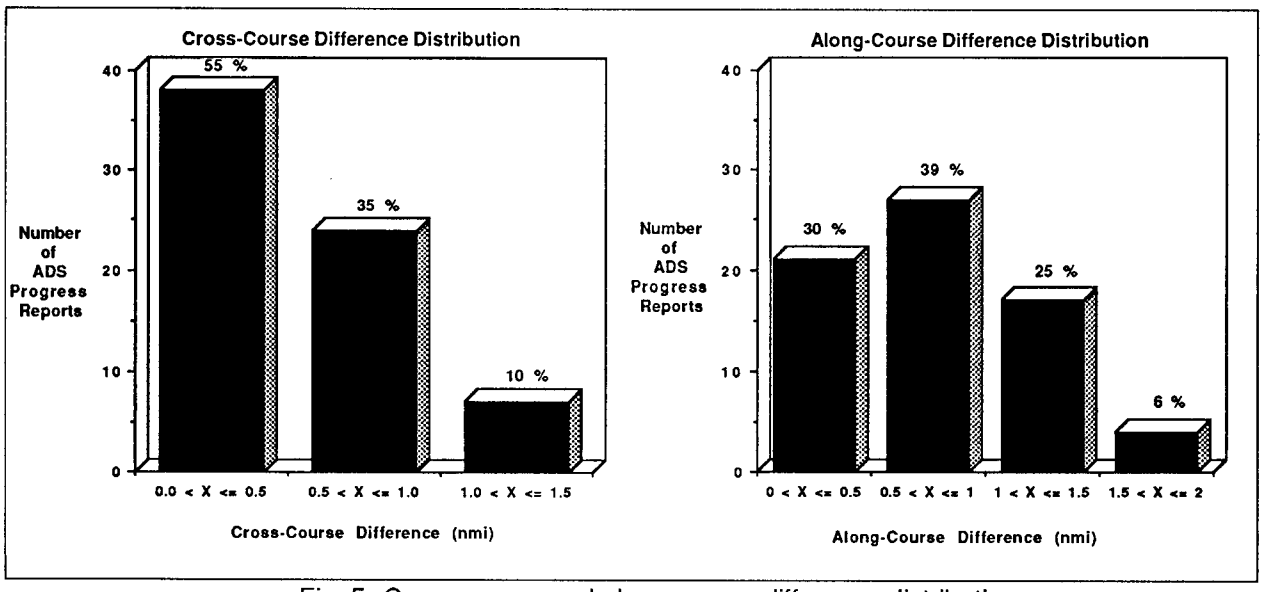

Fig. 5--Cross-course and along-course difference distribution

The cross-course difference is the measurement of the lateral distance between the aircraft and the projected flight path. The along-course difference is determined as a combination of time and position deviation between radar data and ADS reports. These were determined as shown in Figure 4.

4.3 Data Statistics

Data were collected and analyzed from two outbound (807 and 805) and two incoming (806 and 808) flights involved in the Pacific Engineering Trials. Table 1 shows statistics for each flight and for the four flights combined.

These data suggest that ADS/radar correlation is adequate to detect navigational system initialization errors greater than five nautical miles or large clock errors on the order of minutes.

Figure 5 shows the distribution for the cross-course difference and along-course difference. Comparing the two charts, the along-course difference has a higher percentage of reports greater than one nautical mile. This suggests that the along-course difference is a combination of time and navigation system inaccuracies. Due to the limited set of data collected from the engineering trials, large outlier differences were not detected.

SECTION 5

CONCLUSION AND RECOMMENDATIONS

A possible application of ADS/radar correlation in oceanic operations would be to provide an independent means to detect INS initialization errors and to validate and update the aircraft clock used to insert time into ADS messages. This study suggest that ADS/radar correlation is adequate to detect large INS initialization and clock errors. Further safety studies are required to determine if ADS/radar correlation is needed as a check against gross errors, or if present safety measures are adequate.

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From 1987-1988, Dr. Wojcik was Transportation Analyst at the Office of Technology Assessment (OTA) of the U.S. Congress, where he made major technical and policy contributions to Congressional studies of aviation safety. From 1988-1990, he was Director of Research at the Flight Safety Foundation. His work involved statistical studies of worldwide commercial aviation safety, evaluations of safety-related technologies, and studies of organizations and management factors in aviation safety.

Dr. Wocjik received a Ph.D in Engineering and Public Policy from Carnegie-Mellon University in 1984, an M.S. in physics from Cornell University in 1979, and a B.A. in Physics from Northwestern University in 1975.

SESSION FOUR: AIR TRAFFIC CONTROL ENVIRONMENT/CERTIFICATION

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Cooperative ADS/AAS Integration

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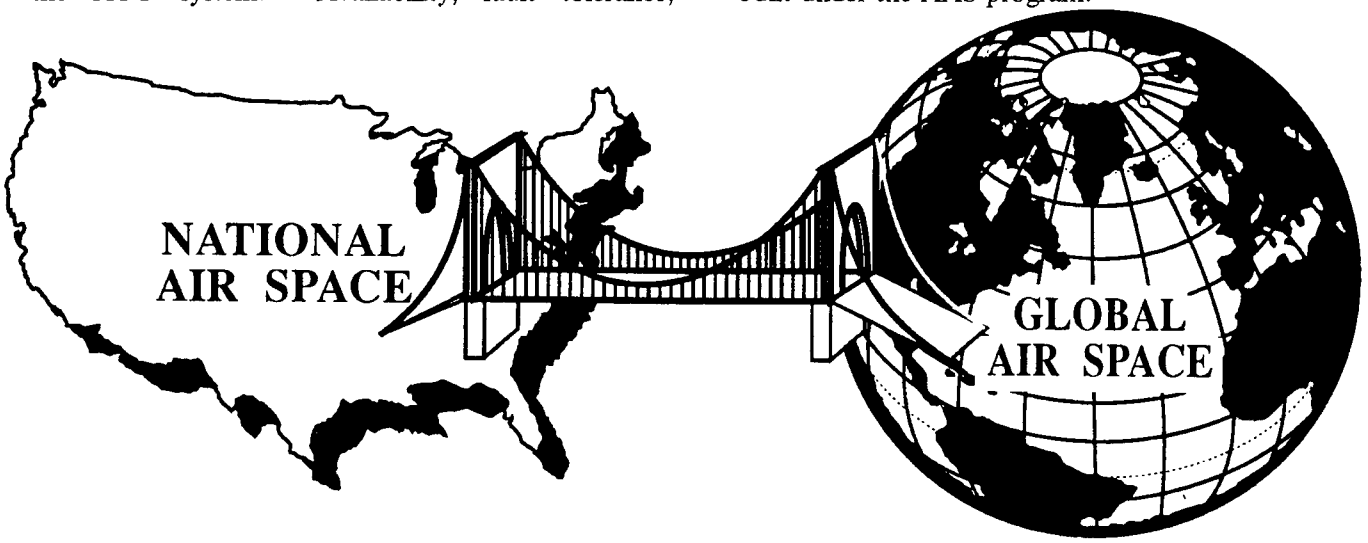
ABSTRACT

Automatic Dependent Surveillance (ADS) offers the aviation community major new capabilities for serving air traffic in oceanic areas and other remote regions. For that potential to be fully realized, it is essential that the FAA Advanced Automation System (AAS) be fully integrated with ADS so that Air Traffic control (ATC) services and communications based on ADS may be provided in a way similar to that now used in the radar environment.

An overview of the AAS is presented. The architecture of AAS has been firmly defined and is now embedded in the AAS acquisition phase contract. The architecture implements a distributed modular network. There are five operational segments, each providing automation enhancements for a portion of the ATC system. Availability, fault tolerance, operational flexibility, and interface growth to accommodate other evolving ATC systems were all considered from the outset.

ADS integration is not now specified as part of AAS. A suggested approach to providing an ADS interface with AAS is described, based on extending an existing AAS interface gateway module design while retaining the base distributed system concepts and standards. The AAS architecture includes radar gateway and communication gateway functions; these gateway functions are being implemented in AAS as distinct hardware and software elements. The AAS gateways could be adapted to provide ADS interface, thus providing a means for full utilization of ADS capabilities in the modern ATC system now being built under the AAS program.



COOPERATIVE AAS/ADS INTEGRATION
Figure 1

INTRODUCTION

Automatic Dependent Surveillance is evolving to meet the ATC needs for surveillance in regions where neither primary nor secondary radar services are available. Through the use of advanced navigation and communications technologies, the position of ADS equipped aircraft can be reliably monitored anywhere, bringing the potential of increased global airspace capacity through improved separation services. Once established, ADS can provide a vital surveillance bridge between the National and Global Airspace control systems, and is of significance to future AAS evolution for several reasons:

1. Aircraft will be transiting the border of National Airspace from/to regions where ADS will be only means of near real-time precision aircraft position surveillance. From the perspectives of both the controller and the pilot, a near seamless interface is desirable in consideration of safety and workload factors. In concept, a cooperative ADS/AAS integration would assure consistency in both the tracker and display data provided the controller.
2. The tracking performance of AAS could be significantly enhanced during critical passages by the inclusion of the track angle information contained in the extended ADS message. (The same applies to radar surveillance if track/heading were made available on the Mode-S data link.)
3. Some aircraft operating in National Airspace may not be visible to the Radar Facility.

Such potential improvements are practical due to the AAS design principles of distributed hardware resources, decentralized function allocation, and standardized data exchange among the many system elements with high performance Local Communications Networks. It is clear that the capabilities being offered for more efficient use of the airspace will inevitably result in the incorporation of ADS data by AAS, and the purpose of this paper is to offer a preliminary concept for that integration.

AAS ARCHITECTURE AND STATUS

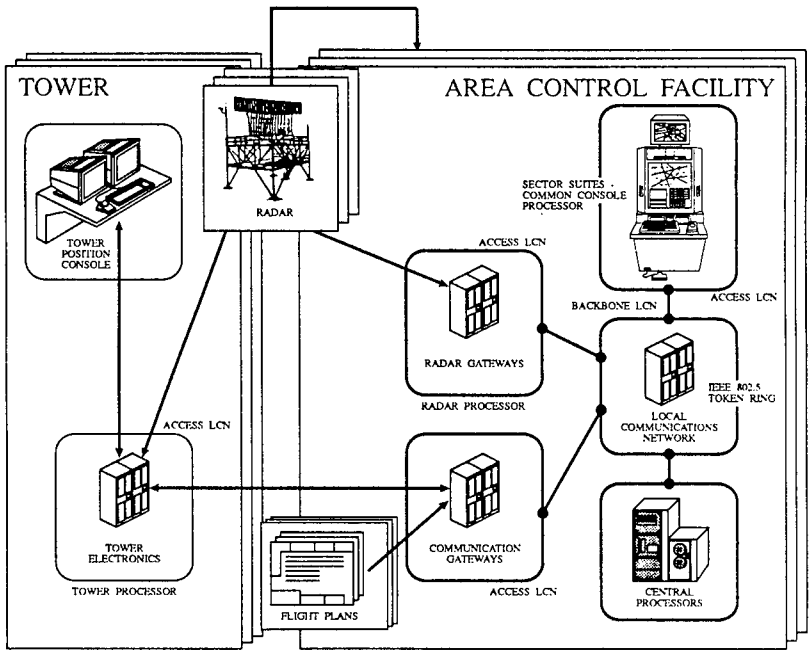
The architecture of AAS has been firmly defined [1] and is now embedded in the AAS acquisition phase contract. AAS is the largest FAA program in the National Airspace System (NAS) Plan. The Architecture definition and validation was carried out during 1983-88 in the competition phase of the program, and when completed at the end of the decade it will completely outfit the air traffic control services in the United States with modern automation systems.

The resulting architecture is a substantial evolution from that envisioned in the NAS Plan in 1983, although the central tenet -- using automation for increased airspace capacity and productivity while maintaining rigid safety standards -- has not changed. Improvements in availability, deployability, and extendability have been found practical as the design was detailed.

Architecture Description

The current AAS architecture partitions the AAS by type of ATC facility and by development phase. Figure 2 provides an overview of the Advanced Automation System which graphically depicts the distributed architecture and the extensive use of high performance redundant Local Communications Networks (LCN) which serve to integrate the system data and control. Some element functions (i.e. Radar) are shared among multiple facilities which may be geographically separated, but are connected with dedicated communication services.

A number of segments have been defined, constituting the AAS. Our emphasis in this paper is on the near-term major system segments, which are most closely concurrent with the overall ADS schedule. In total, AAS is structured into 5 operational system segments:



FACILITY OVERVIEW
Figure 2

- Peripheral Adapter Module Replacement Item (PAMRI) - a hardware segment upgrading radar and communications Input/Output (I/O) hardware in the Air Route Traffic Control Centers (ARTCCs).
- Initial Sector Suite System (ISSS) - the first major system delivery, including new controller workstations, a new data communications network linking the workstations to the existing central processors, and additional central processors. Each ARTCC will be equipped with ISSS.
- Terminal Advanced Automation System (TAAS) - automatic systems for the Terminal Radar Control (TRACON) function, including the consolidation of designated TRACONs into ARTCCs.
- Tower Control Computer Complex (TCCC) - automation systems for Airport Traffic Control Towers, including interfaces to supporting TAAS.
- Area Control Computer Complex (ACCC) - a software-only upgrade to the ARTCCs (renamed Area Control Facilities [ACFs] when TRACONs are consolidated into ARTCCs) to provide enhanced ATC functions.

Other non-operational segments will also be provided at the FAA Technical Center for support to the operational segments.

The ISSS Segment will equip each ARTCC with several hundred new workstations, called Common Consoles, replacing the existing M-1 consoles and Flight Strip Printers. Significant processing capacity is distributed as part of each Common Console in the form of general purpose computers and of specialized display graphics support. Most of the Common Consoles of the ARTCC are used as workstations for Air Traffic Controllers; a few are used for other supporting functions, such as facility control by the System Engineer. From one to four Common Consoles are allocated to each sector in the ARTCC depending on the number of Controllers operating the sector, a geographic subarea of control assignment.

One of the design tenets of AAS is to replace paper with electronic displays. The Common Console is the primary vehicle for carrying out that change of operational concept for ATC purposes. The key display device of the Common Console is the Main Display Monitor, a 20 by 20 inch Sony color display with 2048 by 2048 pixel resolution. This is the display surface used by the Controller for all operational ATC: it shows all required graphical and text displays. No paper flight strips are used, which drives the stringent availability requirement of 0.9999999 for annotated radar separation service displays. The Main Display Monitor is augmented by an Auxiliary display, a 1024 by 1280 pixel color display mounted directly above the main display. The purpose of the Auxiliary Display is to show static data, e.g. charts, reference publications -- replacing paper reference publications. These display surfaces are driven by an IBM RISC System/6000 processor and a Ratheon Main Display Controller, providing the very substantial computation, storage and graphics generation required. Controller command input is through a standard QWERTY keyboard and trackball.

The Common Console also includes elements of another system that is not part of AAS: the Voice Switching and Control (VSCS). VSCS provides the voice communications switching capability, both landline and radio, used by the Controllers and other personnel for intra-ARTCC, inter-ARTCC, and air ground voice communications. Each Common Console includes two VSCS control modules, which are connected with the VSCS switching and control system in the ARTCC.

Most of the primary flight plan processing in the ARTCC remains in the existing Host central processing system at the time of ISSS introduction. Communications and radar interfaces are provided through PAMRI, which precedes ISSS to the field.

TAAS, the next AAS segment to deploy, provides a replacement for the existing ARTS terminal automation systems. TAAS also represents a new operational concept, in that the TAAS automation system will be located at the ARTCC that provides enroute ATC services in that area. This consolidation, where possible at larger terminals, will provide savings in long term operations and maintenance expenses. Smaller terminal areas will continue to be served by facilities located at their airports.

TAAS brings additional Common Consoles to the facilities, and a new central processing suite. The intra-ARTCC data communications system will be extended as part of integration with the existing ISSS enroute automation system already operational at the ARTCC.

The last two segments to deploy are TCCC and ACCC. TCCC will provide a new automation system for Airport Traffic Control Towers, enhancing the predominantly manual system now used. ATC services within the local area of an airport rely on visual input, and thus the implemented functions are formulated to be very interactive to efficiently aid the Tower Controller. Each TCCC is tightly linked with its associated ACCC to facilitate the handoff of traffic arriving and departing the airport.

ACCC, predominately a software upgrade, integrates the separate ISSS and TCCC functions into a consolidated system, ACCC, and enables removal of the outdated Host processors. Mode-S data link capabilities are included in this segment definition.

Development Status

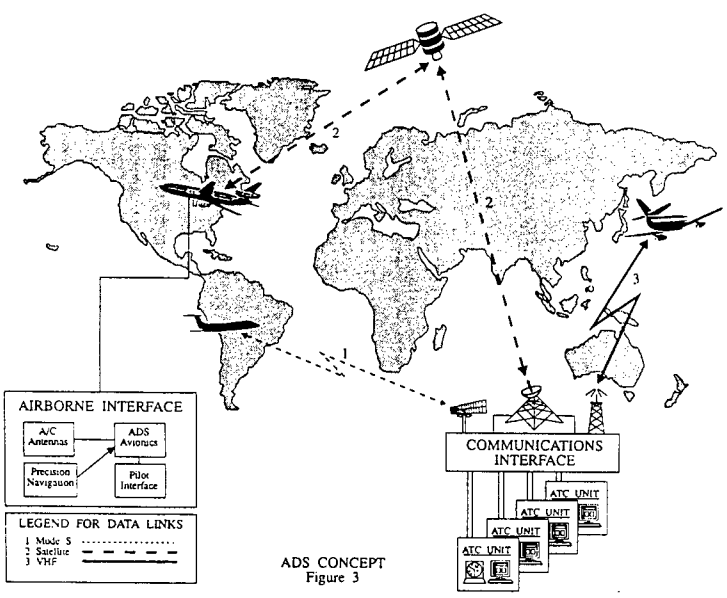
All ISSS hardware development has been completed, and the initial PAMRIs have been deployed as the initial step in the system transition evolution. The principal current development activity is ISSS software, most of which operates in processors contained in the Common Consoles. Over half of this software is in test. Delivery of the first complete ISSS to the FAA Technical Center will occur early the fourth quarter in 1992. After a several year test at the FAA Technical Center, deployment of tailored ISSS automation systems to the 20 CONUS ARTCCs will start.

The other operational segments are in the last stages of software design and early development. While there are relatively minor hardware development efforts associated with these other segments, the principal development effort is software.

System delivery schedules extend over many years, with the last installation being the TCCC system for Hilo Tower, Honolulu in 2001.

AUTOMATIC DEPENDENT SURVEILLANCE

Automatic Dependent Surveillance is an evolving concept to provide precision aircraft position information in near real-time on a global basis. Figure 3 depicts the system concept of automatically providing onboard precision navigation data (e.g. GPS) to an ATC unit by way of a digital data link (e.g. Satellite). Proof of Concept engineering trials have been conducted on Pacific Oceanic routes [2], and the potential use of such technology for Oceanic ATC [3] has been well documented by Peter Massoglia, et al.



ADS CONCEPT
Figure 3

Performance of ADS position reporting can be comparable with the Mode-S radar facility at the higher message rates service. Data specifications for the two surveillance systems [3] [4] are comparable as is presented in Table 1. The Mode-S capability represents the best anticipated radar service, but achieving this service is dependent on upgrade of both the radar and the Common Digitizer equipment. In fact ADS would clearly be the superior if full accuracy GPS service were made available rather than the degraded Horizontal Reference service commitment for civil applications as indicated in the table.

Table 1. Surveillance Data Characteristics

	ADS	Mode-S
Horizontal Reference	100 m*	2 m
Position	75 ft	79x722 ft @100 nm
Altitude	2.4 m	100 ft Q
Track/Heading	0.1 deg	Not Available
Data Set Period (min)	10 sec	4.2 sec

(* - Not Corrected for SA)

Global digital communications by satellite are now available as of last March [5], and the net economic rewards [6] for increasing the capacity of Oceanic Airspace through the application of ADS data is significant. The Air Transport Association [7] not only states near term requirements for ADS surveillance on international non-radar routes, but projects the application of ADS surveillance in domestic airspace. It is clear that with ICAO support, the ADS concept is about the blossom into a vital element of international ATC systems.

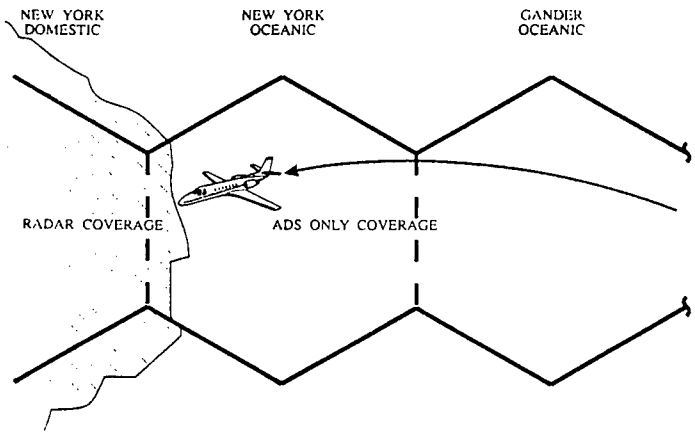
COOPERATIVE ADS/AAS INTEGRATION OPPORTUNITIES

Clearly separation services and flight plan conformance monitoring in the National Airspace will continue to rely on Radar Facilities. Many of the domestic aircraft can not be expected to carry ADS equipment, and the primary radar capability does add significantly to safety in the presence of aircraft equipment failures. Questions do however arise when comparable surveillance performance is available from another method of surveillance and the boundaries of service aren't physical surveillance constraints.

Surveillance Sensor Transition

ADS service appears inevitable for Oceanic Airspace, but what happens when an aircraft transitions to/from National Airspace as is depicted in Figure 4? Is the transition abrupt? Is ADS data of

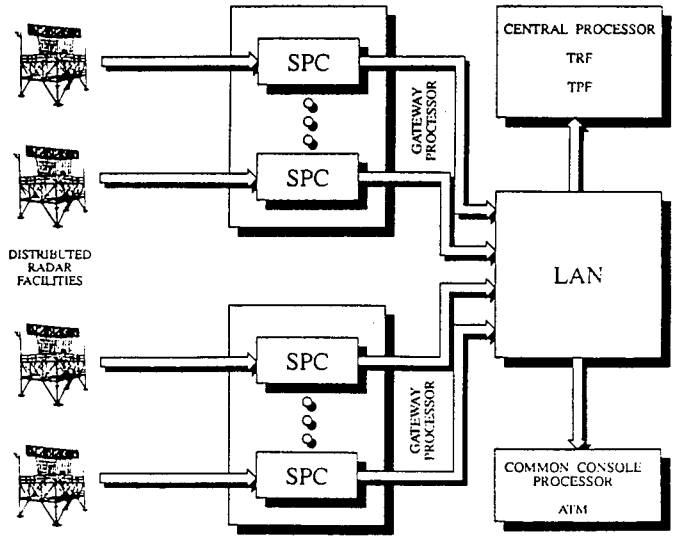
no use in domestic airspace? Is established NAS track data of no initial value to the Oceanic ADS system?



AREA CONTROL
Figure 4

Precedent does exist for handling such transitions in domestic ATC. Data from one Radar Facility is distributed to more than one ARTCC when its surveillance coverage is of value to both facilities. In this way, controllers at both Centers can utilize the same sensor data during the handoff. This section will describe the integration of the Radar Sensor in the AAS distributed system architecture. The flexibility to easily accommodate additional sensor interfaces on the Network ring while retaining the existing ATC display and track functions without disruption is significant for expandability of center capabilities. In concept, the surveillance situation with ADS need be no different for either the Oceanic Airspace transitions or for joint sensor use within National Airspace.

Figure 5 illustrates the Surveillance Data flow in the AAS architecture. Multiple Radar Facilities provide range and azimuth data to their associated surveillance Processing and Correlation (SPC) function implemented in Radar Gateway Processors. The resulting processed information is distributed to both the Common Consoles and the Central Processor by the system of Local Area Networks (LAN).



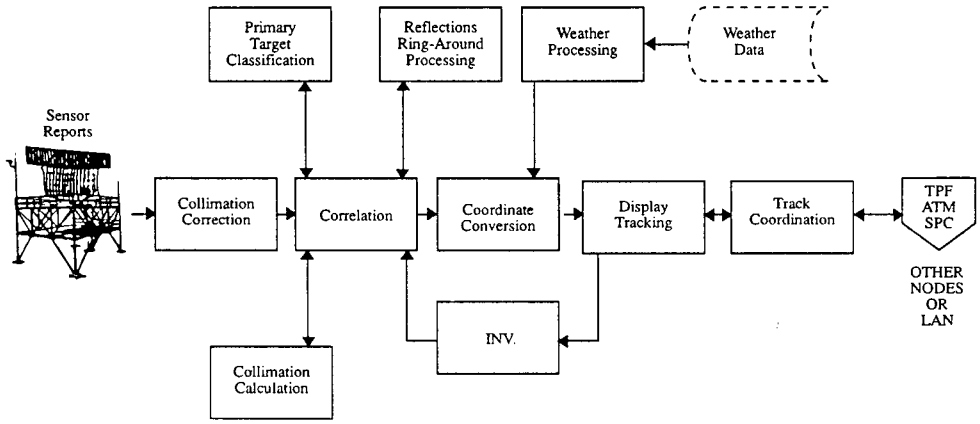
AAS SURVEILLANCE DATA FLOW
Figure 5

An overview of the SPC data flow is provided by Figure 6. Although some of the functions are unique to the processing of Radar data, most are generic to processing surveillance data to support ATC. Correlation initiates, maintains, and terminates tracks on aircraft targets. Correlation's main job is to identify and associate incoming target reports with existing tracks at the center. When a set of reports are received which don't match an existing track, a new track is initiated for the system.

The coordinate conversion process converts the position of the target reports to the sterographic system plane for that ARTCC. The display oriented smoothing and prediction functions maintain the 2 - dimensional horizontal track estimation states for display to the controllers and also maintain the vertical track. Extrapolation to the next expected sighting of the aircraft is included to compensate for the low raw measurement rate.

Once an update to the track state is made, the new track state and covarience is broadcast to other SPCs (processing input from other Radars). It is the object of the Track Coordination function to keep one track identifier among all SPCs for a single aircraft. This is accomplished by "track fusion" in the Track Coordination function which associates multisensor contact of one aircraft. Once the

association is firm, measurements from other sensors are shared as input to the display tracker, establishing the multisensor tracking capability among all sensors on the Local Area Network (LAN) rings.



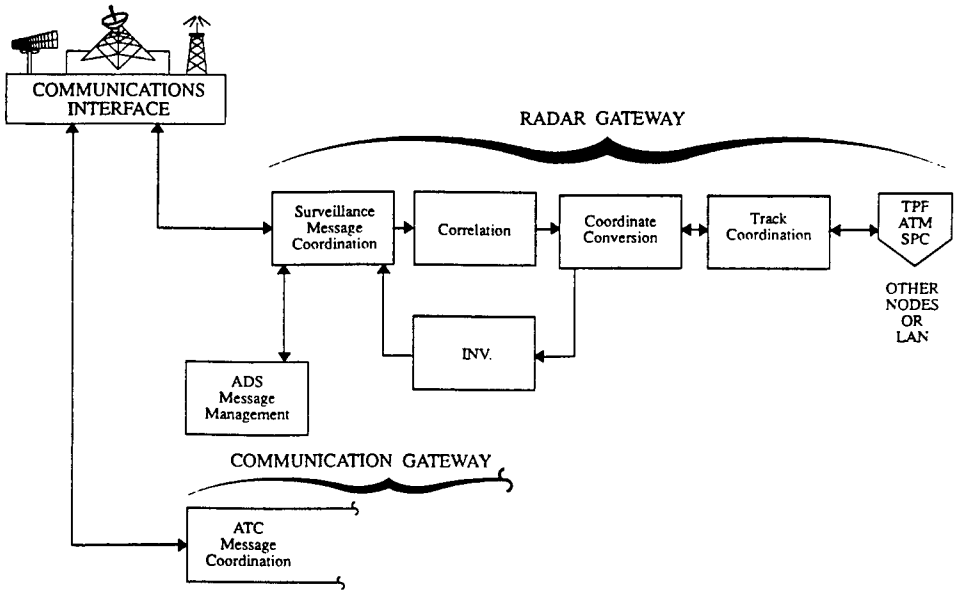
RADAR SENSOR
SPC DATA FLOW OVERVIEW
Figure 6

Note that it is the SPC in the Radar Gateway that for a single sensor initiates the aircraft track, maintains the extrapolated real-time track, distributes the data to the Aircraft and Track Management (ATM) function in the Common Console to drive the controller's display, and implements the surveillance sensor transitions as the aircraft moves through the sensor's coverage area. It also establishes the target association and data sharing among the SPCs to achieve the advantages of multisensor tracking.

Data is also distributed to the Central Processor to drive the Separation Assurance Horizontal Tracker (SAHT) in the Tactical Prediction Function (TPF). Its output is used in the Conflict Alert, the Minimum Safe Altitude Warning, and the Conflict Resolution and Advisory functions. Resolutions are derived in and the associated Tactical Resolution Function (TRF).

Adaptation for ADS

The tracking and flight plan processing functions of the automation system could use ADS position data in almost the same manner as for radar tracking information. The ADS capability would be integrated into AAS as a pseudo-sensor. With an SPC function for ADS implemented in a gateway, all transactions on the LAN could be identical to those for radar sensors and AAS architecture would by its design support the controller displays, separation assurance functions, multisensor tracking (ADS & radar), and surveillance sensor handoff. The surveillance transitions would be seamless in terms of data utilization and display, although it would be prudent to include a display symbol distinction so that the utilized sensor type is clear to the controller. Separation assistance via conflict alerts and conflict resolution advisories could be extended to oceanic traffic. Figure 7 illustrates a SPC data flow appropriately modified for the ADS sensor, and the congruency of data flow with that for the Radar



ADS PSEUDO
SPC DATA FLOW OVERVIEW
Figure 7

Sensor is obvious. Radar unique processing is stripped away, and the correlation function would be performed in spherical geographic coordinates rather than range-azimuth of the radar. However, the baseline SPC data flow and control structure would be retained for system operational compatibility.

This ADS SPC would coexist on the LAN as just another surveillance input adapter node and full ATC functionality would be achieved for ADS throughout the center. Seamless integration of the ADS sensor would help the controller by making additional ATC information available without imposing new display or system operation burdens. Heinrich and Wank report measured crew error reductions on the flight deck due to workload reduction when Digital Data Communications is used to integrate ADS, and the same is expected at the controller's end if the integration adheres to the established display and data utilization standards of AAS. The Cooperative ADS/AAS Integration concept is summarized by Figure 8, which portrays the Aeronautical Telecommunications Network as a typical and probable communications service to support all ATC needs has been described by Ludwig and Weiss (9) and also by Aleshire (10).

Enhanced AAS Capabilities

Integration of ADS information into the operations of AAS will enhance the ATC capabilities at the center. This paper has established the conceptual feasibility of incorporating ADS information as another surveillance source consistent with the established system operations which will extend the vision of the controller and ease the transition from/to oceanic (or other area of limited surveillance opportunity) while retaining normal AAS system operations familiarity. Cooperative integration with ADS will extend the AAS functional features of Radar surveillance to the ADS and the ADS/Radar environments.

COOPERATIVE ADS/AAS INTEGRATION

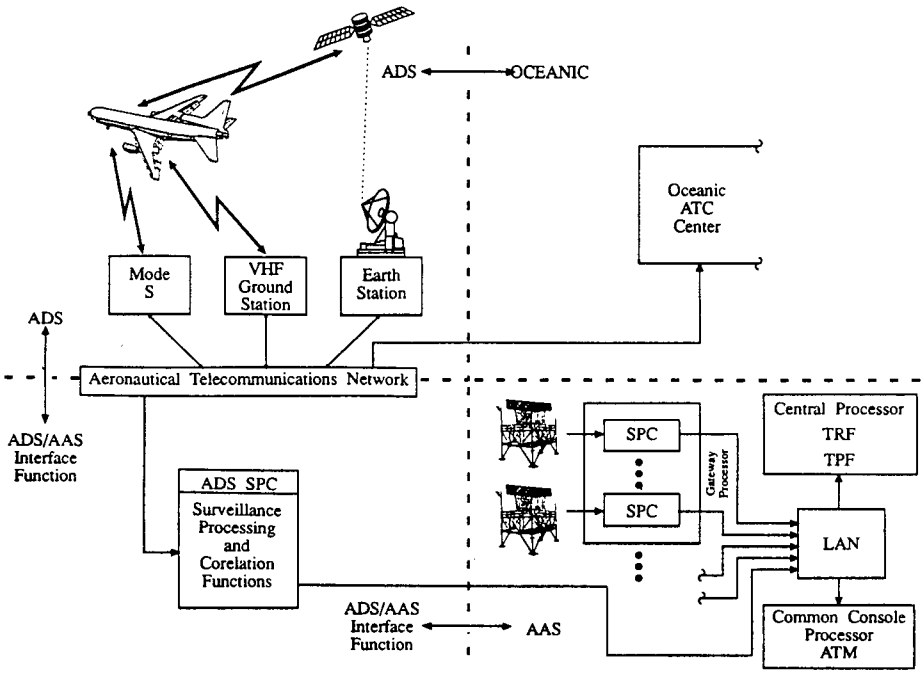


Figure 8

The potential for additional AAS performance enhancements exists due to the rich data content of the ADS message. Although not deemed critical, these could add to the AAS capabilities in busy airspace which often exists in the vicinity of oceanic terminals. ADS provides valuable track measurement information not available from the radar sensor such as track angle, speed, vertical velocity, and improved altitude reporting quantization. If made available to prompt the trackers, less lag would be encountered when an aircraft enters or terminates a maneuver.

At best, ATC is data poor due to the low aircraft contact rate of the mechanically scanned radars. Filters are used to provide smoothing and to extrapolate the position so as to improve the utility of the displays. In crowded airspace , logic must be applied to detect the exact initiation time of an aircraft maneuver. The filter tracking is managed on the basis of these detections to prevent a lag in the displayed information while retaining the desirable smoothing for normal flight. The design is sensitive, and the displayed information must have integrity including time currency at all times. Figure 9 illustrates the onset of a constant rate turn, and shows the difficulty of determining the onset from position data alone. The deviation form projected track is very gradual. However the heading trend changes abruptly at the transition, and fewer measurement opportunities are required to firmly establish the presence and time of a maneuver. Digital Data Link data could be of great value to tracking and with the Mode-S data link, a real-time heading or track information may become available for many aircraft. The data should be used when available.

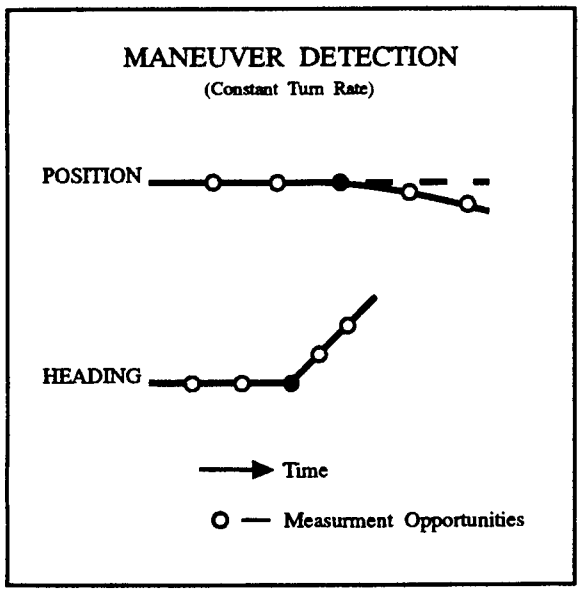


Figure 9

Consistency of operations is the most important AAS enhancement that would result with the Cooperative ADS/AAS Integration. One of the objectives of the NAS plan was to achieve increased airspace capacity while containing the workload through automation. Artificial boundaries adopted for the convenience of ATC are envisioned to become less distinct as the capabilities evolve to handle more direct routing. The newer aircraft have the range to avoid the congestion at established gateways to Oceanic Airspace gateways. The concepts presented in this paper provide AAS the flexibility to make the bridge to global airspace without geographic constraint.

CONCLUSIONS

Summary

The AAS implementation and function make it an ideal base for integrating extended ATC functions. The ease of function extendability was a stated initial design objective, and this paper's consideration of ADS data utilization shows that future accommodation of ADS surveillance is clean. A near-seamless interface to the ADS system in terms of surveillance handover and information utilization would not be disruptive to the AAS architecture. This product of the established distributed system principles will permit a close integration of Air Traffic Control functions to reduce Controller/Pilot workload and to increase the operational flexibility available for efficiently managing the limited airspace resources. The modular distributed architecture of AAS has proved valid as a technique to permit future accommodation of new interfaces and function with little waste impact on any component.

Major Issues

Many issues must be resolved to achieve the Cooperative ADS/AAS Integration as suggested by this paper. Communications Services are obviously required to acquire the ADS report on a timely basis. Space communications are relatively expensive, and the mechanisms to economically share the ADS data is not clear. It is our understanding that all of the anticipated communications system concepts (i.e. ATN, AVPAC) are conceived to be point-to-point which would impose the expense of redundant communications with the aircraft to share data of joint utility to two or more facilities. A mechanism to permit multiple user application nodes at the ground is very desirable to make best use of the surveillance data within the constrained financial and bandwidth resources.

Management of the ADS message reporting rate will be an issue due to the economic implications. Clearly a dynamic assignment of ADS message rate based on the current local traffic situation has the potential of achieving the most benefit for the incurred operating cost. However a fixed cost investment would be required to logically merge multiple requests so as to cover the most demanding, and such economic considerations may preclude automatic adjustment of the reporting rate.

Use of multisensors (even if they are both radar facilities) are sensitive to sources of registration error. GPS has the inherent required accuracy in the WGS-84 geodetic system, but full accuracy service is unlikely. Many of the receivers automatically convert position to locally preferred datums, and the user of ADS should understand the reference specific to the received data. This topic must be be reviewed when joint use of radar and ADS data is considered.

Navigation service integrity is critical to the use of ADS in ATC. Today's convention is to provide the controllers with timely Navigation Service status independent the aircraft. As use of GPS by aviation evolves, the protection of ADS operations in National Airspace should be covered.

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CO-AUTHOR

CHARLES A. KENGLA is a Senior Engineer in the Advanced Automation System program of the Federal Sector Division of IBM. He is Program Manager for Automated En Route ATC, Phase 2 (AERA 2). His earlier assignments have generally been in the development of satellite communications systems, data communications, and communications switching systems. He has 29 years experience in government and military command control communications and intelligence systems. He has a BSE from MIT, and a MSEE from George Washington. He holds a Commercial Pilot license with an Instrument rating.

Operational Oceanic Air Traffic Control
Using Satellite Data Link - Initial Implementation

Presented by: Donald Armstrong, Manager
Flight Test Branch, Aircraft Certification Office
Federal Aviation Administration

Background

Operational air traffic management for oceanic flights currently depends on voice communications over a high frequency (HF) radio link. Information, requests, clearances and acknowledgements (verification of received messages) for Air Traffic Control (ATC) and Air Operations Control (AOC) in today's operational environment are handled by the exchange of spoken messages.

The HF radio communications are provided for the FAA by ARINC personnel located at three Comm Centers: San Francisco, New York, and Honolulu. The ARINC operators act as intermediaries for both the oceanic air traffic controllers and the plans that traverse U.S. Flight Information Regions (FIR).

System performance under this approach suffers from long transaction times and error rates on the order of 1%. Performance will degrade as the increasing oceanic traffic drives the allocated channels toward saturation.

The same air traffic management can be accomplished more efficiently using data communication procedures. Data transactions can be completed much more rapidly and with higher accuracy and integrity than voice transactions.

Objectives

Develop a phased transition plan for ATC/DataLink implementation.

- A logical step-by-step transition from the first demonstration into progressively more complete Air Traffic services via satellite will pave the way toward the development of concepts for improving the efficiency of air-space management, including the capacity to handle growth.

Contribute to the long-term development of both airborne and ground automated systems incorporating flexible systems to meet future ATC System demands.

- Although there are many differences in the details of messages used in the Domestic ATC System, compared to the Oceanic ATC System, the principles by which DataLink are to be applied are very similar. United Airlines is keenly interested in applying the knowledge gained from the Oceanic ATC/DataLink Trials and operations with the Interim System to the Domestic ATC scene.

Demonstrate the use of satellite data communications for Air Traffic Services.

- Transmit Waypoint Progress Reports via ACARS/SATCOM through the ARINC network directly into the ODAPS computer, in the same format used for HF Voice reports but with much higher accuracy.

- Transmit pilot requests for clearances using ACARS/SATCOM and the response from ATC over the reverse route.

- Continue to demonstrate the reliability of ADS position reports until such time as the FAA's ground computer system is ready to process same routinely.

The FAA has approved a plan for implementation of satellite data link through a five phased approach which provides for the incremental introduction of satellite data and voice communications into ATC. The phases are described as:

PHASE 1 - Satellite data link between aircraft and ARINC communications center. Satellite two-way data link and HF between Aircraft and Communication Center.

Phase 1 will provide demonstration of capability of two-way data link between aircraft and communication center.

PHASE 2 - Satellite voice between aircraft and ARINC communications center. Begin pre-operational voice trials (both satellite a HF to ease transition of voice backup capabilities. Use of voice link between Aircraft and Communication Center for both back-up (no procedural changes for controller).

Phase 2 will demonstrate the capability of satellite or HF voice between ARTCC, communication center, and aircraft.

PHASE 3 - Data link and voice between aircraft and ARINC. Two week trial period of operational cutover at OAK, demonstrating capabilities achieved in Phase 1 & 2. One way data link capabilities between aircraft and individual ARTCC sectors for operational cutover - HF voice replaced by data link between aircraft and communication center (communications become operational). Communication center will route data to specific sectors ZOA. Data received on printers and by ODAPS.

Phase 3 will result in operational implementation of two way data link between a/c and communication center, and one way data link from communication center to individual sectors.

PHASE 4 - Prototype workstation development for two-way data link. Pre-operational test phase. Install RS-6000 workstation with two-way data link capabilities between aircraft and FAATC. Install a workstation at ARTCC for pre-operational evaluation. Verification of interface capabilities to ODAPS and DOTS. Development of requirements and procedures for operational implementation of workstation.

Phase 4 will result in the demonstrated capability of two-way data link between ARTCC and aircraft.

PHASE 5 - Operational two-way data link workstation (based on availability of RS-6000). One month trial period of operational cutover for two-way data link at each sector within ARTCC, demonstrating capabilities achieved in Phase 4. Integrate satellite data and voice communications. Two-way data link (including oceanic clearance) fully operational within ARTCC on RS-6000. Satellite voice used for operational routine communications and as operational backup for non-route communications. In this phase, satellite data link will be the primary operational means of communication. Satellite voice will be primary backup. HF voice will be secondary backup. Phase 5 will result in the pre-operational verification and subsequent full implementation of end-to-end two-way data link with satellite voice backup.

Benefits

United Airlines predicts substantial savings in fuel burn due to the reduced time to receive

stop-climb clearances. In some cases, these fuel-burn reductions will be enough to eliminate diversions for added fuel; unplanned fuel stops are typically very costly events in trans-oceanic operations.

Data Collection

The FAA Technical Center (FAATC), in support of the certification of satellite data link for use in air traffic control (ATC), will include the collection, reduction, and analysis of data link messages transmitted to and from commercial aircraft during oceanic flights.

The initial certification of satellite communications for ATC will enable data link communications between the aircraft and the Aeronautical Radio, Inc. (ARINC) communications centers only. Communications between the communication centers and the ARTCCS will remain procedurally the same as today during the initial phases of implementation. Downlink messages from the aircraft will be addressed by the Communication Center to the appropriate ADNS printer within the ARTCC. Duplicate messages will be sent to the Oceanic Display and Planning System (ODAPS) which is used to provide flight data processing for oceanic ATC in the U.S. In the forward direction, messages from the controller will be communicated to the Communication Center by voice, as performed under current procedures. At the Communication Center, the uplink will be transcribed into the ARINC Air/Ground System (AGS) by the radio operator, and then sent to the aircraft via data link. The use of high frequency (HF) radio communications will remain available for backup.

United Airlines has applied for certification of an enhanced ACARS MU, transmitting the satellite data link for two-way ATC communications in oceanic airspace. In support of this effort, a data collection program is required to establish validity of data communications for certification by the FAA Aircraft Certification (ACO) in Long Beach, California.

This plan is designed to evaluate performance of the existing satellite data link and verify the proposed ATC data link communications procedures, based on an analysis of the messages transmitted and received by end users. The communication architecture is gradually evolving into a bit oriented system, fully conforming with the ADS and ATN standards currently under development. The goal of this test plan is to evaluate performance from the end user perspective, without regard to the characteristics of the underlying communications media.

During the flights, the HF progress reports, data link progress reports, HF ATC clearance requests and responses, data link ATC clearance requests and responses, and all transcribed uplinks for the satellite equipped aircraft will be copied to the FAATC for evaluation. The FAATC will receive a log of the transmitted and received aircraft messages from the airline.

Archives of the data will be maintained at ARINC headquarters. In addition, a hard copy of all messages which are sent from the communication center will be available for up to thirty days after the flight.

Data Reduction and Analysis

The data collected at the FAATC will be compared for consistency and transmission delays between satellite data and HF transcribed data, and between the data recorded on-board the aircraft and data transmitted and

received on the ground. Evaluation of the data will be based on the following parameters:

- Technical Time Delay
- Operational Time Delay
- Undelivered Messages
- Message Integrity

Conclusion

The ICAO Future Air Navigation System (FANs) outlines the importance of an iegrated Communications, Navigation, and Surveillance (CNS) approach to Air Traffic Control. The transition from voice based to data link system require flight deck and ground procedures development.

The first SATCOM-based data link messages were exchanged just last September (1990). This trials demonstration, under the auspices of the FAA as the Pacific Engineering Trials (PET), has demonstrated automatic and pilot entered messages origination and ground based uplink capabilities. It is the intent that a step-by-step approach be taken to ensure proper procedural and end system development. The two-way data link trials will further support the growth and establishment of air traffic management via data link.

SESSION FOUR: AIR TRAFFIC CONTROL ENVIRONMENT/CERTIFICATION

PANEL DISCUSSION:

"Operational Approval and Implementation of Satellite Data Link into the Oceanic Environment"

PANEL MEMBERS

Donald Armstrong
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William L. Umbaugh
Manager, Automation
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SESSION FOUR: AIR TRAFFIC CONTROL ENVIRONMENT/CERTIFICATION

PANEL BIOGRAPHIES

ONLY THOSE BIOGRAPHIES ARE LISTED THAT DO NOT APPEAR ELSEWHERE.

Howard E. Hess
Federal Aviation Administration

Howard E. Hess's responsibilities as the Special Programs Branch Manger includes:

- Providing the focal point for developing and implementing national concepts, policies, standards, criteria, guidance, and procedures related to the flight operational aspects of enhanced air traffic control concepts, human factors, navigation systems, separation assurance, and other complex and controversial flight technical programs.
- Developing flight operational concepts, criteria, requirements, specifications, and limitations for the introduction of new en route navigation systems.
- Conducting in-flight tests and evaluations of special technical concepts and procedures.
- Providing technical representation to ICAO on matters related to complex and controversial special technical operations.

Currently Mr. Hess is the Flight Standards advisor to ICAO's North Atlantic Systems Planning Group and the Informal Pacific ATC Coordinating Group. Additionally he is an advisor to the Gulf of Mexico Task Force, and has been a participant in the FAA delegation working toward the development of new air routes and expanding air traffic services between the U.S. and U.S.S.R.

Mr. Hess's branch has been designated as the sponsor for the operational implementation of new satellite technologies. Personally, Mr. Hess has been designated as the FAA Headquarters project pilot for the certification of the Boeing 777.

SESSION FOUR: AIR TRAFFIC CONTROL ENVIRONMENT/CERTIFICATION

PANEL BIOGRAPHIES

ONLY THOSE BIOGRAPHIES ARE LISTED THAT DO NOT APPEAR ELSEWHERE.

John A. Scardina
Federal Aviation Administration

John A. Scardina is manager of the Automation System Engineering Division within the Federal Aviation Administration's (FAA) NAS System Engineering Service. In his current position, he is responsible for planning the evolution of the FAA' ATC automation systems in the various operation domains, including en route, terminal, tower, oceanic, traffic management, flight services, and data link, as well as for ensuring that these automation systems are properly interfaced with and integrated into the National Airspace System. This is accomplished by working closely with the operating service to determine their needs and translate them into operational requirements which in turn forms the basis for FAA R&D and acquisition activities.

Other assignments in the FAA have included technical and managerial contribution to the advanced automation program, weather programs, remote maintenance monitoring, collision avoidance systems, oceanic automation, and the aerostat program. Prior to joining the FAA in 1975, Dr. Scardina was a Group Leader with the MITRE Corporation in McLean, Virginia, where he worked on automation systems and satellite applications for the FAA and Department of Commerce.

Mr. Scardina received the BSEE degree from the Virginia Polytechnic Institute, Blacksburg, Virginia, in 1964, and the M.S. and Ph.D degrees in Electrical Engineering from the Georgia Institute of Technology, Atlanta, Georgia, in 1966 and 1968, respectively.

SESSION FOUR: AIR TRAFFIC CONTROL ENVIRONMENT/CERTIFICATION

Dr. Clyde A. Miller
Manager, Future Design Staff
Research and Development Service
Federal Aviation Administration

Dr. George C. Chang
FTMI Project Manager
Federal Aviation Administration

FLIGHT OPERATIONS AND AIR TRAFFIC MANAGEMENT INTEGRATION

Dr. Clyde A. Miller
Dr. George C. Chang
Federal Aviation Administration
Washington, D.C.

Abstract

Flight management systems are installed in many air carrier and business aviation aircraft for the purpose of assisting the flight crew in assuring a safe and efficient flight trajectory in accordance with the cleared flight plan. The FAA and other air traffic management service providers are aggressively pursuing automation improvements to enhance system capacity and to better accommodate user operations along their preferred flight trajectories. Recently, the FAA launched a comprehensive R&D project focused on the use of air-ground data link for integrating the operation of airborne flight management computers and ground-based air traffic management automation. An initial project plan will be available in October, 1991 for discussion with airspace users.

Goal and Objectives of Air Traffic Management

The goal of the air traffic management (ATM) process is the safe, efficient, and expeditious movement of aircraft. The principal subsidiary processes are: (1) air traffic control (ATC) to prevent collisions between aircraft and to assure that aircraft do not violate special use airspace and (2) traffic flow management to allocate traffic flows to scarce capacity resources.

The following specific objectives of the ATM process are relevant to this paper:

- Maintain and improve the safety of flight operations
- Increase system capacity and fully utilize capacity resources as required to meet traffic demand
- Better accommodate user-preferred flight trajectories
- Increase user involvement in decisionmaking and option management.

Note: This paper was presented at the Third Annual International Aeronautical Telecommunications Symposium on Data Link Integration, McLean, Virginia. May 20-23, 1991.

The extent to which users operate in accordance with their preferred trajectories (routes, altitude profiles, speeds, and times of departure and arrival) is inversely related to the extent to which the ATM process intervenes to assure that trajectories meet essential ATM requirements (principally separation standards and airspace and flow restrictions). A minimum intervention rate requires effective planning and decisionmaking based on a reliable data base of relevant information. The information required includes system capacity resources available, demand forecasts, expected weather conditions, status of airway facilities and airports, aircraft performance characteristics, and user operating objectives.

It is apparent that:

- Not all of the required information is nominally in the hands of the ATM service provider; important elements are available only from users.

- Similarly, the planning and real-time decisionmaking required are shared responsibilities. The flight dispatcher, the flight crew, and the ATM service provider are all involved.

- Effective planning and decisionmaking require that all decisionmakers are provided the same data on common information elements. There cannot be three versions of the wind velocity at 30,000 ft over Cincinnati, one version for the flight crew, another for the dispatcher, and a third for the ATM service provider. The correct wind velocity should be provided to all three.

- The objective stated earlier that user involvement in decisionmaking should increase is simply recognition that effective air traffic management requires teamwork among the three operational elements based on shared information and on dialogue and negotiation to arrive at effective solutions.

Flight Management System and ATM Automation Developments

It is sometimes suggested that ATM planning and decisionmaking should be relegated to the cockpit. Today, three parties share these responsibilities; it seems certain that all three will be involved for the foreseeable future. Nonetheless, new functions and responsibilities will migrate to the cockpit based on new aircraft capabilities, in particular, improved navigation and data link systems and sophisticated flight management systems [1].

Current flight management systems (FMSs) support flight planning with provisions for entry, storage, and modification of a complete flight plan from the departure gate to the destination runway. They also provide guidance commands for the autopilot to automatically fly optimum vertical profiles and speeds along the prescribed route of flight, including the capability to arrive at prescribed waypoints at specified times (4D navigation capability). The objective of flight management automation (the FMS) is to assist the flight crew in assuring a safe and efficient flight trajectory in accordance with the cleared flight plan.

Automation in the ATM facility is intended to aid controllers in assuring that aircraft trajectories meet essential ATM requirements (separation standards, etc.) with minimum disruption to operators' flight paths. Current FAA initiatives include the development of a series of sophisticated terminal automation aids in cooperation with NASA [2,3]. Comprehensive computer-based planning will assist controllers in metering, sequencing, and spacing arrival traffic in order to make best use of available runways. Capacity improvements approaching 25 percent may be achieved for a single runway in instrument weather conditions with less vectoring and speed adjustments than the flight crew would experience today. Initial field evaluations of these techniques are planned at Denver and Dallas/Ft. Worth beginning in 1992. National deployment is anticipated in the 1994-1995 time frame.

In the en route environment, a number of automation aids to support traffic planning at the sector level have been developed by the Automated En Route ATC (AERA) initiative [4]. These aids will assist controllers in detecting and resolving aircraft trajectory conflicts with ATM requirements (e.g., predicted violations of separations standards and special use airspace restrictions), in monitoring aircraft conformance with flight plans, and in coordinating traffic planning among sectors. AERA will include a number of data link applications for delivering clearances and ATC instructions to the cockpit, for filing flight plans and amendments from the cockpit, and for better predicting future positions of aircraft [5,6]. National implementation is scheduled for the 1999-2000 time frame.

Flight Operations and ATM Integration

A principal theme of the future ATM system will be integrated operation of flight management and ATM automation [7,8]. As shown in an attached illustration, air-ground data link communications will be the principal ingredient in effecting this integration.

A number of studies have begun to look at this subject in some detail. NASA has flight tested a data link system in their Transport Systems Research Vehicle (TSRV) B-737 aircraft [9]. Data link was used as the primary means of communication for ATM, weather, and company information. The FMS multifunction control display unit was used in conjunction with a dedicated touch panel CRT display unit to format messages and control data flows into and out of the FMS. Results indicate that communications workload and errors were reduced significantly.

A second NASA initiative has simulated 4D flight management operations in a time-based terminal ATM environment [10]. The simulation scenarios required time delay absorption by the subject aircraft as it approached the terminal area. Time delays were implemented using speed control alone and in combination with path stretching. Flight crews achieved metering fix times with a negligible mean and a standard deviation of 2.9 seconds in test conditions with no wind errors. Some in-trail conflicts developed in moderate and heavy traffic because the FMS-derived descent speed schedules differed from those assumed by the ground-based ATM automation - an example of the difficulty that can arise when system components use different data for a common element of necessary information. In addition, flight crews experienced some confusion when vectors, speed changes, and/or altitude restrictions were added to 4D clearances. The use of air-ground data link for exchanging all the information required to support 4D arrival operations was cited as a possible requirement.

An alternative approach to exploiting FMS/ATM integration in managing arrival traffic flows postulated a family of routes to the final approach course [11]. As aircraft approach the airport, they would communicate their top of descent point and desired descent and approach speed profiles. Aircraft would be assigned routes and speed schedules, if necessary, to assure conflict free flight paths to the runway. The analysis of a limited sample of 59 aircraft arriving at one airport indicated a 14 percent increase in the runway throughput, 30 percent fewer control instructions, and an average fuel savings of 54 gallons per aircraft.

The FAA System Design Review Team recently recommended that a comprehensive R&D project be established to develop techniques for integrated operation of flight management and ATM automation. In response to this recommendation, a project plan is under development in cooperation with NASA, industry, and airspace users. A systems engineering approach will be used. Operational scenarios for integrated FMS/ATM operations will be developed and potential

benefits assessed in terms of the ATM objectives stated earlier.[1] System requirements will be defined based on selected operational scenarios and alternative system concepts for meeting these requirements will be formulated and analyzed. The concept selected for test and demonstration will be developed using part-task simulations, flight testing of experimental equipment, and the development and in-flight evaluation of a demonstration FMS. Project products will include certification guidance for flight management systems capable of integrated operation with ATM automation, technical materials to support development of specifications for the necessary ATM automation enhancements, and interface control documents to define the associated data link requirements.

The project schedule will depend upon resource availability which, in turn, will reflect the extent to which the user community supports the initiative. An initial project plan, including candidate operational scenarios, will be available in October of this year and we will be canvassing the community for indications of interest and support at that time.

Conclusions

Integrated operation of flight management and ATM automation appears to offer benefits for airspace users and ATM service providers. FAA has initiated an R&D project to define the relevant operational scenarios and system requirements and to develop and demonstrate an appropriate system concept. An initial project plan will be available in October as a basis for discussions within the community on the need for and directions of such an initiative.

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[1] While FMS/ATM integration studies to date have focused on terminal area and domestic en route operations, it seems likely that oceanic airspace may offer the principal opportunity for near-term beneficial applications. Satellite-based communications and navigation capabilities are rapidly emerging in oceanic airspace. The automatic dependent surveillance technique will exploit these capabilities to provide reliable, accurate aircraft position reports to oceanic control centers and a number of these centers are installing modern ATM automation capabilities. Finally, the oceanic aircraft fleet is generally well equipped and operators are highly motivated to reduce operating costs. FMS/ATM integration may be one element of an imminent revolution in oceanic air traffic management capabilities.

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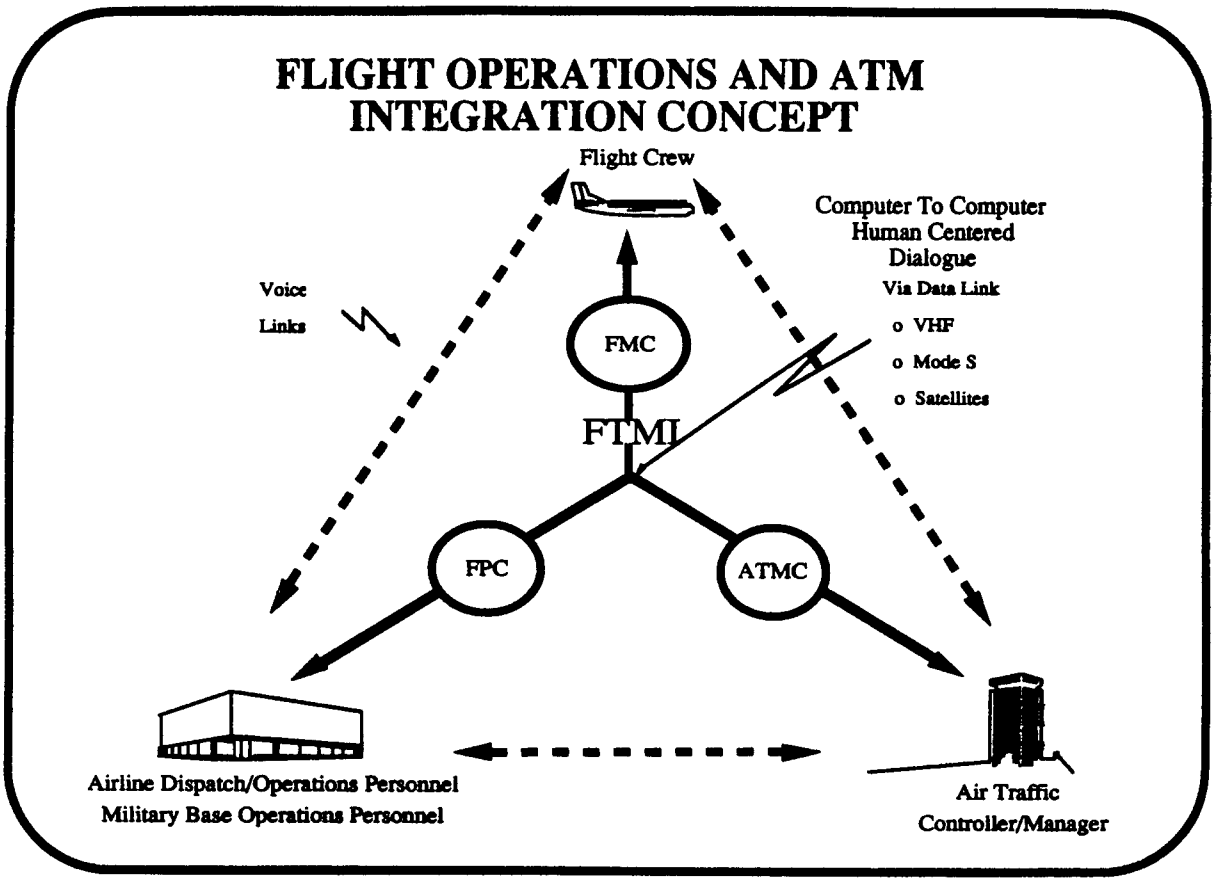
FLIGHT OPERATIONS AND ATM
INTEGRATION CONCEPT
Flight Crew
Computer To Computer
Human Centered
Dialogue
Via Data Link
o VHF
o Mode S
o Satellites
Voice
Links
FMC
FTMI
FPC
ATMC
Airline Dispatch/Operations Personnel
Military Base Operations Personnel
Air Traffic
Controller/Manager

SESSION FIVE: AIRLINE PROGRAM/OPERATIONS

Thursday, September 26, 1991

Session Chairperson - Raymond J. Hilton, Director Air Traffic Management, Air Transport Association of America

2:00 **Data Link Human Factors Team** - William M. Russell, III, Director, Flight Technology, Air Transport Association of America

2:20 **ADS Cost and Benefit Analysis** - George J. Couluris, PhD, Consultant, IAT

2:30 **Benefits to Airlines Presentation by:**

Northwest Airlines - Captain David R. Haapala, Director, Flight Operations Development
United Airlines - William B. Cotton, Manager, Air Traffic Systems
American Airlines - Paul R. Ryan, Manager, Operations Systems Planning

2:50 **Communications Needs of the Future - Air-Ground Interface** - Anthony J. Martin, Manager, Flight Management Systems and Data Links, Boeing (Co-author - N.D. Molloy, Senior Specialist Engineer, Data Link Integration, Boeing)

3:00 **Model Human Engineering Approach to Development of Cockpit Data Regulations** - Renate J. Roske-Hofstrand, Chief Human Factors Engineer, Air Traffic Systems Division, CTA Incorporated (Co-author - Albert Rehman, Technical Program Manager, Federal Aviation Administration; Jack Berkowitz, Staff Human Factors Engineer, Air Traffic Systems Division, CTA)

3:20 **BREAK** sponsored by **BALL Communications Systems Division**

3:50 **ATC Data Communications Operational Development and System Implementation** - Wayne W. Aleshire, Manager, Air Traffic Systems, United Airlines

4:10 **Ground Automation Processing of Near Term Oceanic ATC Data Link Messages** - Dr. Yueh-Shiou Wu, Member of the Technical Staff, The MITRE Corporation (Presentation by Jane Hamelink, Group Leader, ADS Program, The MITRE Corporation)

4:25 **Flight Deck Systems Analysis for Data Link Equipped Aircraft** - Virginia L. White, Senior Staff Engineer, ARINC (Co-author - Richard E. Heinrich, Advanced Satellite Systems Engineering, ARINC)

4:45 **Potential Use of VHF Data Link (AVPAC) Where Available as an Alternative to Satellite Communications** - Austin L. Snively, Systems Engineer, Communications, American Airlines

5:00 **Panel Discussion: What are the Airlines Doing?**

Panel Members:

William B. Cotton, United Airlines	David R. Haapala, Northwest Airlines
Paul R. Ryan, American Airlines'	Virginia L. White, ARINC
Robert Hester, MacDonald Douglas	Anthony J. Martin, Boeing

5:45 **Symposium Closing** - Master of Ceremonies - Robert D. Till

SESSION FIVE: AIRLINE PROGRAM/OPERATIONS

SESSION CHAIRPERSON

Raymond J. Hilton
Director Air Traffic Management
Air Transport Association of America

Raymond J. Hilton has been with the Air Transport Association since 1981. He is responsible for monitoring the FAA modernization program to assure the interest of the ATA member airlines are served. He does this by maintaining close liaison with the engineering and operating services of FAA and by maintaining current knowledge of the FAA national airspace system modernization program, its budget requirements, and other government agency and industry influences affecting the modernization program. He coordinates and cooperates as necessary with corporate and government representatives interested in FAA program development and implementation, and participates in national and international committees and technical conferences to influence airspace development and modernization to the benefit of the airlines.

Prior to joining ATA, Mr. Hilton spent twenty-nine years in government service as an air traffic controller for nine years in the Air Force and FAA, and 20 years in engineering and development at FAA. He worked as an air traffic controller at various military control towers and at New York air route traffic control center, and for those who remember, the Pittsburgh air route traffic control center as an air traffic controller/computer programmer. He spent six and a half years at the FAA technical center at Atlantic City in experimentation and evaluation of air traffic control hardware and software systems. The remaining 14 years of his FAA career was spent at Washington headquarters planning, designing, developing and implementing air traffic control hardware and software systems. Two and a half years of that time was spent assigned to the AEROSAT Coordination Office at the European Space Agency in Holland where he was responsible for managing the development of an internationally coordinated test and evaluation plan for the application of satellite technology for air traffic control.

SESSION FIVE: AIRLINE PROGRAM/OPERATIONS

William M. Russell
Director, Flight Technology
Air Transport Association of America

William M. Russell is the Director - Flight Technology in the Operations and Safety Department of the Air Transport Association (ATA). Mr. Russell is responsible for programs on human factors and advanced technology.

ATA is a service organization representing the U.S. scheduled air carriers, providing an airline forum and endeavoring to achieve implementation of airline goals. ATA also hosts a number of industry and government groups, including the Human Factors Task Force and the Data Link Human Factors Team, which develop broad consensus of current issues.

Mr. Russell joined ATA in June, 1970, after serving as Senior Engineer at Beech Aircraft Corporation and as Project Engineer for the FAA. he is a graduate of Northwestern University in Evanston, Illinois, where he received a B.S. degree in electrical engineering. He is a Member of the Institute of Electrical and Electronics Engineers and a Senior Member of the American Institute of Aeronautics and Astronautics. Mr. Russell is a pilot holding a flight instructor certificate with instrument and airplane ratings.

Originally from Fernadale, Michigan, Mr. Russell has lived in many areas of the United States and now resides in McLean, Virginia.

SESSION FIVE: AIRLINE PROGRAM/OPERATIONS

Dr. George J. Couluris
Consultant
IAT

Dr. George J. Couluris, IAT, has an extensive background in the development and analysis of air traffic systems, with an emphasis on computer-based modeling. He has directed and participated in projects involving air traffic control operations analysis, capacity and delay modeling, controller workload and productivity assessment, man-machine interface design, air traffic control automation development, aircraft flight performance modeling, benefit-cost and cost-effectiveness analyses, test and evaluation planning, and regulatory impact assessment. He directed the Automatic Dependent Surveillance benefit and cost study and the Oceanic Air Traffic System Improvement Study (OASIS). Dr. Couluris has developed numerous modeling tools, including the Flight Cost Model, the Airport/Airspace Delay Model (the basis for SIMMOD), the Sector Workload Model, the Macronet Model of air traffic flow, the Controller Workload Model, and the Investment Decision Analysis Model. Dr. Couluris received the B.S. and M.S. degrees in civil engineering from Rensselear Polytechnic Institute and the Ph.D. in transportation engineering from the University of California, Berkeley.

Dr. Couluris has been active in transportation systems development and operations analysis for over 20 years. He has served in management and technical staff positions at SRI International, FAA, the Port of New York and New Jersey Authority, and elsewhere. He is a member of the Transportation Research Board Committee on Airfield and Airspace Capacity and Delay.

AUTOMATIC DEPENDENT SURVEILLANCE BENEFIT AND COST ANALYSIS: INTERIM STUDY RESULTS

George J. Couluris

IAT, Menlo Park, California

ABSTRACT

This paper summarizes the results of an interim study of the economic and operational impacts of automatic dependent surveillance (ADS). ADS service will make provisions for satellite communications and advanced air traffic control (ATC) automation and will enhance air traffic services in oceanic and other airspaces. ADS will provide direct communication between pilots and air traffic controllers and enhanced ATC flight monitoring and airspace management capabilities. The benefit and cost study identified the operational benefits and implementation requirements of ADS and analyzed their potential impacts on users and providers of air traffic services. Potential safety benefits were qualitatively assessed, and potential cost savings due to ADS operations and ADS implementation costs were quantitatively estimated. The expenditures considered in the analysis include user flight operating costs, air-ground communication user costs, aircraft ADS communication equipage costs, and ATC system enhancement costs. The study examined ADS implementation and potential operational impacts for the North Atlantic and Pacific oceanic areas through the year 2010. The resulting estimated cost savings due to ADS exceed the estimated implementation costs.

INTRODUCTION

Automatic dependent surveillance (ADS), which is currently under development, is designed to use satellite communications and advanced air traffic control (ATC) automation to improve air traffic services [1-4]. This capability would be particularly effective in oceanic airspaces where radar coverage is not available and where high-frequency (HF) technology provides indirect air-ground voice communication between pilots and air traffic controllers. Operationally, ADS would use digital data link to provide frequent updates of aircraft position reports and direct air-ground communication between pilots and controllers. These capabilities would improve oceanic air traffic controllers' ability to monitor and manage air traffic.

BENEFITS

ADS would be the basis for potentially significant enhancements in flight safety and would support potentially significant reductions in flight operating costs.

Safety Enhancements

Current HF-supported oceanic air traffic operations are vulnerable to certain flight navigation errors associated with human blunders by pilots, controllers or radio operators. Examples include waypoint insertion errors and ATC communication loop errors. The ADS-based ATC automation would be capable of detecting the occurrence of many such errors, and ADS-based direct pilot-controller communication would expedite their resolution and prevent potential mishaps.

Flight Operating Cost Savings

In association with improved aircraft navigation performance, ADS would support reductions in separation minima. Separation minima reductions would lessen delays and diversions from preferred flight paths, and would significantly reduce flight operating costs in comparison with current oceanic operations. ADS also would support improved ATC flexibility, which would enable controllers to be more responsive to air traffic flight preferences with or without separation minima reductions and would contribute to flight operating cost savings.

COSTS

The realization of ADS benefits will require expenditures to establish, maintain and use the ADS system. ADS would require: expenditures by users (or others depending on institutional arrangements) of the satellite-based air-ground communication system for data link message transmission services; expenditures by aircraft operators for ADS communication equipage; and expenditures by ATC provider authorities for ADS system development and facility and equipment programs.

ADS Air-Ground Communication User Costs

The implementation and maintenance costs incurred by providers of satellite-based air-ground communication service would be recovered through user charges. The user costs pertaining to ADS are those associated with ATC and other air traffic services message transmissions. The messages include aircraft position reports, pilot clearance and information requests, controller clearance instructions, meteorological reports, weather advisories and emergency communications.

Aircraft Satellite Communication Equipment Costs

Aircraft operators would incur expenses for satellite communication equipment purchases, installations of the equipment on board aircraft, and continual maintenance of the equipment.

ATC Provider Costs

ATC provider authorities would incur expenses to establish and support ADS-based air traffic services. These expenses account for research and development of ATC hardware, software and procedural enhancements, ATC facility preparations and equipment procurement, and continual operating and maintenance requirements.

BENEFIT AND COST COMPARISON

Since the ADS establishment, operating and maintenance costs could be considerable, the value of developing ADS depends on the relationship between implementation costs and the benefits achievable. An interim study [5] was conducted to examine and evaluate the relative costs and benefits. The study developed preliminary assessments of ADS impacts based on data available. The study qualitatively assessed the potential safety benefits of ADS, and quantitatively evaluated non-safety related costs and savings for the North Atlantic and Pacific during the years 1990 through 2010. The areas under study include oceanic airspace jurisdictions of Canada, Iceland, Japan, Portugal, the United Kingdom, and the United States (US).

The study compared ADS operations and costs with those of a baseline system. The baseline system represents ATC operations with the Oceanic Display and Planning System (ODAPS) or equivalent ATC automation. ODAPS is being developed and implemented by the US, and comparable systems are being or will be developed by other ATC provider authorities.

Flight cost savings due to reduced separation minima were estimated by updating the results of previous computerized simulations [6] of baseline and ADS operations. The updates accounted for traffic loading and aircraft type distribution changes based on recent surveys and forecasts and for current and projected aircraft flight performance characteristics. Flight cost savings due to improved ATC flexibility were based on analyses of potential reductions in flight diversions. The cost saving estimates were adjusted to account for ADS coverage limitations based on proposed configurations of the satellite constellation and for ADS-based ATC service limitations based on the reported ADS implementation plans of ATC provider authorities.

Estimates of aircraft satellite communication equipment costs were based on analyses of the relevant cost factors. These factors include the unit price of the equipment, the number of aircraft in the ADS fleet, the number of aircraft requiring retrofit installation versus the number of aircraft that are fully-equipped new deliveries, and operating and maintenance requirements.

Estimates of ADS air-ground communication user costs and ATC provider cost were based on data provided for US programs and operations. These estimates, subject to revision, were used to also represent non-US costs.

The US ADS program plan [3] included a transition period for the step-wise introduction and establishment of ADS. The benefit and cost study assumed that full ADS operations with reduced separation minima would commence at the start of 1995. To facilitate the initial cost analysis, 100% of the participating oceanic aircraft was assumed to be ADS equipped starting in 1995. The study developed estimates of ADS-based flight cost savings for the years 1995 through 2010. However, all relevant implementation costs during 1990 through 2010 were included. Costs and savings were estimated in 1990 US dollars and inflated at a 5% compound annual growth rate for subsequent years. To enable economic comparisons, the 1990 present values were calculated using compound annual discount factors of 10% for ATC provider authority costs and 12% for the other costs and the flight cost savings.

A potential net savings of $176.6 million was estimated by the interim study:

	1990 Present Value ($ million)	
Flight Cost Saving due to:		
Reduced Separation Minima	$502.7	
Improved ATC Flexibility	$41.7	
Total Saving		$544.4
ADS Air-Ground Communication User Cost Increase	$41.3	
ADS Equipage Cost for Aircraft Operators	$213.2	
ADS System Cost for ATC Providers	$113.3	
Total Cost		$367.8
NET SAVING		$176.6

These results represent the discounted values of the costs and savings estimated for the years 1990 through 2010.

COST FACTORS

The key assumptions used to develop the cost and savings estimates are described in the following paragraphs. Cost estimates are in 1990 US dollars.

Flight Operating Cost Factors

A fuel price of $1.00 per gallon was assumed based on costs reported for 1990. Fuel prices fluctuated drastically during the interim study, ranging from $.60 to $1.40 per gallon. The interim study was concluded in November 1990. A sensitivity analysis indicated that significant net benefits would still result under reasonable variations in the assumed fuel price or the fuel price inflation rate.

ADS Air-Ground Communication User Cost Factors

ADS satellite communication user costs were assumed to be incurred at a rate of $1.20 per kilobit processed. A typical ATC data link message was assumed to require one-half kilobit, including message management overhead, which resulted in an estimate of $.60 per ADS message. ADS position reports were assumed to be transmitted at 5 minute intervals from each aircraft, and other ATC data link messages were assumed to increase ADS message loading by an additional 10%. The cost recovery requirement of the baseline HF voice communication system were assumed to total $20 million annually for the North Atlantic and Pacific airspaces under study.

Aircraft Satellite Communication Equipment Cost Factors

The purchase cost of satellite communication equipment for one aircraft was assumed to be $137,000, which accounted for a satellite data unit, communication management unit, ADS unit and low gain antenna. Ret-

rofit installation cost was assumed to be $100,000 per aircraft. Annual maintenance cost was assumed to be 6% of the purchase and retrofit installation total cost. The low gain antenna would support ADS communication as well as airline operational communication and airline administrative communication. ADS was assumed to account for 50% of these data link messages, and the equipment cost was allocated accordingly. Although high gain antennae may be installed to provide air-ground digital voice communication, the high gain antennae were not assumed to be an ADS requirement and their cost was not considered in the study. The study assumed that 1200 aircraft would be ADS-equipped by 1995, 1400 by the year 2000 and 1840 by the year 2010. New deliveries were assumed to account for 300 ADS-equipped aircraft by 1995, 500 by the year 2000, and 940 by the year 2010. Retrofit installations of ADS equipment would apply to 900 aircraft.

ATC Provider Cost Factors

The ATC system research and development cost relating to ADS was assumed to be $7 million for each of the six provider authorities. Facility and equipment cost was assumed to be $7 million for each of the nine ATC centers responsible for air traffic services in the airspaces under study. Annual maintenance cost was assumed to be 2.5% of the facility and equipment cost, which allowed for replacement of baseline ODAPS equipment.

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SESSION FIVE: AIRLINE PROGRAM/OPERATIONS

Captain David R. Haapala
Director of Flight Operations Development
Northwest Airlines

Captain David R. Haapala, Director of Flight Operations Development at Northwest Airlines, has played a major role in developing Northwest's terrestrial-based datalink and Northwest's planned evolution toward space-based data and voice communication systems.

Within the airline industry he chairs the Datalink User's Forum (an Airline Electronic Engineering Committee sponsored group) which examines datalink issues affecting airlines, avionics vendors and service providers. He also served as Northwest's representative to AvSat, which was one of the earliest industry attempts to launch satellite services for airline use. In 1989, he was instrumental in formulating an agreement between Northwest and the FAA to conduct ADS trials in the Pacific.

Prior to his present position he served as Northwest's director of Flight Standards for the A320, B-757 and the B-747-400 and helped introduce those airplanes into Northwest's fleet. He has also been a line pilot, instructor pilot and check airman at Northwest and type rated on the B-727, B-757, DC-10 and B-747 airplanes.

He is a graduate of the University of Minnesota and is a former U.S. Air Force pilot.

SESSION FIVE: AIRLINE PROGRAM/OPERATIONS

William B. Cotton
Manager, Air Traffic Systems
United Airlines

William B. Cotton is Manager - Air Traffic Systems for United Airlines. Hired as a pilot by United Airlines in 1967, Mr. Cotton has flown six types of transport aircraft and currently flies as Captain on the DC-10. He has instructed and checked United flight crews on the Boeing 727, DC-8, DC-10.

Mr. Cotton's interest and participation in air traffic control (ATC) affairs has been continuous since 1969 when he became Chairman of the Airline Pilots Association's National ATC Committee. After serving in that position for 13 years, he moved into United management and began to represent the company at ATC industry forums and improvement efforts. Mr. Cotton was also United's Flight Operations representative in the traffic alert and collision avoidance system (TCAS) evaluation contract with Allied Bendix Aerospace. In this work, he was instrumental in the design of displays, symbology, and flight procedures to be used on this new avionics system. He now leads the effort by his airline to achieve ATC efficiencies through growth features of the TCAS. He also coordinates United's Flight Operations activities for the development and implementation of other avionics systems for use in the airspace management and control systems of the future.

Mr. Cotton was educated at Swarthmore College, the University of Illinois, and the Massachusetts Institute of Technology. He holds bachelor's and master's degrees in Aeronautical and Astronautical Engineering. His thesis work at M.I.T. was on the subject of air traffic control, and specifically called attention to the potential utility of traffic information for use by pilots.

SESSION FIVE: AIRLINE PROGRAM/OPERATIONS

Paul R. Ryan
Manager, Operations Systems Planning
American Airlines

Mr. Paul R. Ryan is Manager Operations Systems Planning - Operations Department of American Airlines. He has held this position since 1987, after having served as Manager Flight Operations Control and M&E Interface. During his twenty-five years with American Airlines he served in a variety of positions within the Operations Department, including Avionics Engineer, and Systems Analyst Flight Operations Systems Development.

Mr. Ryan joined American Airlines in 1966 as a draftsman of Airport Analysis while completing his college studies in New York City. In 1969 he moved to Tulsa, Oklahoma, as an Avionics Engineer in charge of Flight Recorder Systems and Air-to-Ground Communications. In 1972 he assumed responsibility for all special Aircraft Communications and Recording Systems, which included the development of the Aircraft Communications and Recording Systems (ACARS), and other Aircraft reporting systems for Engine, Airframe, and Crew Monitoring. In 1975 he transferred to the Flight Operations Development Group to design a computer system to support the Flight Planning, Flight Following, and Data Link Systems. In 1988, Paul was assigned to the Air Transport Association of America's Airspace Systems Task Force/Data Communications Working Group and as Chairman he has helped guide the Data Link system requirements for Airline and Air Traffic Digital Communications.

A native of Queens, New York City, Mr. Ryan earned a scholarship to The Cooper Union School of Engineering, New York City, New York, and was awarded an Electronic Engineering Degree in 1969. He also earned a Master's Degree in Engineering Management from The University of Tulsa, Oklahoma.

SATELLITE SURVEILLANCE AND COMMUNICATIONS AIRLINE BENEFITS - THE TELEPHONE MYTH

Paul R. Ryan

Air Transport Association of America/American Airlines

ABSTRACT

When Satellite communication was first announced for airline usage, the designers and marketers proposed that the airlines would install the system to provide a public telephone in the aircraft to be used by the passenger. However, when airline executives reviewed the benefits from satellite communications, it became clear that the Automatic Dependent Surveillance function, which provides the "FREE" airspace flying and associated Minimum Time Track savings, was cost justified. Satellite was added as a necessary requirement to deliver the ADS information to the Air Traffic Control people.

INTRODUCTION

When the Avionics and Satellite providers announced the development of the Mobile Aircraft Satellite system, the marketing staffs approached the airlines that the best way to purchase this new capability was from a combination of benefits derived from the following;

Marketing Will generate new revenue from telephone usage and "Inflight" sales

Operations Will reduce Operations cost with Minimum Time flights

Safety Will make flying over the Ocean regions safer.

In today's airline economics, only the Operations Department can provide the cost/benefit from the installation of Satellite through the proposed Automatic Dependent Surveillance services provided by the Air Traffic Authorities, with the establishment of the FREE airspace and Co-operative Air Traffic Management Concepts. The FREE airspace provides the Minimum Time Track and crossing track capability to reduce the time to fly between city pairs and reduce both the cost of fuel used and the cost of Crew pay. The Co-operative Air Traffic Management Concept ensures no delays into or out of the Oceanic Regions, which provides the ON TIME dependability benefits to the airline.

This paper provides one airline's perspective of justifying the requirements and benefits from the installation of SATCOM and the ADS function, plus the American Airlines approach to the Satellite public telephone and Safety of Flight issues.

$$\frac{\text{One}}{\text{Aircraft}} \times 10 \frac{\text{calls}}{\text{flight}} \times 2 \frac{\text{flights}}{\text{day}} \times 300 \text{ days} \times \frac{\$1.00}{\text{call}} = \$6{,}000 \text{ per year}$$

Notes:

1. Average time over the North Atlantic outside of the terrestrial area is 2.5 -3.5 hours. The average number of telephone calls made is assumed to be 10.

2. The aircraft assigned to the Trans-Atlantic segments make one round trip per day, therefore average flights per day is 2.

3. On the average a Trans-Atlantic aircraft flies 300 days per year, with 60 days required for scheduled monthly and yearly maintenance.

TABLE 1

COST ECONOMICS and THE TELEPHONE MYTH

The satellite advocates voiced their support for the SATCOM system based upon three areas of benefits: Marketing (increased revenues), Operations (decreased expenses), and Flight Safety. The airline executive quickly disposed of the Safety benefit by asking the question, "How many aircraft have we lost in the Non-Radar controlled airspace over the past 10 years?" The answer was "NONE", therefore Satellite for safety of flight was dismissed as a benefit.

The next analysis was conducted on the potential revenue generators for the Marketing Department. The satellite advocates suggested that the airlines, in cooperation with a favorite telephone service provider, could price the telephone call at a rate high enough to pay for the Satellite installation. After a detail review, the Satellite system equipment was valued at $300,000 (USD) and the airline would receive approximately $1.00 (USD) for each telephone call made by a passenger. The analysis above destroyed this Satellite Myth.

Based upon the $300,000 cost for the basic Satellite equipment, it would take 50 years to pay back the system (Reference Table 1). Even if the revenue was $10.00 per telephone, the pay back would take 5 years. Add to this analysis the cost to install and certify the total system, a revenue increase over $100.00 (USD) would be necessary to justify another look at Satellite for the marketing Department. With the recession of the last couple of years, no airline was capable to invest in the Satellite system without a guarantee of over $100.00 per flight. None of the telephone service providers would provide this guarantee.

That left the Operations Department to justify a Satellite system from the decrease in expenses based upon reduced flying times between city pairs.

OPERATIONS DEPARTMENT ANALYSIS

The Operations Department's cost

REGION NON RADAR CONTROLLED	SAVINGS FUEL	CREW PAY
NORTH ATLANTIC	$2,000,000	$4,000,000
CARIBBEAN	$1,500,000	$3,000,000
PACIFIC - North/South/HNL	$1,000,000	$2,000,000
SOUTH AMERICA	$ 500,000	$1,000,000
TOTAL (ALL REGIONS)	$5,000,000	$10,000,000
ANNUAL SAVINGS		**$15,000,000**

NOTES:

1. Dollars are $ USD value of 1991.
2. Fuel savings are based upon 1991 costs.
3. Schedule is 1991 flying hours with TWA's London and Continental's NRT routes.
4. Savings are based upon FREE Airspace analysis (MIN TIME TRACKS, FIR BOUNDARY to FIR BOUNDARY).

TABLE 2

analysis was simply defined by the assumption that with an ADS function on the aircraft and the ADS services provided by the Civil Aviation Authority, the time enroute in the Non-radar controlled area could be reduced. At American Airlines, we ran a large number of flight plans under the current North Atlantic Track System (NATS) rules and then ran the flight plans again assuming a minimum time track capability from FIR Boundary to FIR Boundary. The results identified an average time reduction of 3% for flights over the North Atlantic area. This equates to an American Airlines savings of $2,000,000 in enroute fuel and $4,000,000 in Crew pay (both Pilot and Flight Attendant). Table 2 above is a summary by Non-radar controlled areas that will benefit American Airlines if the FREE airspace services are provide to our aircraft.

The fuel savings for each airline will be similar for that of American Airlines, but the Crew savings will vary depending upon the Pilot and Flight Attendant contract details.

The $15,000,000 savings looks impressive, but to secure these savings, American Airlines will have to invest $65,000,000 to install the SATCOM and ADS function in over 150 aircraft. The simple pay back is calculated as:

$65,000,000/$15,000,000 = 4.4 years.

The real Return On Investment parallels that of the purchase of a new aircraft. The airlines invest all their capital upon the delivery of an aircraft and then hope that the aircraft will generate adequate revenue to pay for the unit over 20 years. For this project we plan to invest in the SATCOM and ADS equipment prior to the adoption of the FREE airspace concept. We hope that we will not have to carry the equipment for a long time before the FREE airspace concept is accepted by the CAA's.

AIRLINE BENEFITS - THE REST OF THE STORY

Now that the Operations Department has justified the purchase, installation, and certification of the Satellite and the Automatic Dependent Surveillance function units, we need to revisit what the SATCOM advocates had suggested earlier. The original proposals for SATCOM advocated benefits from:

Marketing Will generate new revenue from telephone usage and from in flight sales

Operations Will reduce Operations cost with Minimum Time flights

Safety Will make flying over the Ocean regions safer.

The previous section provided the benefits proposed by the Operations Department. The benefits from the Safety Department are also real. If the ADS information provides up to a 400% improvement over the current Ocean Airspace information, then a reduction in the current spacing by over 50% is logical. Therefore the first benefits from the Safety of Flight are both reduced separation and the acceptance of crossing traffic in areas such as the Caribbean airspace. When Air Traffic experience in the use of the ADS function and services are gained, we then will request more for our investment, that being the FREE airspace and Co-operative Air Traffic Management Concept. Under the current ATA plan, the airlines are requesting the following calendar plan for these services;

YEAR	SERVICE
1993	Step Climbs and Two-way Communications
1995	Reduced Separation Reductions to; 30 miles Nose to Tail 05 minutes Wing Tip to Wing Tip 1000 Feet Altitude Separation
1998	FREE Airspace with Co-operative Air Traffic Management Crossing traffic No delays out of or into the Oceanic area

Once the SATCOM equipment was purchased for the Oceanic aircraft, the Marketing Department might find the revenue benefits that would allow them to install a public telephone on the aircraft. Instead of justifying the $300,000 (USD) for SATCOM, they would only have to justify the cost of the connection to the SATCOM equipment and the voice Codes necessary for voice communications. That cost is projected to be less than $100,000 per aircraft. Assuming revenue of $6,000 (USD) per year, this still requires 16.6 years to pay back the investment at $1.00 (USD). If the pricing or volume assumptions improve, they may be able to produce an acceptable business case for the Public Telephone as

the cost of the Satellite Communications System equipment would not be part of their capital costs. When this occurs, the Telephone Myth becomes a success story.

SUMMARY

Satellite Surveillance and Communications is here. The rate at which the industry equips all aircraft is controlled by the acceptance of the system by the Civil Aviation Authorities and their willingness to provide the services we have requested. The SATCOM and ADS equipment investment by both the airlines and the CAA's requires a firm and absolute commitment to the ICAO concept of Co-operative Air Traffic Management. In purchasing, installing, and operating the SATCOM and ADS systems the airlines have made their decision to accept this concept: we ask the same of all the CAA's.

When the ATA first advocated the 1993/1995/1998 projected dates, the CAA's worldwide said the dates were unrealistic and a myth. We can turn the ATA's myth into reality by working together and proving the need for, and the benefits from SATCOM, ADS, and the Co-operative Air Traffic Management Concept. Thank you.

SESSION FIVE: AIRLINE PROGRAM/OPERATIONS

Anthony J. Martin
Manager Flight Management Systems
And Data Link
Boeing Commercial Airplanes

Anthony J. Martin graduated from Manchester University, England in 1960 with a BS in Electrical Engineering. After working as an Avionics Engineer for Hawker Siddley Aviation, and as a Submarine Navigation Engineer for Vickers Shipbuilders.

For Boeing he has worked on the development and certification of Inertial Navigation Systems, Colour CRT Electronic Displays, Flight Management Computers, Maintenance Systems and Data Link Systems for the 757/767, 737-300, 747-400 and 777 airplanes. He is currently the Manager of 747-400 and 767 Flight Management and Data Link systems group with responsibility for Flight Management Computers which include the ADS function, SATCOM and ATN Data Communications Management.

Communications Needs of the Future Air-Ground Interface

Anthony J. Martin, Manager
Flight Management Systems and Data Links
Boeing

N.D. Molloy, Senior Specialist Engineer
Data Link Integration
Boeing

SUMMARY

The successful evolution of air ground data link applications is dependent on international cooperation and agreements to establish the environment to provide economic returns to participating airlines and meet the safety requirements of the future Air Traffic Control environment.

This paper addresses a Boeing perspective of the future requirements for air/ground data links, with emphasis on the near term uses of SATCOM. The current status of SATCOM systems on the 747-400 airplane is described together with the development efforts underway to achieve Oceanic Air Traffic Control capability via SATCOM data links by 1993. The design approach being taken for the new Boeing 777 airplane is also described.

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Conclusion

Introduction

The use of data links on commercial airplanes started with the Aircraft Communications Addressing and Reporting System (ACARS) which was initially used for Airline Operational Control (AOC) data traffic.

Recognizing the value of ACARS data, the airlines have been purchasing SATCOM systems for 747-400 and 767 long range airplanes and using the SATCOM link to extend the geographic area of ACARS coverage to the oceanic regions and expanding the scope of the ACARS messages to ATC-type applications.

The International Civil Aviation Organization (ICAO), through its Future Air Navigation System (FANS) committee has recognized that satellite technology is the only viable solution to overcome the shortcomings of the present Communications, Navigation, and Surveillance (CNS) system and to fulfill the needs and requirements of the foreseeable future on a global basis. (Figure 1.)

Boeing's primary strategy is to develop products which satisfy our customers current and future operational requirements. In response to customer requirements, Boeing plans to develop, install, and certificate avionic systems which are compatible with the future CNS requirements defined by ICAO. Recognizing the continuing evolution of both the data link infrastructure (communication links, networking protocols, addressing standards, etc.) and the data link applications (Automatic Dependent Surveillance, Two-Way ATC Communications, etc.), Boeing will work cooperatively with the airlines, avionics vendors, air traffic control authorities, and airworthiness authorities to define operational, system implementation, and certification requirements for data link systems. Airline involvement will ensure that the development sequence of data link infrastructure and applications is consistent with the operational economic priorities.

Commercial Aviation Data Link History

Initial operational evaluations of data link systems in air transport environment occurred in 1971 on a Boeing 747 operated by American Airlines. The Aircraft Communications Addressing and Reporting System (ACARS) was introduced in 1977. ACARS began as a simple Out, Off, On, In (OOOI) reporting system but has rapidly evolved into a complex system communicating many types of Airline Operating Control (AOC) messages. ACARS data links are supported over land masses worldwide by a network of ground stations, terrestrial communication links, and VHF radio links operated by and ARINC, SITA, Air Canada, and AVICOM.

Figure 2, courtesy of American Airlines, shows the projected growth of data link equipped aircraft in the United States.

Currently Boeing is in the process of certifying and delivering systems from four different ACARS suppliers. So far in excess of 50 different airline unique part numbers have either been delivered or are committed for delivery on Boeing 737, 757, 767 and 747-400 airplanes.

Future Growth of Data Link

Boeing expects a rapid growth in data link functions continuing the pattern that has been established with ACARS. The arrival of the ARINC 741 SATCOM system has opened up a large new area of opportunity.

The initial application of SATCOM has been the extension of the Airline Operational Control (AOC) type of ACARS messages to the Oceanic arena using the SATCOM Data 1 capability.

The endorsement of satellite technology by FANS, and the promotion of the Aeronautical Telecommunications Network (ATN) using International Standards Organization (ISO) standards by both the regulatory agencies and the airlines has identified the requirement for a unified approach to the air/ground data link network.

Boeing, as the leading airframe manufacturer, is responding to this data link revolution by first upgrading the 747-400 systems to be compatible with ATN data links, and incorporating ATN-compatible data link capability into the basic design of the new 777 airplane.

The physical communication channels systems which are being planned for include:

SATCOM Data 3 / Voice 2

VHF AVPAC

- ARINC 716 Analog VHF Radio with Modem Interface
- ARINC 750 Data Radio

Mode S Transponder

HF Data Radio

Gatelink

Examples of the classes of information which will be transmitted over these channels are contained in the following lists.

Automatic Dependent Surveillance (ADS) Reports

Air Traffic Service Communications (ATSC)

- Air Traffic Control (ATC) messages

  Emergency condition reports (windshear, fire, hijacking), clearance requests, clearances and acknowledgements, transfer-of-communication instructions, proposed flight plans and flight plan amendments, flight progress reports, altimeter settings

- Flight Information Services (FIS) messages

  Weather reports and forecasts, NOTAMS, ATIS

Aeronautical Industry Service Communications (AISC) messages

- Airline Operational Control (AOC) Messages

  Weather information, flight plans and progress data, maintenance reports, including automatically transmitted Central Maintenance Computer and Aircraft Condition Monitoring System reports, connecting flight data, Out-Off-On-In (OOOI) data, and aircraft and medical emergency data

- Aeronautical Administrative Communications (AAC) Messages

  Cabin provisioning and passenger service type messages such as seat assignments, baggage tracing, continuing travel arrangements, and customer

Aeronautical Passenger Communications (APC) Services

Voice telephone and digital services such as fax electronic mail and personal computer network connections

Customer unique communication requirements will be accommodated by providing tailorable message content, message triggering logic, and message presentation formats.

747-400 Status and Plans

The first 747-400's were delivered without operational SATCOM systems and with baseline Flight Management Computer System software called Package A. Boeing made a commitment to offer upgraded FMC software sometime after initial certification. The upgraded FMC software, called Package B, contains data link functions.

747-400 SATCOM

Virtually all 747-400's are delivered with SATCOM provisions installed. Figure 3 shows the number of SATCOM provisioned aircraft that Boeing expects to deliver between 1991 and 1993. Similar provisions are offered on the 767. Figures 4 and 5 show the installation of SATCOM antennas and avionics, respectively, on a 747-400.

Boeing has been and expects to continue to be involved in the continuing evolution of commercial aircraft SATCOM systems. Boeing activity includes installation, integration, test, certification, and commissioning of SATCOM systems in response to change requests generated by airline customers.

Data Level 0

Boeing delivered the first operational SATCOM system on a 747-400 in September of 1990. Four such systems were delivered under a special agreement with INMARSAT until a fully qualified system was available. This system was used by United Airlines (UAL) for Pacific trials to demonstrate the automated position reporting via SATCOM.

Data Level 1

The first fully qualified Data Level 1 system was certified by Qantas on a 747-400 in December of 1990, and the first delivery of a Data Level 1 system from the Boeing Everett production line occurred in February of 1991. This configuration is shown in Figures 4 and 5.

Since that time through July 1, 1991 Boeing has delivered 9 airplanes with SATCOM installed to 6 different customers. Change requests for other 747-400 customers and 767 customers are in process. Projected SATCOM deliveries are 23 in 1991 and 26 in 1992 as shown in Figure 6.

Data Level 2

Boeing is currently studying the offerability of SATCOM Data 2 systems in 2nd quarter of 1992. Change requests have been received from three airlines and suppliers have plans to have equipment available in this time period.

American Airlines plans to use SATCOM Data Level 2 on the 767 for position reporting trials on Atlantic routes.

Data Level 3

Data Level 3 SATCOM using the International Standards Organization (ISO) Open System Interconnection (OSI) communication protocols is required for compatibility with the Aeronautical Telecommunications Network (ATN).

One customer airline has already asked Boeing for a proposal to deliver a Data Level 3 SATCOM system in mid 1993.

Two Avionics suppliers have indicated to Boeing that they intend to have systems available in this time period.

SATCOM Voice

Single channel Voice 1 or 2 is currently being studied for offerability. No Boeing activity is underway now to offer multi-channel voice due to lack of hardware availability in the avionics industry. Cockpit voice via satellite will provide full duplex capability in contrast to the half duplex capability provided by VHF and HF. Control of the cockpit voice function will be provided by the Multi-function Control / Display Unit (MCDU). Exploitation of multi-channel voice capability for cabin voice services requires a Satellite Telecommunications Unit and a Cabin Telecommunications Intermediate Unit. Requirements for these systems are currently being developed by the AEEC ARINC 746 Sub-Committee.

Flight Management Computer System (FMCS) - Package 'B'

Another essential ingredient for an Oceanic ATC compatible system for the 747-400 is a major software update for the FMCS called "Package B". Two major new functions included in Package B are Automatic Dependent Surveillance (ADS) as specified in the AEEC Characteristic 745 and two-way data link messages.

The ADS and ATC data link message functions are just two of the many operational enhancements which the 747-400 airline customers have endorsed for the FMCS. Package B will also support data link exchange of the following types of information:

Flight plans (both with the airline dispatch office and ATC authorities)

Performance data (weights, fuel quantity, cost index, engine and airframe characteristics)

Takeoff parameters (runway characteristics, weights, winds, temperature, altitude, thrust and flap setting, and speeds)

Predicted enroute winds and temperatures

Position and progress reports

Destination alternate airports including weather predictions

Package B also includes the capability for the airline to define up to ten customized MCDU pages which can be downlinked as data link messages.

Industry and government activity through ICAO, RTCA, ATA, and AEEC is underway to complete the definition of Oceanic ATC data link function. Operational requirements and implementation standards for the ATC data link function are currently being developed by a Working Group of the RTCA Aeronautical Data Link Applications Special Committee (SC-169). As well as providing an officially sanctioned forum for the FAA participation in the requirements development process, SC-169 working group will involve participants from the ATA Human Factors and AEEC Data Link committees and rely to the maximum extent possible on the output of these groups. Time is of the essence due to the length of the software development process required to satisfy the DO-178 Level-2 certification requirements. To meet the mid-1993 certification date, system and software requirements must be frozen by the end of 1991.

Communication Management Unit (CMU)

A crucial system for the airborne end of the data link network is the Data Router function. Figure 7 shows the Data Link System Architecture applicable to 747-400 and identifies the areas of development and growth. This system must be capable of accessing all subnetwork links and routing uplink and downlink messages from many airborne systems or functions which may be packed in different and multiple black boxes on different airplane types to or from the appropriate ground function.

This brings up one of the issues being addressed in the industry definition of ATN requirements specifications, namely "logical" versus "physical" addressing of air to ground data link messages. For example, the Automatic Dependent Surveillance (ADS) function may be a function within pilot selectable Left or Right Flight Management Computers on one airplane, Left, Right or Center Guidance Computers on another airplane, dedicated ADS computers on another, or in the new ARINC 651 Integrated Modular Avionics concept it may be a function in software which could migrate from one physical module to another under dynamic fault containment conditions.

The addressing method as well as the scope of the network management function must be resolved in the near future. In resolving these issues the limitations of memory, airborne computer thru-put, and air-ground bandwidth must be weighed against the objective of achieving 100% commonality with existing terrestrial networks and software. The alternative of modifying the terrestrial software to interface with a simplified airborne system be considered before a requirement is generated that adds complexity to the avionics. In addition to the avionics hardware and bandwidth constraints, the software development and certification impact of adding functionality to the avionics equipment is a factor. If large amounts of network management software have to be retrofitted into memory and thruput limited avionics black boxes, then there will be a prohibitive cost associated with upgrading existing airplanes such as 747-400 to ATN compatible data link.

A second issue specific to the CMU is the stated regulatory requirement that all software associated with the airborne handling of ATC messages must be certified to level 2 standards as defined in DO 178A - Software Considerations in Airborne Systems and Equipment Certification. Figure 8 shows the FAA imposed Flight Manual Limitation restricting the use of SATCOM data link on the 747-400. This limitation is due to the fact that the software used to process the messages in the airplane is certified to the non-essential Level 3 standard. The primary goal of data link certification standards must be to ensure the necessary of end-to end message integrity and availability commensurate with the specific type of data being transmitted. The potential for failures or design errors at any point in the network to either interrupt or corrupt essential data must be assessed. Based on this assessment a coherent set of requirements should be developed and levied on both the airborne and terrestrial elements of the entire communication system.

The AEEC Characteristic 748 which defines the CMU requirements allows the CMU data router function to be integrated in the same black box as the existing ACARS. To date all ACARS software has been certified to Level-3 and exists in more than 50 different part numbers for Boeing airplanes alone. These part numbers are generally unique to each individual airplane type for a given customer. The cost of recertifying this software to Level 2 is prohibitive so segregated CMU software seems to be the answer. Boeing is actively studying alternate configurations one of which includes a separate CMU data router black box. An alternative 747-400 system architecture using this approach in conjunction with an existing ACARS is shown in Figure 9.

Definition of the CMU architecture, functional requirements, and certification requirements as well as the detailed design, integration, and test is the critical path for achieving an ATN compatible data link on the 747-400 by mid 1993.

United Airlines Team DUTCH

The MITRE Corporation, in support of the FAA, has organized an ATN Project to validate the ATN data link concepts. As participants in this project both American Airlines (AAL) and United Airlines (UAL) have decided to incorporate production certified avionics on commercial airplanes for operational evaluation of the ATN.

The United Airlines team called DUTCH (United, Unisys, Teledyne, Collins and Honeywell) is developing SATCOM Data Level 3, ACARS/CMU, FMCS Package B and Airborne Condition Monitoring System (ACMS) to be certified as production equipment on a 747-400 in mid 1993. Boeing is system integrator for testing and certification.

Boeing is also the design authority for the FMCS Package B which is purchased by Boeing and sold to the airlines as Seller Furnished Equipment (SFE). SATCOM, ACARS/CMU and ACMS are purchased directly by the airline and installed and certified on the airplane by Boeing as Buyer Furnished Equipment (BFE).

It is hoped that the product of this Team DUTCH effort will be the first certified ATN compatible data link system using SATCOM. By the time operational evaluation commences in 1993 both UAL, AAL and potentially other airlines will have conclusively demonstrated the superiority of SATCOM Data Links over current HF voice systems in the oceanic arena, and the ATC authorities will be ready with the ground based networks to complete the link between the airplanes and the Oceanic control centers. In addition to the physical infrastructure required to implement data link services the operational community, including pilots, controllers, and regulators, must work together to develop the operational concepts and procedures that will allow the airlines to exploit the economic benefits that their investment in data link technology promises.

777 Data Link Design

The core of the 777 Avionics system is a dual cabinet arrangement of electronic modules which is called Airplane Information Management System (AIMS). This is a design generally in accordance with the AEEC Characteristic 651 for Integrated Modular Avionics. It utilizes fault tolerant technique and integrates multiple functions in a few core computers using robust partitioning techniques for software segregation and isolation.

The FMCS, the CMU Data Router, ACARS, and the ACMS are all functions integrated into AIMS. The schedule for 777 requires mature systems by October of 1994 and certification in April of 1995.

Figure 10 shows the 777 architecture from a data link perspective. Note that all physical interfaces outside of the airplane are via the AIMS cabinet. Connectivity to the Electronic Library System (ELS) and Cabin Management System (CMS) is via an on-board Fiber Distributed Data Interface (FDDI) Local Area Network.

The AIMS design integrates the following functions:

Flight Displays
Engine Displays
Crew Alerting
Flight Management
Thrust Management (Auto Throttle)
Fault Monitoring and Reporting for Maintenance
Signal Consolidation for Flight Recorder

Automatic Checklists
Software Data Load Gateway
Signal Consolidation and Retransmission for Engine and Flight Control Systems

ATN Router
Data Link Message Processor Including Flight Crew Display and Control (formerly ACARS)
Airplane Condition Monitoring System (ACMS)

The first group of functions have traditionally been provided by Boeing as Seller Furnished Equipment (SFE) due to either criticality, unique interface or system architecture characteristics, or for proprietary considerations. The second group of functions are new to a Boeing airplane and are included in the SFE AIMS for the following reasons. Of the last group of functions ACARS and ACMS have traditionally been Buyer Furnished Equipment (BFE) specified and procured by the airlines and installed, integrated, tested, and certified by Boeing.

For the 777 Boeing has chosen to integrate these traditionally BFE functions into the SFE AIMS cabinet. The AIMS design will accommodate the airline requirement for flexibility in these functions by using a table-driven approach. Flexibility will be built in to the operational software. Specific

modifiable features will be invoked by customer generated tables that are loaded into AIMS via either the onboard software data loader or gatelink. The table driven approach will allow the operating software to remain unchanged and therefore significantly reduce the cost associated with recertification of each new customer option. A ground-based software tool being designed in conjunction with AIMS will be used by both Boeing and the airlines to generate the loadable tables that configure the AIMS optional features.

Industry Activity

To make the Aeronautical Telecommunications Network a reality requires international and industry standards for design, certification, and interoperability. The major organizations and their primary activities and responsibilities are listed below :

FAA and Foreign Regulatory Agencies

Origin/Destination of air/ground traffic related to Air Traffic Service Communication (ATSC) including Air Traffic Control (ATC)and Flight Information Service (FIS) information

Developer and operator of ground terminals connected to the ATN

Key participant in industry activities to develop standardized means of representing ATSC information (Data Dictionary)

Developer of airworthiness standards and certification requirements for airborne ATN components and installations.
(Advisory Circular 25XX)

MITRE

Program Manager for FAA sponsored ATN Demonstration Program

Airlines

Origin and destination of Aeronautical Industry Service Communication (AISC) including Aeronautical Operational Control (AOC) and Aeronautical Administrative Control (AAC)

Defines functional requirements for BFE equipment

Ultimate purchasors and operators of airborne ATN equipment.

Developer and operator of ground terminals connected to the ATN

Participants in Industry activities to develop standards for both airborne and ground ATN components and systems.

Sponsors and/or participants in ATN demonstration programs

Avionics Manufacturers

Designers and vendors of airborne ATN equipment

Participants in Industry activities to develop standards for airborne ATN components and systems.

Participants in ATN demonstration programs

Aeronautical Radio Incorporated (ARINC)

Provider of ground-based network services to transmit and route data between airborne ATN terminals and ground-based regulatory and airline computer systems.

The Airlines Electronic Engineering Committee (AEEC) sponsors meetings of airlines and avionics and airframe manufacturers to establish consensus design standards for airborne ATN equipment. Consensus design standards are published as ARINC Characteristics.

Radio Technical Committee for Aeronautics (RTCA)

Sponsors meetings (Special Committees) composed of government and aviation industry representatives to develop Minimum Operational Performance Standards (MOPS) for the entire ATN, network subsystems, and specific ATN applications.

International Civil Aviation Organization (ICAO)

Develops through Industry coordination and publishes Standards and Recommended Practices (SARPS) defining the architecture and operational characteristics required to achieve international interoperability of the ATN.

Participates in the definition and international coordination of addresses for all ATN ground elements, airplanes, and application functions.

Air Transport Association / International Air Transport Association (ATA/IATA)

Represents airlines in developing human factors requirements for ATN applications.

Establishes communications protocols and standards for airline-specific ground-based ATN applications and coordinates address assignments.

Airline Consultative Committee for Telecommunication Systems (ACCTS)

Involved in address assignments and the specific application of OSI standards to the ATN.

These organizations have authorized the a large number of committees / working groups to develop specific aspects of the ATN and its applications. Figure 11 developed by the FAA shows the major organizations and the number of sub-groups involved.

Conclusion

Boeing foresees large scale application of data link for Airline Operational Control and Air Traffic Control. Boeing also endorses the standardization provided by ATN with its Open System Interconnection. The oceanic sector can be the first ATN application in 1993 using SATCOM Data Level 3, FMCS Package B and an ACARS/CMU. The technical issues to be resolved are manageable; the risk involves the schedule for defining firm design requirements endorsed by the international aeronautical institutions.

Communication Needs of the Future – Air Ground Interface

"Satellite technology is now the only viable solution that will enable one to overcome the shortcomings of the present CNS [Communication, Navigation, and Surveillance] system and to fulfill the needs and requirements of the foreseeable future on a global basis"

Figure 1 ICAO Future Air Navigation System (FANS), Fourth Meeting, May 1988

Communication Needs of the Future – Air Ground Interface

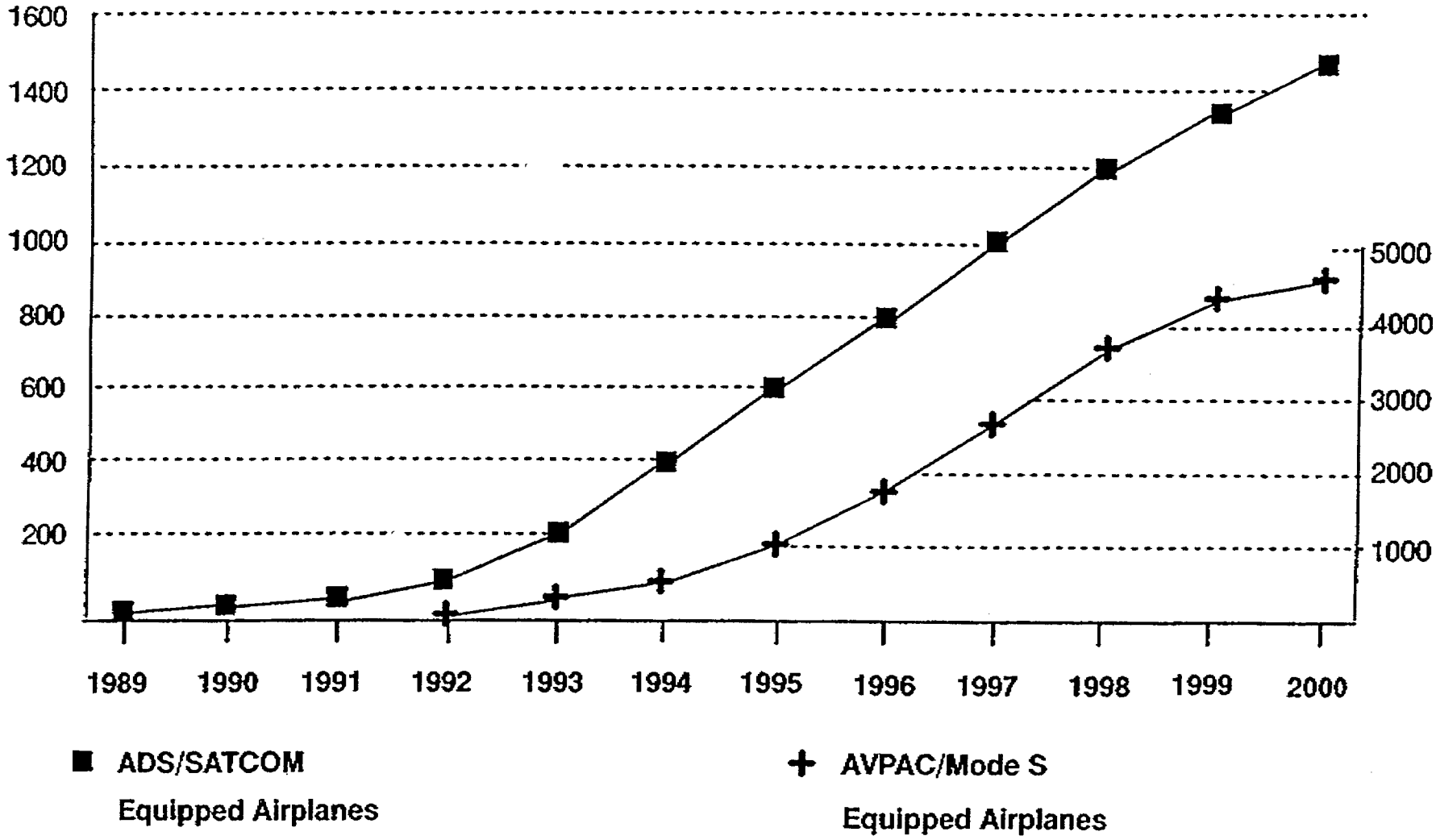

Figure 2 Projected Growth of Data Link Equipped Airplanes

Communication Needs of the Future – Air Ground Interface

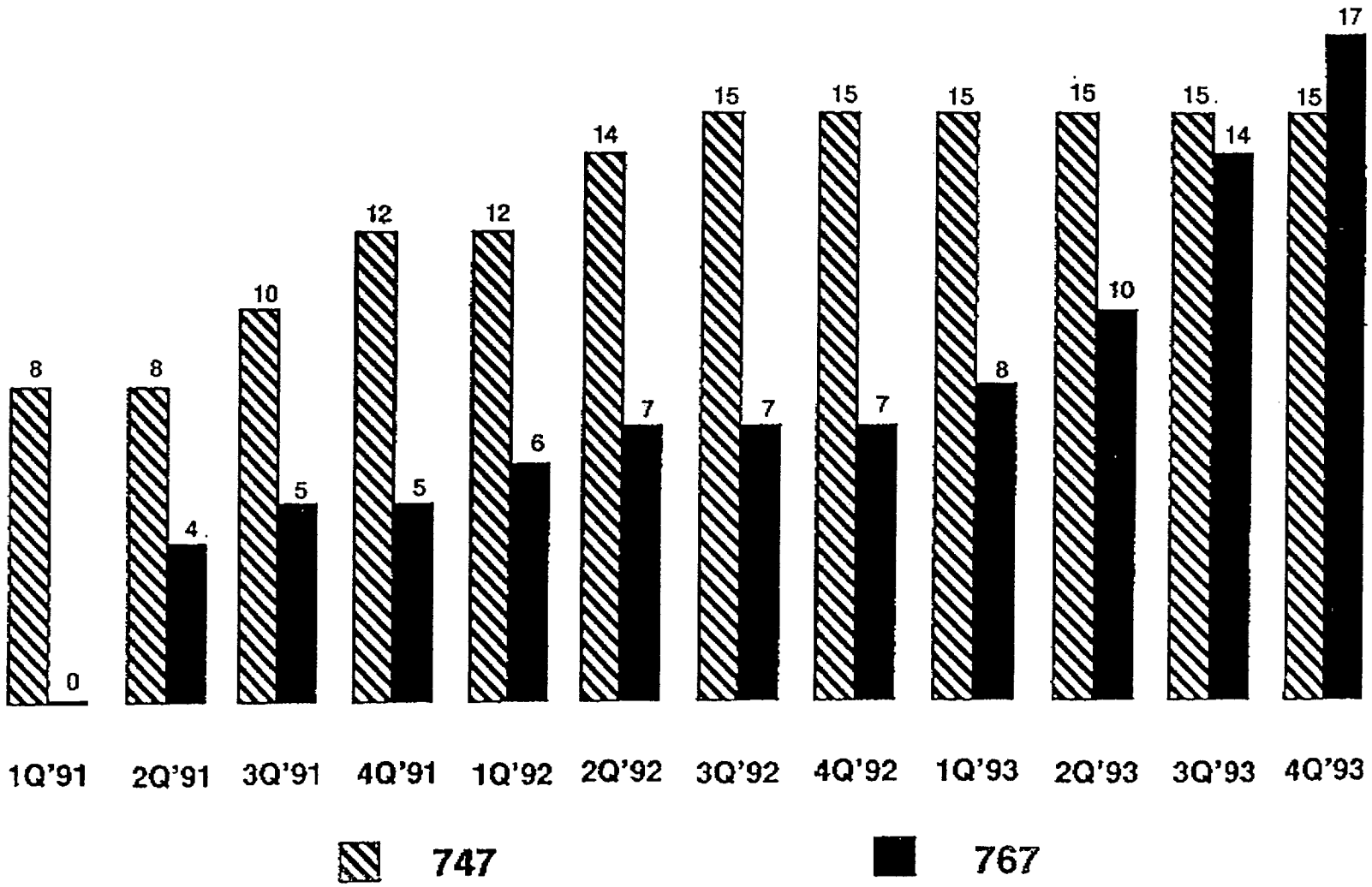

Figure 3 SATCOM – Provisioned Aircraft Deliveries

Communication Needs of the Future - Air Ground Interface

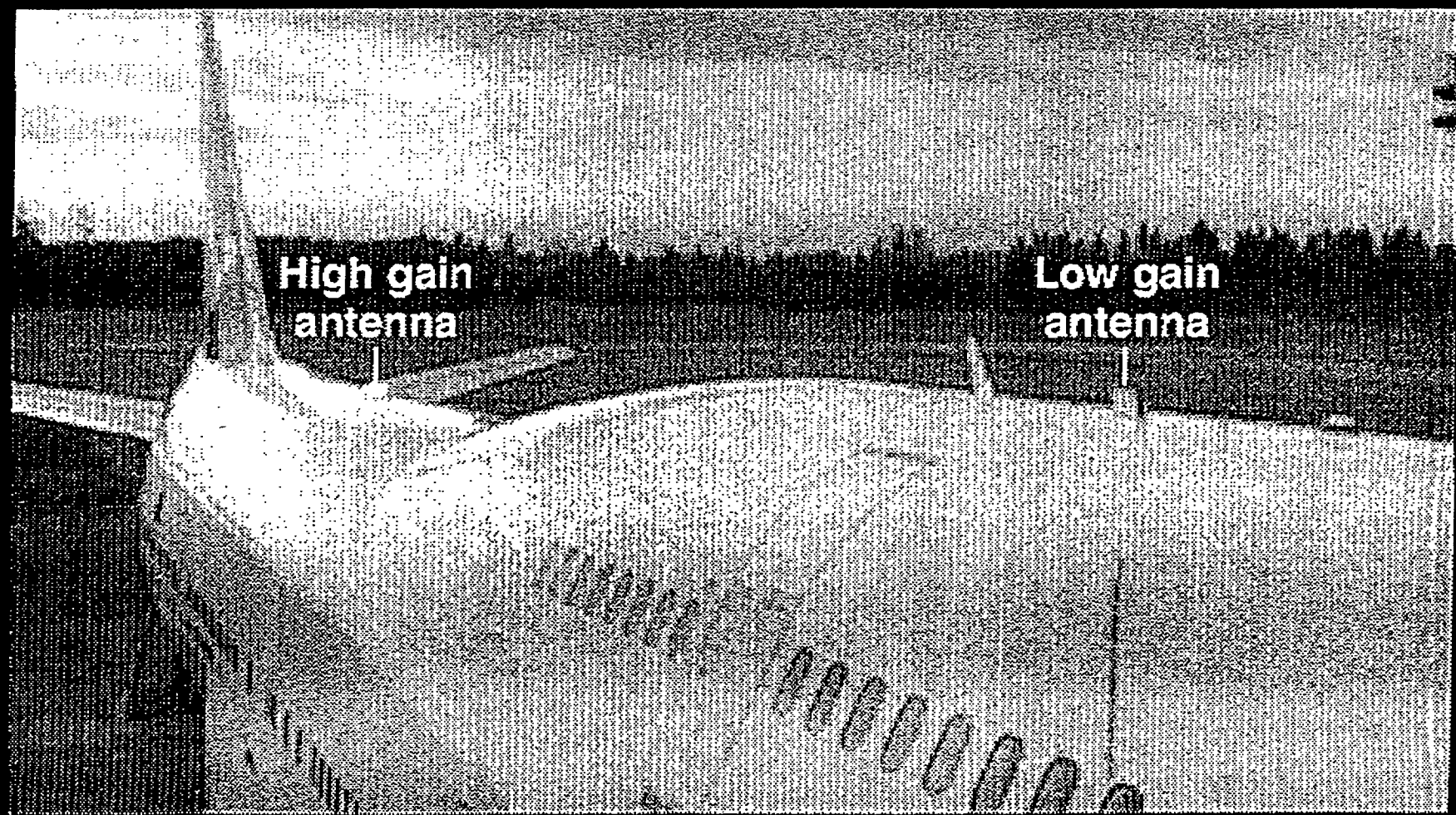

Figure 4 - 747-400 SATCOM Antenna Installation

Communication Needs of the Future - Air Ground Interface

Figure 5 - 747-400 SATCOM Avionics Installation

Communication Needs of the Future – Air Ground Interface

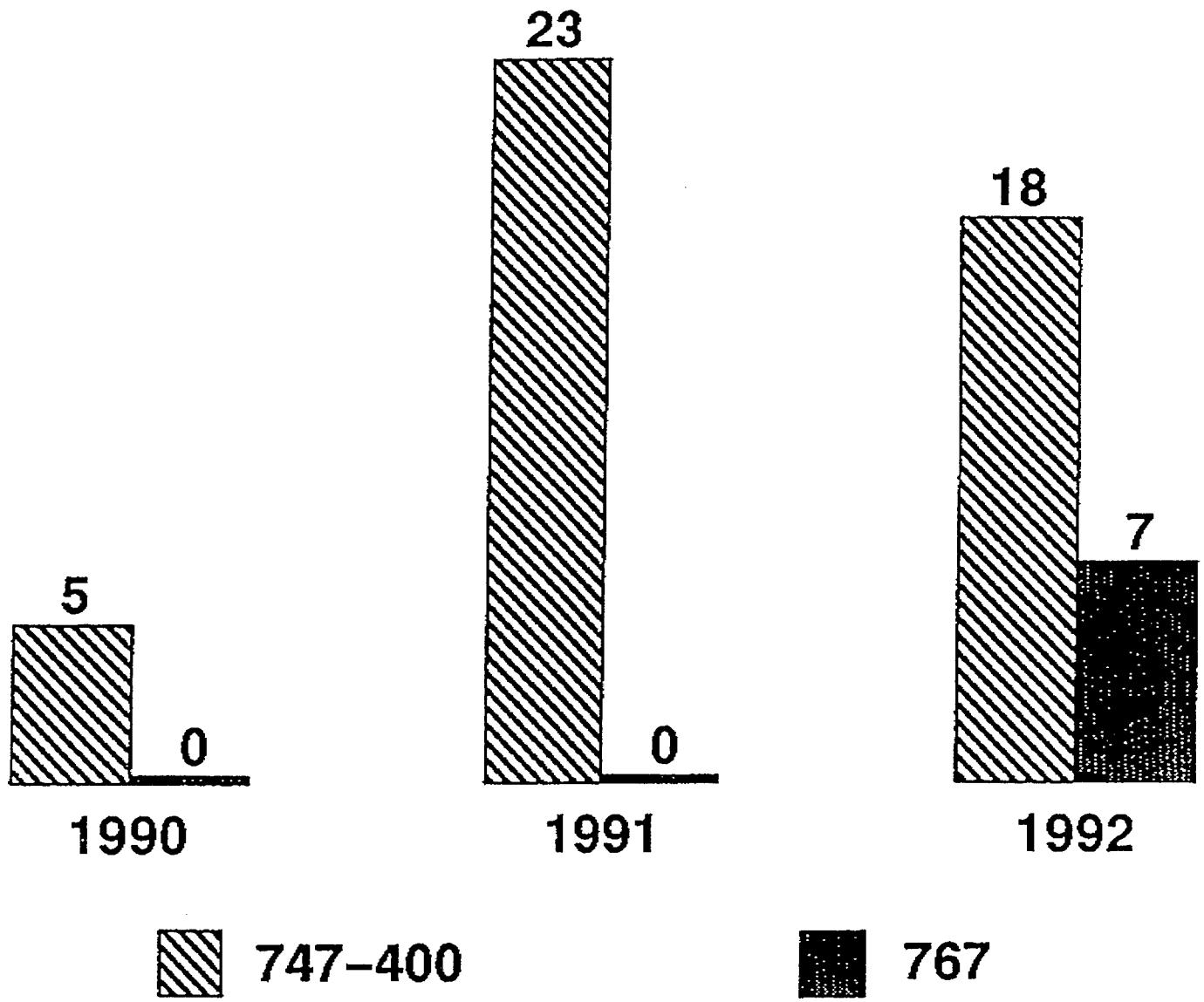

Figure 6 Previous and Currently Committed 747–400 and 767 SATCOM System Deliveries

Communication Needs of the Future – Air Ground Interface

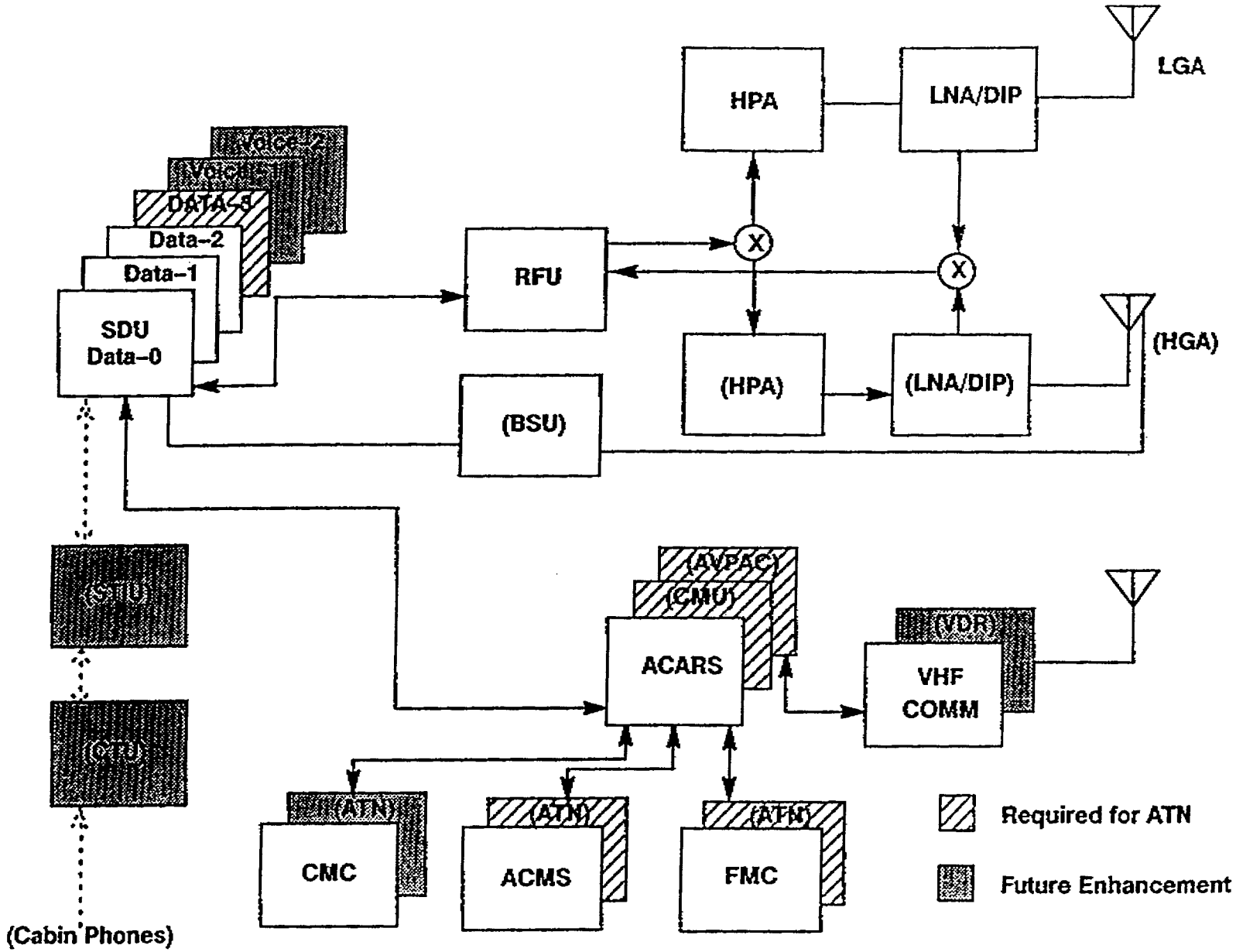

Figure 7 747–400 Data Link Evolution to Support ATN

Communication Needs of the Future – Air Ground Interface

Flight Manual Limitation

The ACARS/SATCOM System has been demonstrated only for the purpose of non–essential information transfer and has not been approved for use in ATC communications. Therefore, compliance with any ATC clearance received solely through the ACARS/SATCOM system is prohibited.

Figure 8 747–400 Operational Limitation Imposed by FAA

Communication Needs of the Future – Air Ground Interface

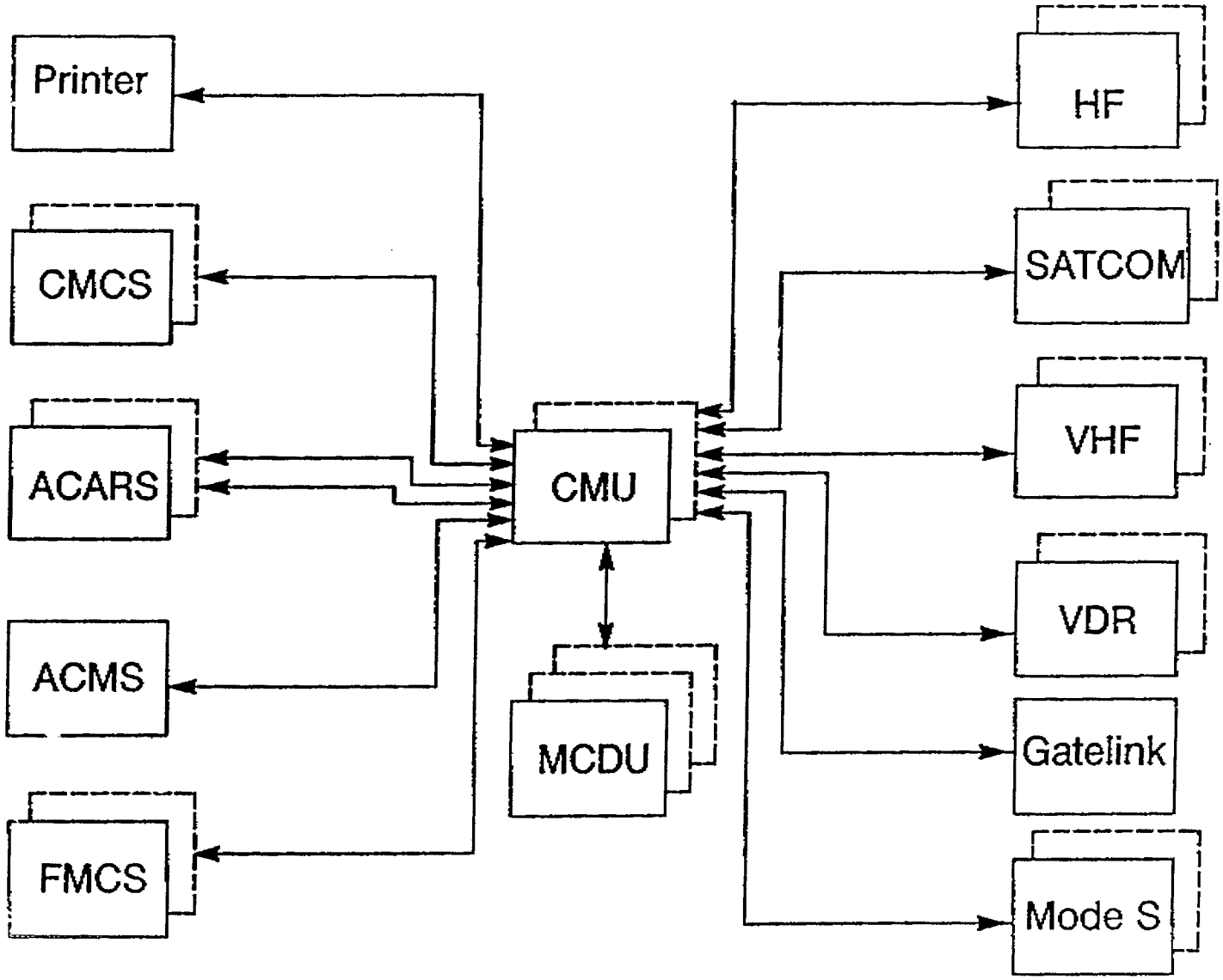

Figure 9 Independent CMU Alternative Data Link Architecture

Communication Needs of the Future – Air Ground Interface

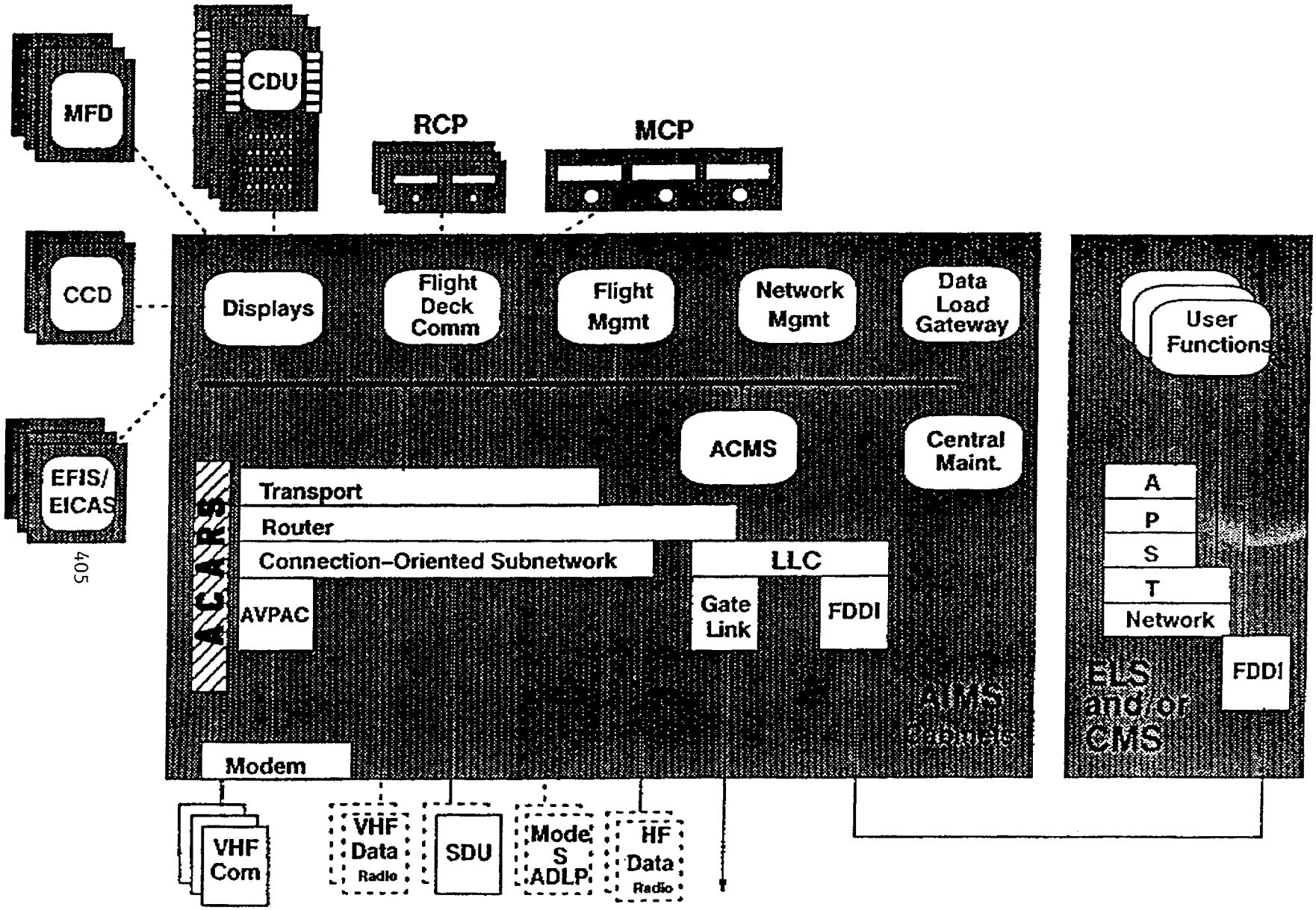

Figure 10 777 Digital Communications Management Functions & Interfaces

Communication Needs of the Future – Air Ground Interface

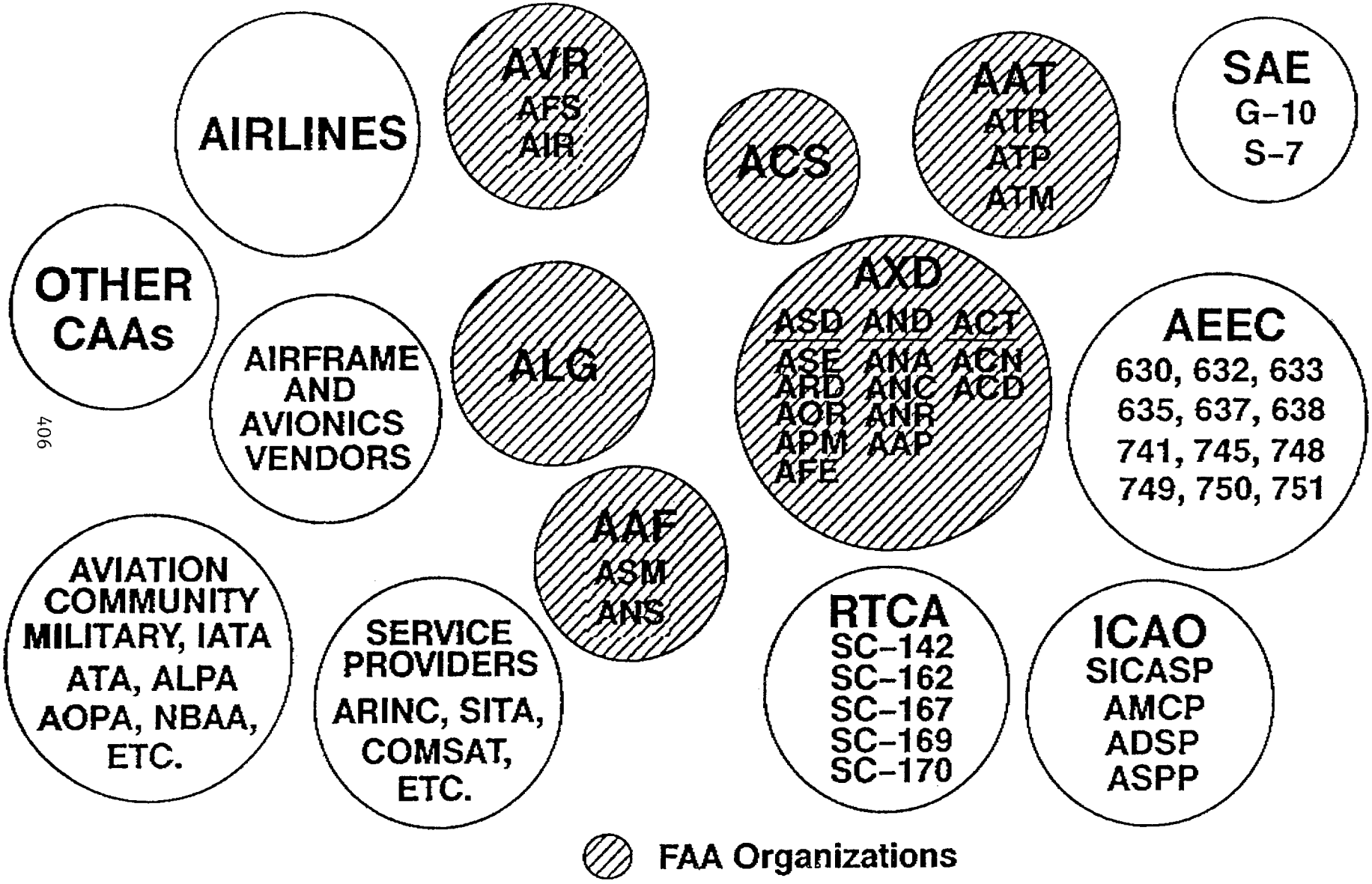

Figure 11 Organizations involved in Data Link Requirements Development

SESSION FIVE: AIRLINE PROGRAM/OPERATIONS

Renate J. Roske-Hofstrand
Chief Human Factors Engineer
CTA, Incorporated

As Chief Human Factors Engineer, Dr. Renate J. Roske-Hofstrand coordinates CTA's human factors efforts in support of the FAA Technical Center's research and development in communication, navigation, surveillance, landing aids, and air traffic control. Based in McKee City, New Jersey, she serves as Task Manager for evaluation research in datalink systems. Dr. Roske-Hofstrand served on the FAA's Scientific Task Planning Group for Air Traffic Control.

Prior to joining CTA, Dr. Roske-Hofstrand served as Principal Investigator for human-computer interface issues and applied cognitive research in aviation at the NASA Ames Research Center, Moffett Field, California. She has conducted research as a visiting scientist at NASA-Langley in Hampton, Virginia and the National Transportation Safety Board in Washington, D.C.

Dr. Roske-Hofstrand holds a Ph.D in cognitive psychology from New Mexico State University. She is a member of many professional organizations including the Human Factors Society, the Association of Aviation Psychologists, the ACM Special Interest Group on Computer-Human Interaction, the European Association for Cognitive Ergonomics, and the Air Traffic Control Association.

Her publications on air traffic control have appeared in the proceedings of numerous conferences (e.g., the biennial International Symposium on Aviation Psychology, Conference on Human Factors Issues in the Use of Artificial Intelligence in Air Traffic Control, Annual Air Traffic Telecommunications symposium on Data Link Integration). Her book chapters appear in Pathfinder Associative Networks: Studies in Knowledge Organization and Handbook of Human-Computer Interaction. Her paper on cognitive networks was featured in Ergonomics (Special Issue on Aviation Psychology). Dr. Roske-Hofstrand holds a Private Pilot Certificate.

A Model Human Engineering Approach to the Development of Regulatory Standards for Digital Communication Technologies: Defining Safety from a Human-Machine Systems Perspective

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Jack Berkowitz
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and

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FAATC-ACD-320

Abstract

This report outlines the initiation of a comprehensive research program which will investigate the integration of digital communications into the flightdeck and will address specific safety considerations. First, a basic research scheme is described. Next, some preliminary results are presented. Finally, future directions, both within the current research scope and beyond, are discussed.

1. Introduction

The advent of digital communication technologies provides the systems design engineer with the unique opportunity to satisfy those functional requirements which are characteristic of optimal flight management, air traffic control and user interactions. Pilots and controllers are required to command an ever increasing number of integrated sub-systems in order to retain control of and manage the flightdeck and air traffic environment. A "glass" cockpit aircraft requires a myriad of information exchanges in the form of system commands and interactions with the aircraft's Flight Management System (FMS). Integrated system technology promises safe and efficient flight; however, each information exchange in this increasingly "automated" system must be viewed as an instance for potential error. From a human factors perspective these situations represent potential penalties on the debit side of the "balance sheet" for human cognition.

2. Error Causes

Errors are a generic term encompassing all those occasions in which a planned sequence of mental or physical activities fails to achieve its intended outcome, and when these failures can not be attributed to the intervention of some chance agency (Reason, 1990). The primary causal mechanisms for error fall into three major distinct categories: human behavioral error factors, contextual and situational error factors, and cognitive and conceptual error factors. This paper will address only that class of human error which appears preventable due to our ability to identify characteristics in system design and its human interfaces.

A number of human factors engineering studies have recently been initiated to investigate the relative efficacy of data link control and display alternatives. The research would typically investigate human behavioral error factors. Despite good progress in terms of defining the types of air traffic control services offered and specifying optimal display format configurations, little research has been done to address optimal integration of the various data link functions. Little attention has been paid to the systematic study of contextual/situational or human cognitive error factors. Only these factors will most directly help to identify any faults or potential human incompatibilities in system design.

3. Methods of Investigation

The methods of investigating human error in aviation systems vary widely and currently only a hand full of investigators have tackled this topic in aviation systems. The most familiar methods to the aviation community take the form of "data base accumulation" and "case studies". An example of the former is NASA's Aviation Safety Reporting System (ASRS) which encourages both pilots and controllers to report on known incidents (those which did not lead to catastrophic consequences). The basic rationale for this type of data collection is that the relatively minute irregularities in daily operations are a useful guide to the understanding of problems in the system. Appropriate analysis of this data can function as an early warning device for problems evolving in the entire aviation system.

The National Transportation Safety Boards's investigations following accidents are an example of the case study approach for investigating human error. The intensive study of a single given case can teach us something about a particular combination of contributing factors and about the limits of human performance. In terms of providing a complete record of events, accident reports fall short, mostly because they are concerned with attributing blame.

4. A Model Approach

Our own model human engineering approach to the investigation of human error is a comprehensive effort that attempts to combine the fields of system safety engineering with simulator studies. Our basic approach builds upon an understanding of human error gleaned from ASRS data, questionnaires, and case studies. With the new data link technologies, we can not benefit from a corpus of available data. Therefore we will make use of computer-based simulations which will create in a laboratory setting many of the dynamic features of real-life, complex tasks using initial new technology designs. These simulator studies will allow us to chart the discourse of error events and their consequences for purposes of defining system design guidelines. With the addition of digital communications into the existing automated navigation and flight regime and the current scarcity of human factors functional requirements, the process of safety assessment for air worthiness certification has gained several layers of complexity. The system to be evaluated and certified includes both airborne and ground-based computers which are capable of being linked or coupled to the primary flight computers.

The FAA Technical Center has recently acquired a vital tool for the comprehensive investigation of error in this system environment. This tool, known as the Reconfigurable Cockpit Simulator (RCS) allows for the rapid configuration and re-configuration of flight-deck equipment and linkage to existing air traffic control simulation facilities. It enables us to run carefully designed and controlled scenarios with the intent to produce "error" situations which will test pilots and controllers. This approach will yield information regarding the relative severity of the consequences of "mistakes" with various interface design features.

Human-machine interactions in complex and increasingly automated flightdeck and control room environments will change with the introduction of digital communication regimes. The new procedural discourse may differ greatly from current tasks yet individual human-machine action sequences are still critical in insuring or endangering safety. The consequences of failure in any one or all of the system elements may involve danger to human life, property. Of particular interest to our planned investigations will be an exploration of how humans behave when things go wrong.

5. Regulatory Standards and Certification Issues

Accidents have traditionally been defined as unplanned events or series of events that lead to an unacceptable loss such as death, injury, illness, damage to or loss of equipment of property. Levinson (1991), in an article addressing software safety, points out that computers and their

displays by themselves are relatively safe devices: they rarely explode, catch on fire, or cause physical harm. The same can be said of the human sub-system: rarely do humans spontaneously combust. However, computers and their human operators on the flightdeck or on the ground can contribute substantially to accidents or incidents.

The distinction between an accident and an incident is made by evaluating the relative severity of the consequences of a particular event. In terms of error categories a distinction can also be made between "active" errors, whose effects are felt almost immediately and "latent" errors whose adverse consequences may lie dormant within a system for a long time before they combine with other factors and breach a system's defenses. In general, active errors are associated with the performance of the front-line system operators: pilots and controllers. In contrast, latent errors are associated with system design flaws, i.e. design and engineering activities removed in both time and space from the eventual actual system operation. The certification process must deal with both categories of event consequence. This is difficult in the absence of sound functional and unambiguous implementation requirements for airframe and avionics manufacturers. The FAA Technical Center's Airborne data link human factors research program investigates the lifetime of sub-system errors and their consequences to fill this gap.

6. Error Analysis and Resource Management Event Trees

A critical first step in the FAA Technical Center's Airborne data link human factors research program involves "error life-time" analysis. This analysis focuses upon event sequences which lead to successful or unsuccessful flight episodes. Charting human action sequences and their consequences as a result of specific precipitating conditions provides important information to both the system design engineer and the certifying authority. Central to the development of our error life-time analysis is the construction of operational resource management event trees. These trees are graphical descriptions of human and system behavior, through which cockpit actions and results may be analyzed. The basic representational format is that of a fault-tree, using events linked through "and" and "or" gates. An entire integrated flightdeck may be assessed by constructing individual resource management trees for each subsystem.

For purposes of illustration, a resource management event tree template is presented in Figure 2-1. This sample tree describes a "climbing" flight segment with required input to a Flight Management System. The tree progresses from the overall goal of successful flight down (or up) through levels of aircraft system and user characteristics. The first level encompasses different desired flight execution phases; including climbing, transitioning, landing, and final approaches. Flight phases reference both the vertical and horizontal components of flight control.

The second level indicates the flightdeck subsystem of interest. Possible sub-systems considered include the FMS, altitude alerting systems, autopilot systems (when separated from FMC), voice radio, and data link. At this stage of development, the interactions between two or more subsystems are not broken out for separate analysis.

The third level describes the user intent in executing inputs to the subsystem. Note that this level of classification concentrates on the intent of the user to perform the function, not whether or not the subsystem is capable of actually performing the function. This distinction is made in reference to the error analysis procedures used in conjunction with these event trees which will be discussed later in this paper.

The fourth level describes, the specific user action followed to execute the user's intent. For the example diagram, "Action Series 2" refers to a sequence of key strokes which will arm the FMS. There may be other key stroke sequences which would also arm the FMS, and these are denoted by the different action series.

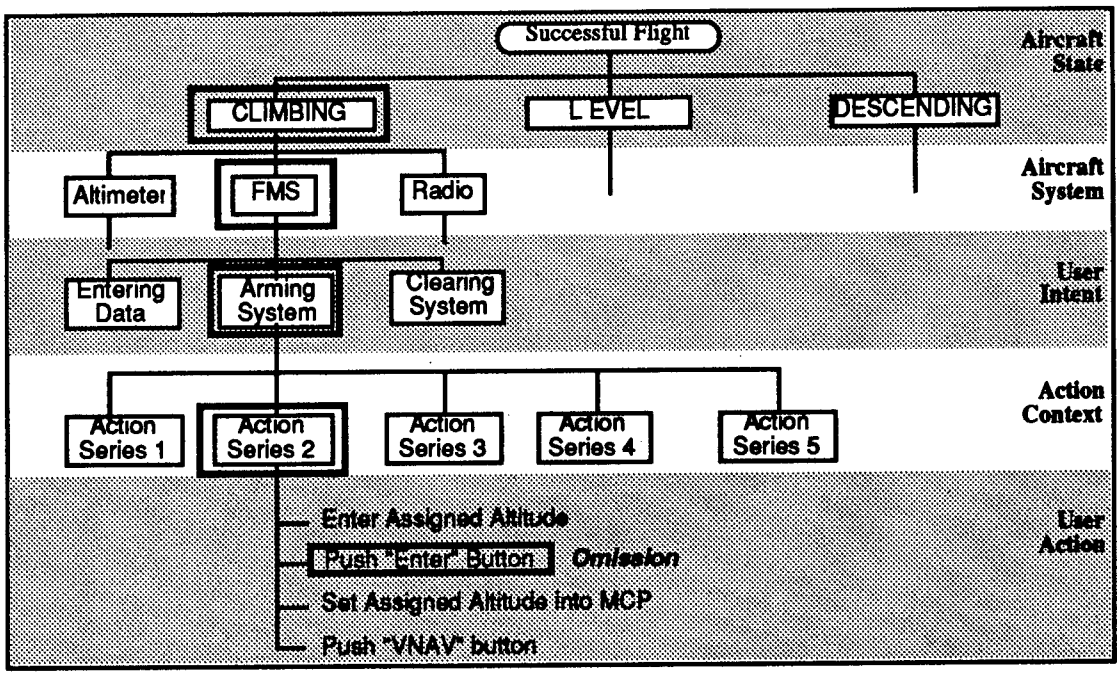

Figure 2-1. Generic Resource Management Event Tree.

At the lowest level of the tree are the user actions which comprise the action series. Included at this level are both observable and inferable user behaviors which constitute a human action series. The actions include such behaviors as pushing function keys, turning dials, reading displays, and verbal output. These actions are classified to the lowest interpretable level. For example, we utilize "Read-back assigned altitude" as opposed to indicating each phoneme separately.

A key component of these trees is the ability to attach numerical probabilities of success to the different human and system events. The attached weighting parameters refer to non-observable human factors, such as the cognitive, perceptual, or physical effort required to perform the individual act. The weighting is assigned based on known cognitive and psychological principles. Once validated through system simulations, the resource management event trees will be an asset to the FAA's certification effort.

A second feature of the trees is the ability to pinpoint action errors in terms of the observable pilot behavior (the lowest level of the tree). By reviewing records of flightdeck incidents involving some type of "pilot" error and classifying these errors according to standardized human error categories, human error templates arise which correspond to the event trees. These categories will be described in detail later; however, the basic hypothesis is that the same form of "pilot" error occurs during a certain action series, and that this error "pattern" is repeated across different incident reports.

A schematic of the data collection requirements for resource management event tree construction is presented in Figure 2-2. Currently, the program is progressing through analyses of the NASA Aviation Safety Reporting System (ASRS), a general investigation of human error classifications tailored to automated systems, and an adoption of generic human error types for use in the flightdeck analyses (the three boxes hilighted in the diagram). Additional data collection and validation will be accomplished through structured subject matter expert (SME) interviews, direct observation of flightdeck activities, and human factors experiments with the RCS simulator system.

The eventual goal of this event tree construction is threefold. First, the event trees will provide a graphical analysis tool for human procedures, decisions, and actions within the flightdeck

environment. Second, through the mathematical analysis of the trees, input to the FAA's certification authorities will be formulated, both in reference to human interaction with solitary sub-systems and to the integration of new sub-systems in the larger flight control system. Last, the event trees will aid in the generation of hardware and software guidelines for new data link implementations and services.

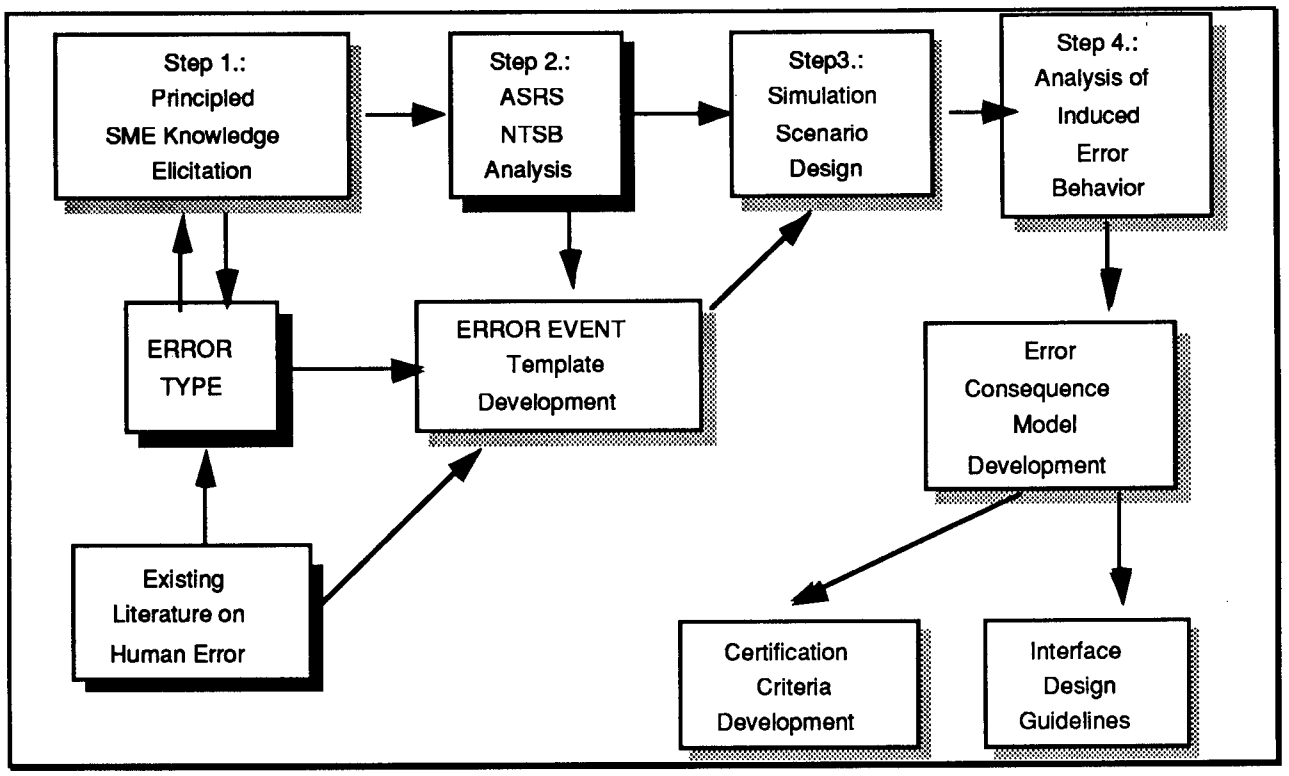

Figure 2-2. Data Collection Requirements for Event Tree Construction.

7. Initial Results from our ASRS Data Analysis

In this section, a preliminary analysis of ASRS reports is described. First, the framework for the reports is detailed, and then some of the study's results are presented.

7.1 Analysis Procedures.

ASRS database selections are provided by a NASA contractor in response to search requests. The search requests are usually centered about broadly defined categories of interest, with the contractor's personnel performing the actual search.

Based on the a priori assumption that the addition of a new communication subsystem would add to pilot distraction, a search request was made using "Heads Down Incidents" as the central topic. "Heads Down Incidents" were operationally defined as the occurrence of an unsafe aircraft control event due to the pilot not maintaining a "normal" instrument scanning and control behavior either outside of or within the cockpit. This behavior alteration can be attributed to high workload levels, the occurrence of an extraordinary event (such as an equipment malfunction), the misuse or lack of acceptable procedures, or other distracting events.

Key words used to search the database included:

Heads Down	Program
Flight Crew Distraction	Key
Flight Crew Attention	FMU
Flight Crew Pre-Occupied	FMC
Instrument Panel	FMS
Input	EICAS
Enter	EFIS
Keyboard	APU
Aircraft Equipment Problem	INS
IRS	OMEGA
GPS	Autopilot
Altitude Alert	

At the time of the database search, the ASRS database contained 33,045 full length incident reports. These full length reports are sanitized to remove any traceability of the reported incident back to the pilot who filed the report. Included in the incident report are data on incident date, position of the person filing the report, the persons involved in the incident, the flight conditions, the location of the incident, the aircraft type, the location of the aircraft, the altitude of the aircraft, and other items concerning both the aircraft and the procedure being employed. In addition, the report provides a narrative description of the incident. Using the key word search, 160 incident reports were selected for further analysis. These reports were provided by the Battelle ASRS Office.

7.1.2 Aircraft Position Classification.

The narrative sections of the ASRS incident reports were analyzed for contributing factors to the head-down incident. The incident reports were categorized according to seven aircraft position classification dimensions. Data for these classifications were drawn from both the narrative sections and the other incident report data fields. These dimensions included:

a. Type of Aircraft
b. Aircraft Flight Phase (Vertical)
c. Aircraft Flight Phase (Horizontal)
d. Central Instrument Utilized
e. Aircraft Position Error

Although an in-depth explanation of these dimensions is beyond the scope of this paper, some general comments are possible. The Type of Aircraft reported was a general classification of aircraft class based on takeoff weight (as opposed to an aircraft model designator like B747-400). The Aircraft Flight Phases referred to aircraft maneuvers at the beginning of the reported incident. The Central Instrument Utilized sought to identify the one sub-system with which the reporter seemed to have difficulty, with which the reporter was preoccupied, or which the reporter utilized most frequently throughout the duration of the episode.

Category "e", Aircraft Position Error, classified the positional error of the aircraft in the incident. There were four levels of this category. "Error - Altitude High" was recorded when the aircraft reached any altitude above the assigned altitude during any phase of flight. "Error - Altitude Low" was recorded when the aircraft descended to any altitude below the assigned altitude. "Lateral deviation" was recorded when the aircraft was flown off course, or was lined up on the wrong runway for takeoff or landing.

For the positional errors, no reference was made in terms of the absolute altitude or heading assignments received by the pilots. Instead, the positional error referred to the relative position of the aircraft to their assigned positions. For example, if an aircraft was 1000 feet above the assigned altitude of 18000 feet, what was recorded was that the plane was in an altitude bust situation, not that

the plane was at any set altitude (say 18000 feet versus 36000 feet). No indication was given as to whether an air traffic conflict resulted or if any separation standards were violated. This information was not directly obtainable from the ASRS reports.

7.1.3 Pilot Error Classification.

The narrative reports were also categorized according to any pilot error that could be identified from the report. Admittedly, this analysis was somewhat subjective; however, the reports did provide an extensive amount of data on which to base categorization decisions.

The error categories used were derived from application of standard human factors error schemes. These errors included:

Commission	Pilot performs unnecessary action.
Generic Command Misapplication	Pilot performs actions generally known to achieve a function, but fail to work in the current situation.
Goal Induced	The pilot correctly enters inappropriate command.
Incomplete Procedure	Pilot begins proper command sequence, but escapes before completing the procedure.
Mode	Pilot performs action when system is in the wrong mode to accept or execute the action.
Omission	Pilot fails to perform a necessary action.
Pre-Requisite Action Omission	Pilot fails to perform necessary selection (action) before proceeding with a planned action sequence.
Option Identification	Pilot chooses a menu selection option to perform one action when in fact the selection performs another action.

7.2 Results.

The 160 ASRS incident reports were analyzed according to the method described above. In this analysis, only incidents which might have involved some degree of perceived pilot error were considered. Those which would not be involved with pilot actions were excluded from the analysis. Thus, only 144 of the incident reports were retained for further analysis.

7.2.1 Statistical Use of ASRS Incident Reports.

The incident reports provided by the Battelle office do not constitute a representative sample of all aircraft incidents. First, the use of the reporting system is voluntary, and thus not all incidents are reported. Second, the selection of the incident reports from the ASRS data base is dependent upon the selection key words which the research technician employs. A different research technician may submit a alternate key words for the search, and thus provide a slightly different selection of incident reports. With this caveat in mind, the statistical use of the ASRS reports is somewhat limited. The true power of their usage is derived through an analysis of the accompanying narratives. Although subjective, the analysis procedures provide a method for the reduction and interpretation of the data.

The results presented below represent a selection of data from the total database. As conventional statistical tests are inappropriate for these analyses, the data presented are those considered relevant to the focus of the project.

7.2.2 Aircraft Position Errors.

The aircraft type data indicated that the majority of the incidents reported were connected to the Medium transport size type (30,000 - 150,000 lbs. takeoff weight) at 45.1%, followed by the Large transport size (150,000 to 300,000 lbs. takeoff weight) at 29%. The central equipment classification focussed on the main piece of equipment mentioned within the narrative section. The equipment type most frequently involved with reported incidents was the Flight Management System/Autopilot classification (37.5%); followed by the Altimeter/NAV aids classification (29.9%).

The horizontal flight phase classification revealed a slanted distribution of horizontal flight phase activity, with Straight flight accounting for 78.5% of the incident reports versus 21.5% for Turning flight. The vertical flight phase classification revealed a somewhat even distribution of vertical flight phase activity across the five classification levels, with the exception of Transitioning Up incidents (10.4% of the total number of reports).

The aircraft position classification revealed the following trends in the data. The majority of the reported incidents resulted in either an altitude high (43.1%) or a low (26.4%) error. Combined,, altitude errors contributed 67.5% of the total number of classifications.

7.2.3 Pilot Error Classifications.

Table 3-1 presents the frequency of occurrence of each pilot error classification across the 144 reports reviewed. The results indicate the majority of the pilot error occurrences involved two pilot error classifications: Omission (27.1%), and Pre-Requisite Action Omission (29.2%). Combined, these two forms of omission accounted for 56.3% of the total pilot errors.

In addition, there were a large number of incidents for which there was no pilot error involved or for which a possible pilot error could not be discerned from the narrative report. The Not Applicable classification accounted for 22.2% of the total. The results of this analysis are presented in Figure 3-1.

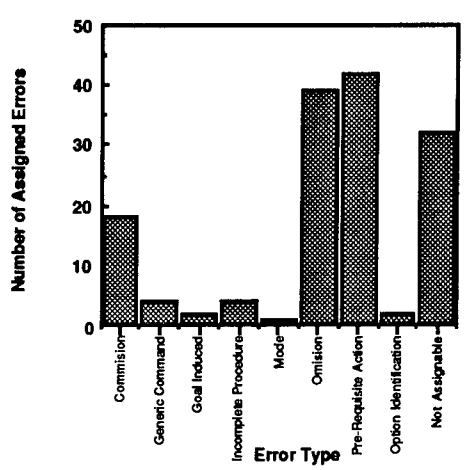

Figure 3-1. Pilot Error Classification.

7.2.4 Interactions between Aircraft Position and Pilot Error Types

In this section, the link between the different aircraft position descriptors and the pilot error classification is investigated. In the text, these relationships are referred to as interactions, even though the data were not utilized within a structured statistical analysis regime.

The two-way interaction between aircraft type and the central equipment utilized indicated that there are significant difficulties associated with the proper command and control of on-board flight computers, particularly in the larger aircraft types. In particular, FMS/Autopilot difficulties accounted for the most errors across the larger transport aircraft types, followed by difficulties with Altimeters and NAV aids. Furthermore, difficulties with radio functions did not seem to be as critical to the larger transport aircraft classifications.

The two-way interaction between aircraft position errors and aircraft vertical flight phase was also investigated. Several interesting, although somewhat predictable, results were found through this analysis. First, altitude high errors are associated strongly with both climbing (takeoff) and transitioning up stages of flight. These errors also occur frequently with transitioning down phases. Second, altitude low errors are associated with descending (landing) and transitioning down flight stages. Third, direction errors occur frequently in descending phases, as well as level flight. Last, a roughly even distribution of errors occurs during level flight, with slightly more altitude high errors recorded than the other three classifications.

The results of the two-way interaction analysis between aircraft position errors and pilot error classification were somewhat mixed. However, there were several trends in the data that are noteworthy. First, the data indicated that altitude high errors and direction errors were associated with Omission errors. In addition, altitude high errors and altitude low errors were associated with Pre-Requisite Action Omission errors. Last, all three classifications of position errors appeared to be associated with the Commission errors. The rest of the analysis indicated an even distribution of aircraft position errors across the different pilot error classifications.

The two-way interaction between aircraft vertical flight phase and pilot error classification was also investigated. The results of this analysis are graphed in Figure 3-2. Again, the results of this analysis detected some significant trends. First, climbing and descending flight phases were associated with Pre-Requisite Action Omission errors and Omission errors. Second, level flight was associated with Omission errors, and to some degree Pre-Requisite Action Omission errors. Last, both transitioning phases of flight were somewhat spread in terms of the pilot error classifications, with a large degree of Not Assignable pilot errors associated with each. However, transitioning down was associated somewhat with Omission errors.

8. Conclusions

The results of our ASRS data analysis indicate some "typical" human factors problems within the flightdeck. For example, pilots committed many omission errors during classically busy phases of flight, and these errors involved data entry into FMS and other flightdeck systems. It is reasonable to expect that similar errors will occur in conjunction with a data link sub-system. In addition, the integration of the sub-system into the overall system may alter the procedural and operational human-machine and human-human relationships within the cockpit.

The role of the FAA's airborne data link human factors effort is to provide inputs to certification. Through the decomposition and subsequent analysis of the flightdeck, recommendations can be formulated about proper integration practices. Included in these recommendations will be inputs about hardware/software design, sub-system integration, intra-cockpit procedures, and pilot-ATC integration procedures.

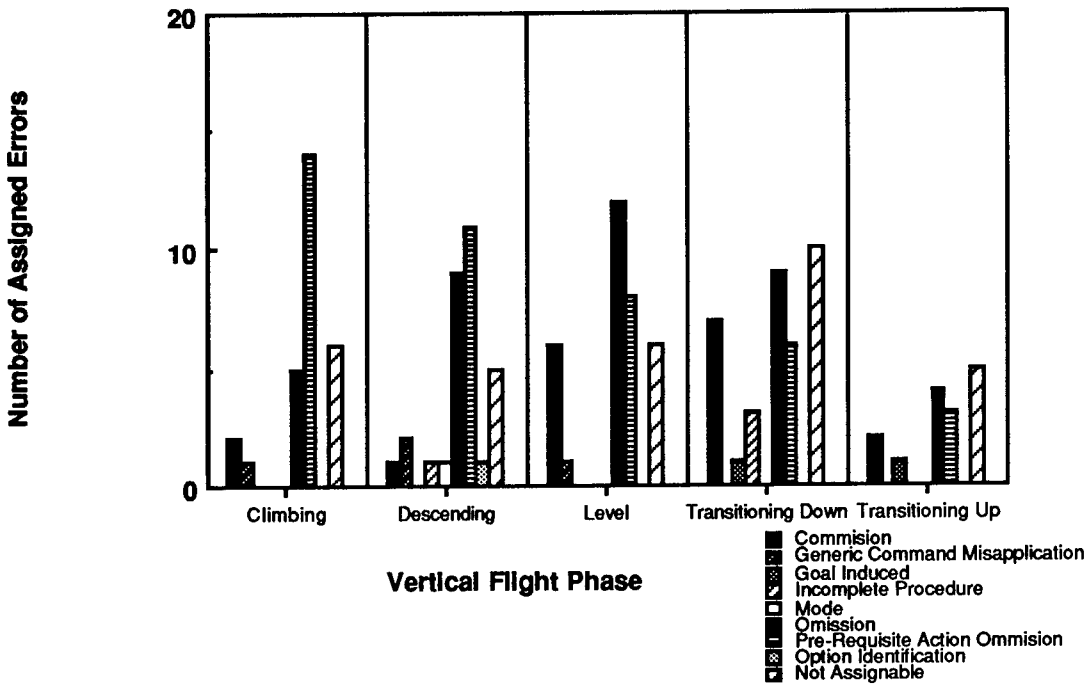

Figure 3-2. Vertical Flight Phase by Pilot Error Classification

As the program develops, other considerations will be incorporated into the general scope. Among these areas are the use of data link within special airspaces, such as oceanic sectors. Furthermore, the expansion of data link for direct aircraft-to-aircraft communication, and the implications of international data link standardization may be future areas for human factors input.

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SESSION FIVE: AIRLINE PROGRAM/OPERATIONS

ATC DATA COMMUNICATIONS

OPERATIONAL DEVELOPMENT AND SYSTEM IMPLEMENTATION

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ACKNOWLEDGEMENT

This paper provides an account of more than two years of system evaluation of data link communication, human machine interface (human factors), aircraft avionics suitability, satellite technology for Air Traffic Services, and an integration of advanced conceptual designs of Flight Management Systems and ATC data link. There are many outside resources from United Airlines that must be recognized for there assistance in making this paper possible.

Aeronautical Radio Incorporated
National Aeronautics and Space Administration
The Mitre Corporation
The Federal Aviation Administration
The Boeing Company
Honeywell Incorporated
International Air Transport Association
Air Transport Association of America
Collins Inc

OBJECTIVE

I. Evaluate and demonstrate an improved communication performance of tactical ATC communications and surveillance in the oceanic/non-radar environment through the provision of Automatic Dependant Surveillance (ADS) and direct pilot to controller data link communication. The link médium for this development has been satellite and/or VHF, depending on the location of communication facilities. The intent was to demonstrate data link for routine tactical and strategic Air Traffic Control messages; optimize the existing aircraft avionics systems; and substitute the current HF voice requirements with data link communication. Eventually, utilize satellite voice for irregular and/or emergency ATC messages.

II. The analysis from this operational development will be part of a continuing process of advanced avionics design, improvements to ATC and inflight operating procedures for advanced automation systems including (AERA3), and ultimately improving airspace capacity and system efficiency.

III. Develop a phased transition plan of introducing ATC data link communications. The transition should include system requirement flexibility incorporating present ATC procedural standards, eventually evolving into an automated environment.

BACKGROUND

The technical merit and utility of Data Communications for Air Traffic Control has been debated for many years. The introduction of predeparture clearance delivery (PDC) at Dallas/Ft Worth (DFW) and Chicago (ORD) has prompted the FAA and NASA to evaluate additional data link communications for tactical ATC utilization. The Air Transport Association (ATA) Airspace System Task Force (ASTF) evaluated various environments where ATC data link communications could best be utilized during early development, and determined the oceanic and other non radar environments would provide the most immediate benefit for international airlines.

The International Civil Aviation Organization (ICAO) Future Air Navigation Systems (FANS) documented the concept of utilizing satellite technology for air traffic services (ATS). The FANS concept focuses on improved navigational performance from the global navigation satellite systems (GPS/GLONASS); ATC tactical communications, both data and voice, via satellite; and surveillance via data link of aircraft derived position (Automatic Dependent Surveillance) and radar where appropriate. Thus, all three elements necessary for air traffic control; communications, navigation, and surveillance (CNS) would be available with the aid of satellite technology and data link communications.

SYSTEM DEVELOPMENT

The development of ATC data communications must include many Human Factors issues associated with information transfer from visual and aural sources other than the normal radio telephony voice communications. The replacement of voice as the primary source of ATC communication will require the evaluation of many new system elements. The placement of the visual and aural cues, in conjunction with the required responses will be key to the success of this program.

The script for tactical ATC messages and requests must be thoroughly evaluated, to exclude any possibility of misinterpretation of the message by crewmembers or air traffic controllers, yet provide the essential elements of an ATC clearance. The message script must include the ability to incorporate semi-automated functions for air crew and air traffic controllers. This may be accomplished through the use of a data library captured within the database of the Flight Management Systems (FMS) and ATC ground based computers. The message within the aircraft and ground based computers would be identical in text and function, however, the data link message would include a prescribed code for the message script followed by the value in a pre-programmed operational field in the FMS. (Example: script would be in lower case letters 'climb to and maintain' followed by the defined value in upper case letters 'FL370') Appendix A has a complete description of the data library analysis.

The response time by the flight crew is an important element in the operational development. Successful rapid message transfer between flight crews and the ATC service provider will speed the implementation process of oceanic ATC system automation and reduced separation standards. The shorter the response time, the more advantageous the ATC system automation will become.

It was apparent during the evaluation, that modifications to the Flight Management System (FMS) for incorporating ATC data link was essential. In addition, it became apparent that entry of data from the ATC UPLINK would have to be simplified to exclude the possibility of entry errors by the flight crew. Furthermore, the actions by the flight crew to determine the proper page of data entry had to be simplified to reduce the workload and head-down time. The development of the data library created the direct relationship with the functions of the ATC UPLINK, the acceptance of the message by the flight crew, and its incorporation in the command functions of the FMS, thusly, enveloping the simplification process of the entry by the crew and reducing the possibility of errors.

During this program, a desk top rapid proto-type work station was utilized to develop ATC message text, location of message information, location of visual alert requirements, and semi-automated functions for inflight procedures. This facilitated the modifications of the Flight Management Computer (FMC) MCDU, incorporating these modifications in an updated program for the B747/400 and B767/300ER FMC's (Package B). The desk top work station affords the opportunity to investigate new concepts for message content and interpretation by pilots and controllers on a real time basis.

ATC DATA LINK TRANSITION

The ability to incorporate ATC data link will depend on many technical issues and the orchestration of the entire concept will require many years of development and coordination of the required systems. There are four succinctly different areas of operational development. There is a very difficult coordination process by all participants to include this improved capability.

- Communications
  - Satellite
  - Mode S
  - VHF
- Aircraft Avionics and Sub-systems
- Ground Based ATC Systems
- Air Traffic Control Procedures

ATC DATA LINK PHASE I JUNE 1991

The initial application of ATC DOWNLINK communication for the oceanic/non radar environment includes the following:

- Progress Reports
- Altitude Change Request
  - Climb
  - Descent
  - Block
- Speed Change Request
- Weather Deviation Request

The initial application of ATC UPLINK communication for the oceanic/non radar environment includes the following:

- Transfer of Communication
- Transfer of Control
- Oceanic Clearance Route
- Tactical Clearances
  - Climb
  - Descent
  - Block
  - Speed Change
  - Weather Deviation

Full description of procedures are provided in Appendix B.

ATC DATA LINK PHASE II JUNE 1993

The next phase of development will incorporate improved satellite capability INMARSAT II, B747/400 Avionics Package B, ATN communication compatibility, OSI system protocols, complete sphere of GNSS and improved aircraft navigation performance. The system must include the incorporation of a semi-automated environment including the development of the data dictionaries for ATC ground based systems and the FMS.

ATC DOWNLINK SERVICES

Automatic Dependant Surveillance (ADS)
Pilot to Controller Communication (Routine)

These elements are available in the B747/400 Avionics Improvement Package B Program and is expected to meet FAA certification in November 1992. (APPENDIX C)

ATC UPLINK SERVICES

Controller to Pilot Communications (Routine)

These elements are available in the B747/400 Avionics Improvement Package B Program and is expected to meet FAA certification in November 1992. (APPENDIX D)

SITUATIONAL AWARENESS

The primary emphasis in the system development, centered on the flight crew and air traffic controller maintaining command and control of there immediate responsibility. No automatic functions will be incorporated between ATC and the aircraft without full crew awareness and specific enabling action by the crew. Every effort will be made to incorporate INTERNATIONAL STANDARDS to develop the overall system design and operating procedures.

BENEFITS

In the Asia Pacific Region, delays gaining access to the oceanic airspace are becoming common due to excessive separation standards and communications congestion. ATC data link communications will provide the ATC service providers and international airlines with an added margin of safety and eventually permit reduced separation minima, allowing more aircraft into the environment without delay. Flight crews and ATC personnel will enjoy the unambiguous and additional flexibility of pre-formatted tactical ATC messages via data link as a supplement to the often unreliable, HF voice channel. Accurate interpretation of the message and timeliness of the ATC clearance will improve both ATC efficiency and safety.

EVALUATION

- Measure the response time of the complete ATC clearance process;
- Measure avionic system integrity and reliability;
- Determine accuracy and availability of the data communication system as compared to voice in the oceanic environment;
- Investigate message interpretation;
- Determine FMC MCDU functions as related to the ATC message and pilot initiated control of the aircraft;
- Seek inputs from flight crews regarding the use of the Mode Control Panel (MCP) or FMC MCDU.

The B747/400 has been an ideal platform to conduct an evaluation of these parameters in the oceanic/non-radar environment to implement an operational program. The operation in the Pacific provided the environment where time was not a critical factor and safety not jeopardized.

ATC UPLINK EVALUATION

The evaluation included an analysis of the five step ATC data communication process. The following defined the parameters of this assessment:

ALERT....Visual and Aural cues to the flight crew.

Determine the location of the **VISUAL** cues to alert the flight crew that an active tactical ATC data link message has been received.

Determine the **AURAL** cue for alerting the crew of an active tactical ATC clearance.

For the initial demonstration, United Airlines provided the **VISUAL** alert on the upper EICAS, and the **AURAL** alert was the call chime.

RECOGNITION....Message location.

The location of the tactical ATC message was on the center MCDU, which is normally utilized for all incoming VHF and Satellite data link messages. Any MCDU may have been utilized by the flight crew for data link messages, however until a standard location and incorporation of the semi-automated data for flight crew utilization is agreed, it was prudent to remain on a non active FMC MCDU. The printer was another source available for viewing the active ATC clearance and have been used as a backup. For the evaluation, the ACARS was used to receive all ATC uplink messages.

All tactical ATC messages used complete words, with no abbreviations or acronyms.

DECISION.....Message content.

All tactical ATC message formats utilized were in accordance with International ATC phraseology.

There were no split words, with no more than 24 characters per line. The inbound ATC uplink message was structured to provide an instruction followed by an assigned value. For example, the message "climb to and maintain FL350" has an instruction of climb to and maintain followed by a definitive value.

RESPONSE.....Message acknowledgement.

There were four responses available to the flight crew for each tactical ATC message, ROGER, WILCO, UNABLE, and STANDBY.

ROGER. Roger means "I have received and understand the message."

WILCO. Wilco means "I understand the message and will comply with the ATC clearance."

UNABLE. Unable means "I am not able to comply with the ATC clearance."

STANDBY. Standby means "I need some time to review my operating requirements and limitations."

The location and content of the response message was on the ACMS, ATC reply page, on the center MCDU.

It became apparent during the evaluation, the word WILCO was used very little in the current ATC environment, and STANDBY was used primarily for flight crew verification of a proposed clearance. During the course of development, as automation is improved, it is anticipated the use of STANDBY and WILCO may disappear.

In the place of the normal responses by the flight crews when receiving an ATC uplink clearance, the use of ACCEPT and REJECT, may become appropriate.

EXECUTION.....Application and adherence of message.

AUTOMATIC DEPENDANT SURVEILLANCE

The function of ADS performed by the flight crewmembers was non-sequential and procedures were totally transparent. The position report was automatically transmitted through the data link system (VHF or Satellite) to the ATC facility. Data collection by the FAA was performed on a not to interfere basis with the flight crew. The flight crew had the ability to initiate or terminate the use of ADS, however, normal operations had ADS automatically begin transmissions at 10000 FT pressure altitude in the climb and terminate during the descent at 10000 FT pressure altitude. Full ADS reports were available for the flight crew review on the ACMS, located on the center MCDU.

AIRCRAFT COMPONENTS AND FUNCTION

There were no requirements to add any new avionics to the existing equipment suite on the B747/400 aircraft. However, software programming of the Aircraft Condition Monitoring System (ACMS), and communications routing by ARINC was necessary.

COMPONENTS

EICAS DISPLAY Visual cue alerting the flight crew to an ATC message.

"* ACARS MESSAGE"

ACMS Software programming to provide pre-formatted outbound ATC messages, and the ADS report. (Appendix B)

AURAL ALERT The flight crew will be alerted to an incoming message by the call-chime. This is the same chime currently in use for SELCAL.

ACARS ACARS-ATC MESSAGE was utilized for the incoming ATC messages.

MCDU The center MCDU was utilized to display the ATC message.

PRINTER A secondary source for viewing the ATC message was available.

CERTIFICATION

The FAA is currently monitoring the efforts of the ATA Airspace Systems Task Force (ASTF), Human Factors Task Force (HFTF), and the Information Transfer and Data Communication Working Group to determine certification requirements for tactical ATC Data Link Communications. The FAA has made available for comment a Draft Advisory Circular (DEC 3, 1990) on certification requirements for tactical ATC data communications airborne equipment.

It is anticipated, there will be little difficulty in obtaining the necessary approvals to implement the initial program (PHASE I), providing the safeguards are in place.

The necessary approvals include the following:

A. Center MCDU for reception of ATC message.
B. ACMS for ATC data link request.
C. Data Level 1 software for the SDU.
D. Verifiable process for ensuring ATC UPLINK is correct and a proper response available to DOWNLINK to ATC.
E. A bonafide backup system. (Voice)
F. Inflight procedures for the data link system.

A recent study of the ACARS/ARINC data link service compared to the present HF Voice communications in the oceanic environment, indicated that data link communications were 10,000 times more reliable in the delivery of an error free message.

INSTITUTIONAL ARRANGEMENTS

The FAA Technical Center and The Mitre Corp provided the programming for ATC clearance uplink and downlink messages within the demonstration Air Traffic Control work station, and ARINC provided the routing requirements throughout the ADNS network.

SUMMARY

The International Airlines and the Air Traffic Service providers face a very difficult and challenging future. The passenger growth rate in the Asia Pacific Region is out-pacing the production of new aircraft. In a few years, the airspace in this region will become a priceless commodity, unless a pre-ordained and coordinated transition plan is adopted to improve the communication and navigation performance standards. Without these improvements, there will be limited relief from the archaic oceanic separation standards, and growth potential in the Asia Pacific Region will be stymied due to ATC services.

The introduction of satellite data communications for tactical ATC messages will revolutionize the conduct of business in future cockpits and Air Traffic Control facilities. It may be as revolutionary as the transition from the piston powered transports to the jet powered aircraft of today. This will be the beginning of modern Air Traffic Control utilizing state of the art computer technology for communications and system automation.

The IATA Asia Pacific Regional Technical Office in concert with the ATA Airspace System Task Force, established a goal of June, 1993, for operational use of automation in oceanic/non-radar Air Traffic Control utilizing satellite technology. Separately, a goal to include GPS as a stand alone Class I navigation system was established for the same period. To process the required research, and run the bureaucratic gauntlet, we must begin the operational development of this new technology now.

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The MITRE Corporation

Dr. Wu is a member of the MITRE Center for Advanced Aviation System Development in McLean, Virginia, where she has been employed since 1988. She has provided technical support in the development of Automatic Dependent Surveillance (ADS). She has been serving as a technical advisor to the U.S. member at meetings of the International Civil Aviation Organization (ICAO) ADS Panel, which is developing international standards for ADS. She is currently involved in the development of a message set for the oceanic ATC automation system.

Prior to joining MITRE, she was a senior programmer/analyst with Planning Research Corporation from 1985 to 1988, and a systems engineer with the Singer Link Simulation Systems Division from 1983 to 1985. She received a B.S. degree in Computer Science and B.S., M.S. and Ph.D degrees in chemistry.

GROUND AUTOMATION PROCESSING OF NEAR-TERM OCEANIC ATC DATA LINK MESSAGES

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ABSTRACT

Effective use of data link requires computer-aided message creation and processing to alleviate the additional work load associated with data entry for both pilots and controllers. This paper describes how ground automation will process pre-defined fixed format oceanic data link messages in the near-term time frame. A message set consisting of message categories, message subcategories and message types is proposed. Required characteristics for this message set are discussed and some significant issues raised. This paper traces one downlink request message as it goes through the various steps of ground automation processing and eventually becomes an air traffic control clearance message delivered to the pilot.

INTRODUCTION

Current oceanic air-ground communications between the flight crew and an air traffic controller are conducted by voice using high frequency (HF) radio. Characteristically, HF is unreliable and subject to disturbances, with the result that flight safety and efficiency may be affected.

Use of data link through satellites substantially improves the reliability of communications over the ocean. Effective use of this capability requires computer-aided message creation and processing to alleviate the additional work load associated with data entry for both pilots and controllers. To reach this goal, each message must be interpreted identically by both avionics and ATC automation.

The Federal Aviation Administration (FAA) is currently developing the ground oceanic automation system that will implement satellite data link and additional oceanic automation. MITRE is assisting the FAA by preparing the functional specification for this system. The specification will contain or reference a detailed description of every uplink and downlink message, it will indicate what processing should be performed on each, it will define how the message should be displayed to the controller, and will describe how the controller will interact with the automation system. Certain requirements will be placed on the format and content of the data link message to allow maximum use of automated message processing. MITRE will identify these requirements so that they may be coordinated with the requirements from the controller's human computer interface development, the pilot's human computer interface development, and the cockpit message processing development.

Currently, several organizations are integrating the various requirements to produce a standardized message set for data link applications. For example, the International Civil Aviation Organization (ICAO) Automatic Dependent

Surveillance Panel (ADSP) is in the process of producing Standards and Recommended Practices (SARPs) for ADS. In the ADS SARPs, messages needed to accomplish the required operational capabilities will be identified and standardized. The Radio Technical Commission for Aeronautics (RTCA) recently established a special committee (SC169) to standardize data link messages.

In this paper a proposed message set for oceanic application, at an early stage of development, is presented. This message set contains message categories, subcategories and message types. As development continues, it is likely that additional messages will need to be created and additional fields added to existing messages. It is not the purpose of this paper to define exact formats of the oceanic data link messages or encoding or compaction schemes for them. Such detailed definition will be done in a way consistent with that for domestic ATC data link as represented in the FAA's draft advisory circular, "Airworthiness Approval of Airborne Data Link System" and the associated document, "Data Link Design Guidelines". It is assumed that these detailed definitions will provide a unique message identification for each message type and a fixed, complete definition of the message format, to include sequence of fixed and variable fields, scaling factors, units, etc. It is intended that these detailed definitions will make the message fully compatible with transmission over the Aeronautical Telecommunications Network.

RATIONALE FOR A STANDARDIZED MESSAGE SET

The following points support the establishment of a standardized message set

• Lessons from the past : A famous Chinese proverb states "Don't forget the experience learned in a previous attempt; use that as a guide for your future endeavors". Aeronautical Radio Incorporated (ARINC) Communications Addressing and Reporting System (ACARS), which uses character-oriented Very High Frequency (VHF) data link is probably the closest predecessor of the satellite data link environment. Lessons learned from ACARS will help avoid repeating the same mistakes again. Several persons familiar with the development of ACARS have indicated that the existence of so many different versions makes the implementation of ACARS expensive and difficult. To avoid having many operational versions of a data link message set, a globally standardized message set must be established in a coordinated fashion at an early stage.

• Formatted, not free format messages are needed: One might consider transmitting uplink and downlink ATC messages as free format messages. But if this were done, it would be very difficult to do automatic processing.

DEFINITION OF MESSAGE CATEGORY, MESSAGE SUBCATEGORY AND MESSAGE TYPE

A message category is a group of messages that provides a related set of operational capabilities. Some message categories are further divided into subcategories while other categories have only one subcategory. Message subcategories contain individual message types. For example, CLEARANCE is a message category. ALTITUDE ASSIGNMENT is a subcategory of CLEARANCE and SIMPLE ALTITUDE ASSIGNMENT is a message type under ALTITUDE ASSIGNMENT. Each message type has required data elements and may have optional data elements. These data elements are either text or variable fields. The sequence of these fields is predefined. Associated with each message category are certain characteristics that dictate how each message in the message category will be

processed for transmission and may also specify how the message will be displayed. The fields for message type SIMPLE ALTITUDE ASSIGNMENT are given below.

DESCEND AND MAINTAIN (flxxx)
[FOR TRAFFIC]

In the example above, capital letters (DESCEND AND MAINTAIN) indicate a text field, small letters (flxxx) represent variable field and text inside the square bracket [FOR TRAFFIC] is an optional field. Optional fields are explanatory only. They represent comments that may be added by the controller or the pilot. They are only displayed; they are not processed by the automation either in the avionics or on the ground.

A PROPOSED MESSAGE SET

A message set containing categories, subcategories, and message types has been proposed for near-term oceanic applications. This message set is based on the expected operational capabilities of the automated oceanic ATC environment in the 1995 time frame. This is a subset of the complete set of messages that would eventually be defined and proposed by near-term (prior to the Advanced Automation System) automation. Appendices A and B contain the individual message name, message content and example phraseology for each of the message types.

REQUIRED CHARACTERISTICS OF DATA LINK MESSAGES

Certain characteristics of data link messages and certain requirements on how they are processed and displayed need to be specified. These characteristics would be spelled out for each message category. All message types within the same category would have the same characteristics. Some of the characteristics to be specified include:

- For a category of ground-to-air message, specify whether or not this category requires a pilot acknowledgement.

- For a category of ground-to-air message, specify what alerting level should be used to alert the pilot on receipt of the message. Three alerting levels are proposed.

- For both ground-to-air and air-to-ground messages, specify what communication priority should be applied. This allows messages of higher priority to be processed ahead of lower priority messages in the same queue.

- For both ground-to-air and air-to-ground messages, specify the maximum acceptable delivery time.

- For both ground-to-air and air-to-ground messages, specify the number of automatic retransmissions to be performed before the message is declared to be undeliverable.

The last three of these characteristics are items that would be used to set parameters in the communication protocols being used to transmit the data link messages.

ISSUES IN DEFINING THE OCEANIC ATC DATA LINK MESSAGE

Our work to date has identified several issues that need to be addressed before the set of data link message types for oceanic ATC can be finalized. The more significant issues include the following:

- Should the route of flight field in an ATC request message, an ATC clearance message or an oceanic clearance delivery message be encoded according only to ICAO rules or according only to U.S. rules or to both? Among other differences, ICAO rules permit the route

of flight to include different altitudes for different segments, while U.S. rules allow for only one altitude for the entire route of flight.

• Should message types be added to allow for automatic read-out by the ground automation of the route of flight actually programmed in the aircraft's flight management computer? This has been proposed as a more direct way of detecting waypoint insertion errors than depending on observing the blunder flight path from ADS position reports. It has also been proposed as a substitute for read-back of route clearance or clearance delivery messages. Not all aircraft would have avionics able to support this automatic read-out from the ground.

• Should message types be included that allow maneuvers at pilot's discretion? A related issue is whether the message set should include block altitude requests and clearances? If either message types are included, how does the ground automation system model the aircraft's future flight path? Does the automation system need to block all requested altitudes for the remainder of the flight in the FIR?

• Do message types need to be included in either direction that can cancel a previous request or ATC clearance message?

• Do compound messages need to be supported? Compound messages would include changes in more than one dimension in a single message. An example is a clearance to change the route and also to change the speed in the same message.

• Will all aircraft flight path projections in the ground automation system be based on the aircraft's cleared route and speed and the ground's estimation of the winds aloft, or will they be based on the aircraft's estimate of time of arrival at future fixes? Some additional message types would need to be added to request the aircraft's time of arrival at a line of latitude or at a line of longitude or a named fix.

GROUND AUTOMATION PROCESSING OF OCEANIC ATC DATA LINK MESSAGES

A few significant features of the ground automation processing of oceanic ATC data link messages are described here. Both fixed format and free format messages are used. There is no automatic processing of free format messages. A free format message entered by the pilot is displayed verbatim as text to the controller and vice versa.

Both the avionics and ground automation must operate according to the same data dictionary for fixed format messages. This data dictionary contains all defined message types and the format and characteristics for each. At present, only one data dictionary is being defined. When new features are incorporated into the ground automation, there will be a new data dictionary defined with some additional message types. It will be necessary for the ground automation system to then support both the old and new data dictionaries, since it would be impractical to require all aircraft to upgrade from the old to the new at the same time.

When the ground receives a downlinked message, it first identifies the message type and performs a message validation process, where it checks that the message has all the required fields of the proper length and format. It then checks any variable fields in the message for reasonableness. Maximum and minimum reasonable values would be stored for each variable to support this process. A downlinked ATC request message will then be submitted to the ATC processing to determine if the requested flight path would cause a conflict. If the request involves a route change, the

requested route will first be processed to ensure that all named fixes and airways are recognized and that all elements in the route of flight can be interpreted. Depending on the result of the ATC processing, an appropriate ATC clearance message or an ATC request denied message will be prepared for the controller's approval for uplink.

ADS position reports will be received at a nominal rate of one every five minutes. The automation processing will check each position report against the aircraft's planned flight path. If this processing finds that the aircraft has arrived at its reported position at a time sufficiently different from the expected time, it will correct the time base for the aircraft. It then executes a conflict probe to determine whether the changes in the planned flight path will place this aircraft in conflict with another aircraft. The controller will be alerted to the change in planned flight path only if the change leads to a conflict situation. If the processing of the position report determines that the aircraft has deviated sufficiently from the planned altitude or planned route, the controller will be alerted. The controller will also be able to view the current aircraft position on a situation display.

For uplink messages, a set of pre-defined message templates or canned messages will be stored. The controller will be able to retrieve them either by choosing from a hierarchy of menus with function keys, or by typing a short alias name. The controller will type in the value of the required variable fields and the automation will check them for reasonableness as each one is entered. If the message is an ATC clearance message, it will be submitted for ATC processing to ensure that the clearance will not cause a conflict before it is uplinked. Once the ATC clearance message has been transmitted, an acknowledgement timer will be started. If the pilot has not acknowledged the clearance within a specified time, the controller will be alerted. If the pilot does acknowledge the clearance with a WILCO, the automation data base will be updated to account for the new clearance.

AN EXAMPLE ILLUSTRATING GROUND AUTOMATION PROCESSING

To illustrate the various steps in ground automation processing, this section describes how a Simple Altitude Change Request downlink is processed.

Initial Processing

The automation system (AS) determines Message Type from the Message Type Identifier (MI) field.

If a match for message type is not found, the AS displays the entire contents of the message to a data edit position, a position able to be assigned to the computer operator' console, a flight data specialist's position, a supervisor's position, or a sector controller's position.

If the message type is not Log-on, the Aircraft Identification (AI) is validated.

If a match for AI is not found, AS displays the message at the flight data edit position with an error message indicating that the AI is unknown.

The AS processes the message according to its message type.

Altitude Change Request Processing

The AS stores the message reference number from the downlink for use in the uplink message that responds to this request.

The AS checks the required fields based on the requirements specified for this message type.

If the required fields for this message type are incorrect, an appropriate error message is displayed to the flight data edit position.

The AS determines whether the requested altitude is reasonable based on airspace, aircraft type and current altitude

The AS puts the request in the appropriate controller's input queue with the following options : "ACCEPT", "REJECT" and "DEFER". The controller is notified of the presence of the new ATC request message immediately.

If option "REJECT" or "DEFER" is selected by the controller, the AS automatically formulates the correct response, either "ALTITUDE CHANGE REQUEST DENIED" or "ALTITUDE CHANGE REQUEST DENIED, REQUEST ON FILE". At his discretion, the controller can append an optional data field to either response with a free text explanation of the reason for denial.

When "ACCEPT" is selected, the AS initiates a Trial Amendment for the AI and the requested altitude. The Trial Amendment function performs a conflict probe on the request without updating the data base. The response from a Trial Amendment may be an error message, an indication of no conflict, or an indication of a predicted conflict.

If an error message, the controller can correct the message and resubmit it as a Trial Amendment, or he can send a free format message to the pilot. If there is no conflict indicated, the AS formulates an appropriate response, in this case an Altitude Assignment message, and presents it to the controller for approval for uplink.

When the response is released by the controller, it will be transmitted with the priority and assurance levels of delivery associated with that message category.

A timer will be initiated for the acknowledgement of this message.

The AS blocks the airspace appropriate for that aircraft from the current altitude through the newly assigned altitude.

If no acknowledgement is received after a parameter time, the AS will alert the controller.

If a WILCO is received, the flight plan data base will be updated appropriately for the aircraft's new clearance.

If an UNABLE is received, the controller is alerted and the reserved airspace will be freed.

If a STANDBY is received, a new timer will be set to check for future acknowledgement.

CONCLUSIONS

Both ICAO and RTCA are in the process of standardizing the oceanic ATC data link message set. Both need to consider the requirements that affect the message set from four different perspectives:

- What the controller needs to conduct his operation and satisfy his responsibilities.

- What the pilot needs to conduct his operation and carry out his responsibilities.

- What the ground automation system needs to provide maximum message processing support to the controller, while still keeping the controller

responsible for all ATC decisions.

- What the aircraft avionics needs to provide maximum message processing support to the pilot, while still keeping the pilot responsible for approving all ATC instructions that affect his aircraft.

This paper has described some of the current knowledge about the third item above. The work to date has shown the need for several new items to be added to the oceanic data link message set. One is to include message reference numbers in both uplink and downlink messages so that ATC clearance messages that are responses to requests can be so identified, and pilot acknowledgement can be linked to the proper ATC clearance message. Other new requirements on the message set are expected as the work to define ground automation processing continues.

This process of arriving at a final set of messages needs to be an iterative one. A first set needs to be established based on an initial concept of operations as was done and reported in this paper. Then, as the processing of these messages is analyzed, new requirements are discovered. As these are reported and coordinated with the results of activities from the other three perspectives, yet more new requirements are identified and analyzed. The process iterates until a stable set of messages evolves.

Appendix A - ATC Uplink Messages

Message Category Message Subcategory Message Type	Message Content/Comments	Example Radio Phraseologies/Comments
RESPONSE TO CRITICAL SITUATION MESSAGE		
Verification of Hijack	MI, AI, MRNO	
CLEARANCE		
Altitude Assignment		
Simple Altitude Assignment	MI, AI, MRN, MRNO, altitude, ACI	CLIMB AND MAINTAIN (flight level)
Block Altitude Assignment	MI, AI, MRN, MRNO, altitude-a, altitude-2	MAINTAIN (flight level 1) THROUGH (flight level 2)
Restricted Altitude Assignment		
Altitude Reached Before Time	MI, AI, MRN, MRNO, altitude, time, ACI	CLIMB TO REACH (flight level) AT OR BEFORE (time)
Altitude at a Future Time	MI, AI, MRN, MRNO, altitude-1, time, altitude-2, ACI	MAINTAIN (flight level) UNTIL (time) CLIMB AND MAINTAIN (flight level)REPORT REACHING
Altitude after Passing A Fix	MI, AI, MRN, MRNO, altitude-1, fix name, altitude-2, ACI	MAINTAIN (flight level) UNTIL (fix) DESCEND AND MAINTAIN (flight level) REPORT REACHING
Crossing Instruction		
Time Restricted Fix Crossing	MI, AI, MRN, MRNO, fix, time, modifier(before or after)	CROSS (fix) AT OR BEFORE (time)
Altitude Restricted Fix Crossing	MI, AI, MRN, MRNO, altitude	CROSS (fix) AT (flight level)
Speed Assignment		
Maintain Speed (=, <, >)	MI, AI, MRN, MRNO, Speed, "M" or "K", modifier (=, < or >)	MAINTAIN MACH (speed)
Oceanic Clearance		
Full Oceanic Clearance	MI, AI, MRN, flight level, speed, present aircraft position, full route, oceanic exit point	Currently, pilot readback required
Abbreviated Oceanic Clearance	MI, AI, MRN, flight level, Mach number, track or route	Currently, pilot read back required

MI : message type identifier. AI : aircraft identification . [] : optional field. MRN : message reference number of this message.
MRNO : message reference number of original message to which this message is reponse (if null, this message is not a response to a requestr).
ACI : altitude change indicator, CLIMB, DESCEND or MAINTAIN.

Appendix A - ATC Uplink Message (concluded)

Message Category Message Subcategory Message Type	Message Content/Comments	Example Radio Phraseologies/Comments
REQUEST		
ADS Report Contract Establishment	MI, AI, MRN, rate for basic ADS report, [rate for projected profile], [rate for air vector], [rate for ground vector], [rate for weather]	No corresponding phraseology / (basic ADS : position, time, figure of merit), (projected profile : next waypoint, estimated altitude at next waypoint, next +1 waypoint, estimated altitude at next + 1 waypoint), (air vector : heading, Mach or IAS, vertical rate), (ground vector : track, ground speed, vertical rate), (weather : wind speed, wind direction, temperature)
ADS Report Request	MI, AI, MRN, [request for projected profile], [request for air vector], [request for ground vector], [request for weather]	
ADVISORY		
Notification of Transfer of Communication	MI, AI, MRN, address of receiving FIR	
Request Denied	MI, AI, MRNO	
FREE FORMAT	Any message composed with the permitted character set	

Appendix B - ATC Downlink Messages

Message Category Message Subcategory Message Type	Message Content/Comments	Example Radio Phraseologies/Comments
CRITICAL SITUATION MESSAGE		
Emergency Message	MI, AI, MRN, aircraft type, type of critical situation, fuel status, number of people on board (critical situation includes: -hijack -impaired engine performance -bomb threat -low fuel -impending forced landing)	

Appendix B - ATC Downlink Message (concluded)

Message Category Message Subcategory Message Type	Message Content/Comments	Example Radio Phraseologies/Comments
ADS REPORT		
Contract Mode ADS Report	MI, AI, basic ADS , [request for projected profile], [request for air vector], [request for ground vector], [request for weather]	No corresponding phraseology
Emergency ADS Report	MI, AI, basic ADS, emergency identifier, [request for projected profile], [request for air vector], [request for ground vector], [request for weather]	No corresponding phraseology
Event ADS Report	MI, AI, basic ADS , event identifier, [request for projected profile], [request for air vector], [request for ground vector], [request for weather]	No corresponding phraseology
REQUEST		
Altitude Change Request		
Simple Altitude Change	MI, AI, MRN, altitude, ACI	REQUEST CLIMB TO (flight level)
Block Altitude Change	MI, AI, MRN, altitude 1, altitude 2	REQUEST (flight level) THROUGH (flight level)
Restricted Altitude Change Request		
Simple Restricted Altitude	MI, AI, MRN, altitude, ACI, fix	REQUEST DESCEND TO (flight level) AT (fix)
Speed Change Request		
Simple Speed	MI, AI, MRN, speed, "M" or "K"	REQUEST SPEED CHANGE TO MACH ---
Route Change Request		
Weather Deviation	MI, AI, MRN, modifier (right or left), number of nm, number of nm	REQUEST WEATHER DEVIATION LEFT OF TRACK -- NM FOR -- NM DOWN TRACK
Destination Deviation	MI, AI, MRN, destination, number of fixex, fix-1, .., fix n	REQUEST DESTINATION CHANGE TO .. VIA PRESENT POSITION DIRECT .---.---.---
INITIATION/TERMINATION		
Log On	MI, AI	No corresponding phraseology
Log Off	MI, AI	No corresponding phraseology
ACKNOWLEDGEMENT	MI, AI, MRNO, option (ACCEPT, REJECT, STANDBY)	WILCO, UNABLE or STANDBY
FREE FORMAT	Any message composed with the permitted character set	

PRESENTER

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Jane Hamelink is a member of the Center for Advanced Aviation System Development of the MITRE corporation, where she has been employed since 1987. She has provided technical support to the Federal Aviation Administration (FAA) in the development of Automatic Dependent Surveillance (ADS). She is currently involved in the development and specification of the functional requirements for an air traffic control system using ADS and its associated two-way data link.

From 1985 to 1987, Ms. Hamelink was a section manager at ST Systems. She was responsible for supporting the FAA in the development of the Flight Data Processing System for the Oceanic Display and Planning System (ODAPS). Prior to joining ST Systems, Ms. Hamelink worked for Sigma Data in support of NASA in the development of global weather models. Ms. Hamelink received a B.S. degree in mathematics from Calvin College in Grand Rapids, Michigan in 1977.

SESSION FIVE: AIRLINE PROGRAM/OPERATIONS

Virginia White
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Virginia White is a Senior Staff Engineer at Aeronautical Radio, Inc., responsible for leading the engineering efforts supporting ADS and two-way data communications system development. Ms. White is an active participant in AEEC, RTCA, and ICAO activities relating to ADS and has contributed to the initial success of the Pacific Engineering Trials while continuing to coordinate network, routing and processing requirements for the engineering trial activities. She holds a BSEE and recently received her Master's of Science in Information Management from The George Washington University.

EVALUATION OF OCEANIC FLIGHT DECK WORKLOAD AND ERROR REDUCTIONS THROUGH THE USE OF DATA COMMUNICATIONS

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ABSTRACT

The use of oceanic data communications provides increased efficiencies to the flight deck for AOC/ATC communications. Through the use of automated and semi-automated systems supported by data link, the flight deck can achieve both workload and error reduction. Furthermore, data link can provide oceanic areas with improved error detection and tracking capabilities that can drastically improve the current system. The industry, with the onset of Satcom in the past year, has undertaken studies, rapid prototypes and trials that have further highlighted data link's potential and made oceanic data link a reality.

INTRODUCTION

The use of data link for flight deck communications promises to reduce the workload and source of error on the flight deck. The inherent reliability and integrity of data communications supports the FANS conclusion that two-way data link provide the primary means of oceanic communications. This paper addresses two related topics. It illustrates the potential benefits to users that will be achieved through the use of oceanic ATC data link. It then presents an overview of industry activities that have been directed toward understanding and developing end systems for data link operation in oceanic areas.

DATA LINK BENEFITS TO USERS

While it is true that current HF voice-based oceanic systems have supported users adequately in the past, ever increasing traffic congestion and message throughput requirements will continue to strain this HF voice based system. Not only will Data link communications serve to ease this strain, but it will also serve to benefit end users more directly than the current system.

Automated Systems

The flight deck benefits of data link are primarily focused upon the use of automated and semi-automated systems. These systems rely on data link's discrete and rapid processing and addressing capabilities.

Semi-automated systems, such as waypoint position reporting, take advantage of the automatic call set-up capabilities of the data link to provide the flight crew with the ability to format messages with simple menu fill techniques. These messages can then be sent to the ground via a single button key stroke. New avionics systems will fully automate these processes to further reduce operational requirements and improve errors.

Automatic systems, such as Automatic Dependent Surveillance, bypass the flight crew and transmit messages to the ground as a background process based on some predetermined event. These events could be time based (specific content received at predetermined intervals) or sensor-based (event driven). Event driven reports would occur, for instance, by setting a flag in the Flight Management Computer to generate an event driven report to the air traffic controller when the airplane has reached a specified altitude. Weather information could be transmitted automatically based on a temperature crossing or winds aloft change.

Further automation and reduction in workload will result with the integration of the communication systems with other aircraft subsystems such as the radio and

Flight Management Computer. In this way, subsystems can be directly updated based on ground-originated data-link messages. For example, tactical reclearances may be directly entered into the flight management computer upon the pilot's acceptance and compliance. Additionally, transfer of communications, which is a continual flight deck workload consideration, can be automated for frequency changes and re-addressing of air traffic control messages. Figure 1 illustrates an integrated data link airplane.

Workload Reduction

By off loading manual tasks, the automated and semi-automated systems will result in flight deck workload reduction. A recent study by Marvin Waller at NASA Langley has shown data link, integrated into the cockpit to enable the automatic updating of subsystems, to be a significant fight deck time savings over voice exchanges followed by manual entry of said commands [Ref. 1]. A previous study by NASA Langley, which utilized data link, but did not integrate it into any aircraft subsystems, had demonstrated a reduction in perceived copilot workload, although failed to prove a definitive reduction of pilot workload [Ref. 2].

It is important to note that all actual simulations to date have compared data link with VHF voice communications and not HF voice communications. There are several flight deck operations specific to HF voice communications that do not exist in the VHF environment. For this reason, a genuine interest of researchers analyzing data obtained from the engineering trials, is dedicated to studing the delay associated with data link.

For a more detailed look into these simulations, three time periods need to be defined: the cockpit response time, network transmission time, and end-to-end message time. The cockpit response time is defined as the period between the appearance of a data link message on the MCDU and the flight crew's acceptance of the message. Network transmission time is the round trip time needed for the message to traverse the data network. End-to-end message time is the time it takes once the controller has sent a message to the time a response (Roger or negative) returns to the controller. End-to-end message time is the sum of the network transmission time and the cockpit response time.

Based on the simulations to date, the average cockpit response time to a data link message has been approximately 10 seconds [Ref. 3]. For the United Pacific Engineering Trials, utilizing satcom (600 bps) and the ARINC network, the average round trip successful transmission time has been approximately 20 seconds [Ref. 4]. This results in an end-to-end message time of around 30 seconds for an existing oceanic data link. In the simulations, this is at odds with end-to-end message VHF voice times of around 7 seconds [Ref. 2]. However, considering the indirect format of HF voice, where average end-to-end times average around 4 minutes [Ref. 5], data link is actually the faster form of communications.

Additional HF related considerations include the need for increased dedication to open and maintain channel communications and the potential for communication lapses. A reduction in the flight deck reporting and communication efforts required for these HF specific tasks will result in additional workload reduction.

Error Reduction

Not only will Data link result in the reduction of errors that are inherent to any manual, voiced-based communications, especially HF voice, but its error processing capabilities will serve to further reduce communication errors.

A review of the current error sources from HF communications must focus on the general poor voice quality of narrow bandwidth channels located within a fading environment. Oceanic voice communications also offer potential language barrier problems. Addressing errors, call sign problems and congestion problems all serve to create additional errors [Ref. 6]. The discrete addressing capabilities and near negligible error probability of the data link will eliminate or drastically reduced these voice related errors. With the off-loading of communications into the data link, there will be a reduction of voice frequency congestion. This will benefit those flight decks that would still require the use of voice systems as a primary means of communications. It will

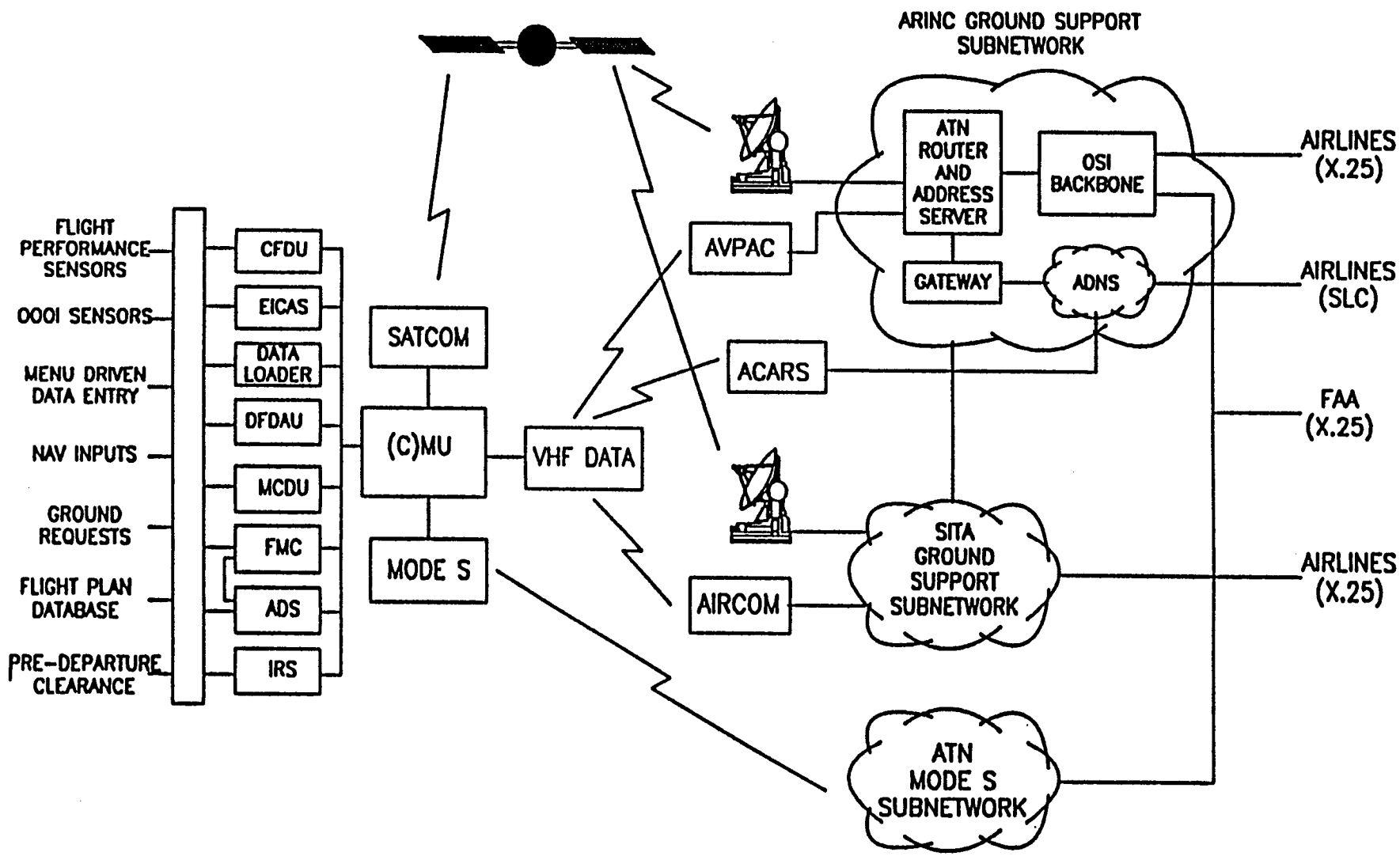


Figure 1: Integrated Two-way Data Link

also serve to benefit all users with the consideration of distress and non-routine traffic remaining a voice mode exchange.

Currently in the cockpit, there is a need for either flight deck memorization or transcription of voice commands. This system offers the potential for error based on anticipation and assumption [Ref. 7]. Data link can provide the cockpit with visual communications with message logging and retrieval capabilities. These features allow the flight crew a continuous reference and past history for the cross-checking of controller instructions.

Due to the consistency of the supplied data, the more timely reporting of data through enhanced link availability, quicker message delivery times and the reduction of missing data points attributed to human error, data link is a more reliable and faster form of communications than voice. Data link's ability to drive end systems, coupled with these high reliance characteristics, will result in improved error reduction capabilities. These capabilities include better flight tracking, improved conflict resolution and better blunder detection.

INDUSTRY VALIDATION

Various elements of industry have been evaluating the oceanic and VHF data link requirements from airline operation/flight deck and ground system viewpoints. This section offers a brief overview of these efforts by referencing several studies that have been used to evaluate the human factors and workload reduction issues. The efforts of prototype and simulation studies concerning the oceanic flight deck and ground-based systems are reviewed.

ARINC

In order to obtain a view of the dynamics of communications in an oceanic environment, ARINC developed a Multi-Control Display Unit/Air Traffic Control (ATC)/ Airline Operation Center (AOC) set of workstations. This system was designed to evaluate a typical transoceanic flight and the class of negotiations that occur between air traffic control, the flight deck and dispatch. This system started to apply such human factor elements as guided message responses, (i.e. altitude presets based on direction, airframe capability, etc.). Since the system was based on menu driven messages, the flight deck was interested only in fill elements. Similarly with the ground by addressing a flight number, flight plan information was made available to the controller. This basic system was used for early requirements analysis of the data link system to make sure that priorities of messages, message retrieval, system automation, and basic human factors concerns could be evaluated in their entirety. Figure 2 illustrates the ARINC workstation prototypes.

United Airlines

United Airlines initially provided a rapid prototype system that focused mainly on the Multi-Control Display Unit for menu development. The emphasis was to minimize the number of page selections required, and to develop ease of flight deck message entry. While created independent of the ARINC system, this was done on a rapid prototype platform that would allow implementation of pilot comments during the evaluation phases of the system. It included separate pages for both the development of air traffic control and dispatch message formats. It contained a limited set of typical exchanges from the flight deck to the ground and from the ground back to the flight deck.

Two features were initiated in this evaluation. The first was the limiting of negotiation dialogue to the most common message exchanges, such as weather reporting and tactical rerouting. The second was the use of message compression. Message compression, in the form of three-letter codes, was employed once the flight deck initiated a message. This was done in order to minimize spectrum utilization and to optimize message throughput. The three character codes are being downlinked from the aircraft today during ATC data link communication with the ground. The codes are expanded by a processor within the ARINC network prior to being received by the ground end system.

MITRE

On the ground side, Mitre developed a workstation for the oceanic ADS program that consists of a position reporting screen and a data link generation system. The data link generation system is a pull down menu

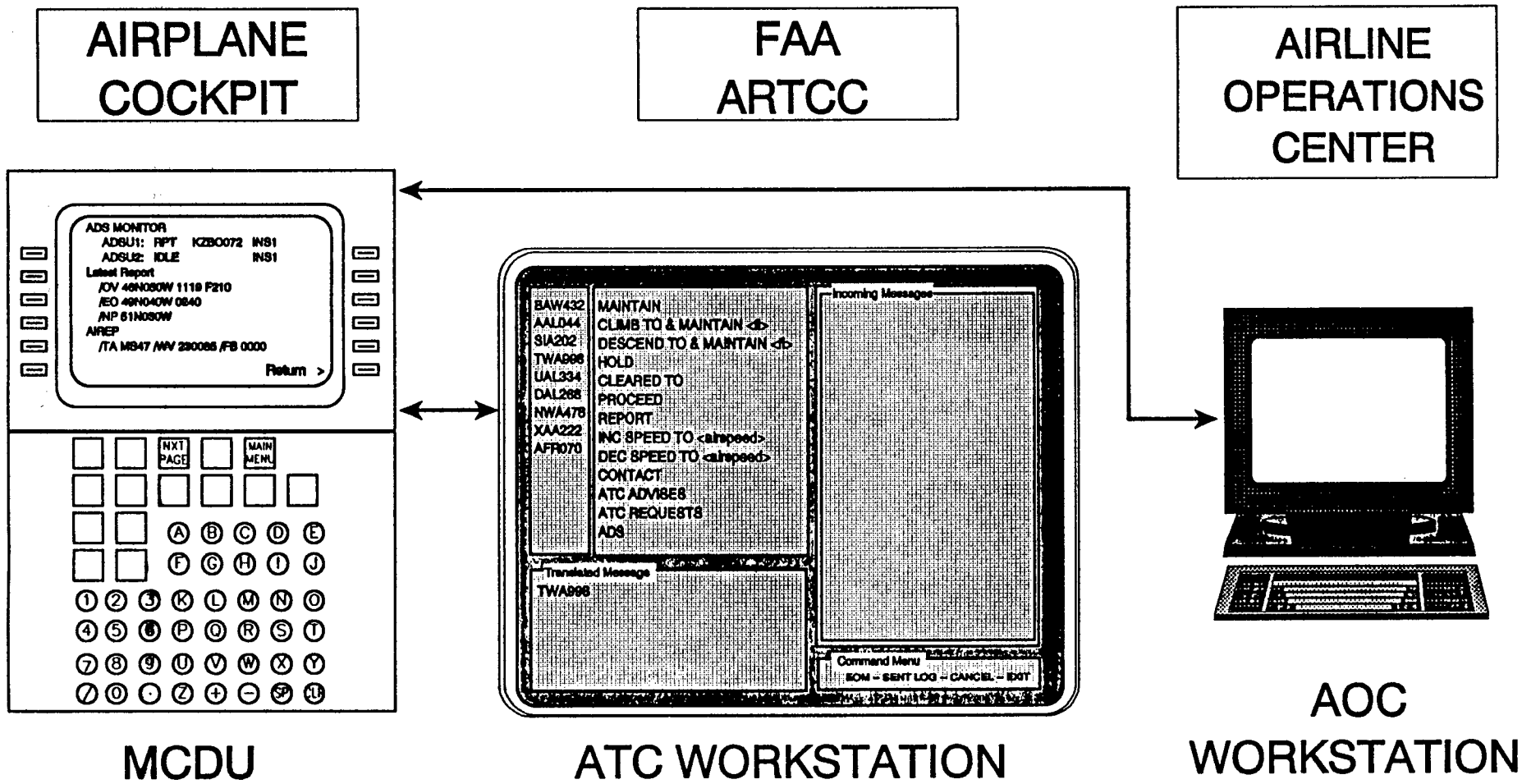


Figure 2: ARINC's MCDU\ATC\AOC workstations

environment used as the basis for evaluation of the ARINC message structures for air traffic control. The MITRE workstation is focused as an air traffic control platform and situation display.

Non-Oceanic Human Factors Studies/Simulations

NASA Langley has conducted several airborne human factors and data link validation studies on board their dual cockpit 737. They have integrated a data link system for evaluation of direct entry air traffic control commands through the data link environment right to flight control end elements.

NASA's Ames Research Center at Moffitt Field, CA, has provided additional review of human factors elements in terms of study programs and true control position analysis. The Air Transport Association Human Factors Task Force has pulled together the industry participants in the information transfer and data link human factors working group to further define the system requirements for data link and to provide overall guidance for end system utilization both on the flight deck and for avionics manufacturers. Efforts continue in other groups headed by MITRE, the Society of Automotive Engineers in their G-10 and S-7 working groups, RTCA, ICAO, Eurocontrol, and the FAA in terms of generation of data libraries and other automated control features that would further enhance the flight deck workload reduction.

Oceanic Trials

United has flown five 747-400 Satcom-equipped aircraft that have participated in oceanic position reporting and have utilized satellite data link for airline operational data. United, through their participation in the Pacific Engineering Trials, has provided evaluations from both line pilot and test pilot comments and review of the data link in terms of the automatic position reporting and simulated air traffic control communications. These trials have indicated a desire to begin utilizing the end systems as soon as possible. United anticipates the use of data link in providing the benefit of priority routing because of improved message throughput.

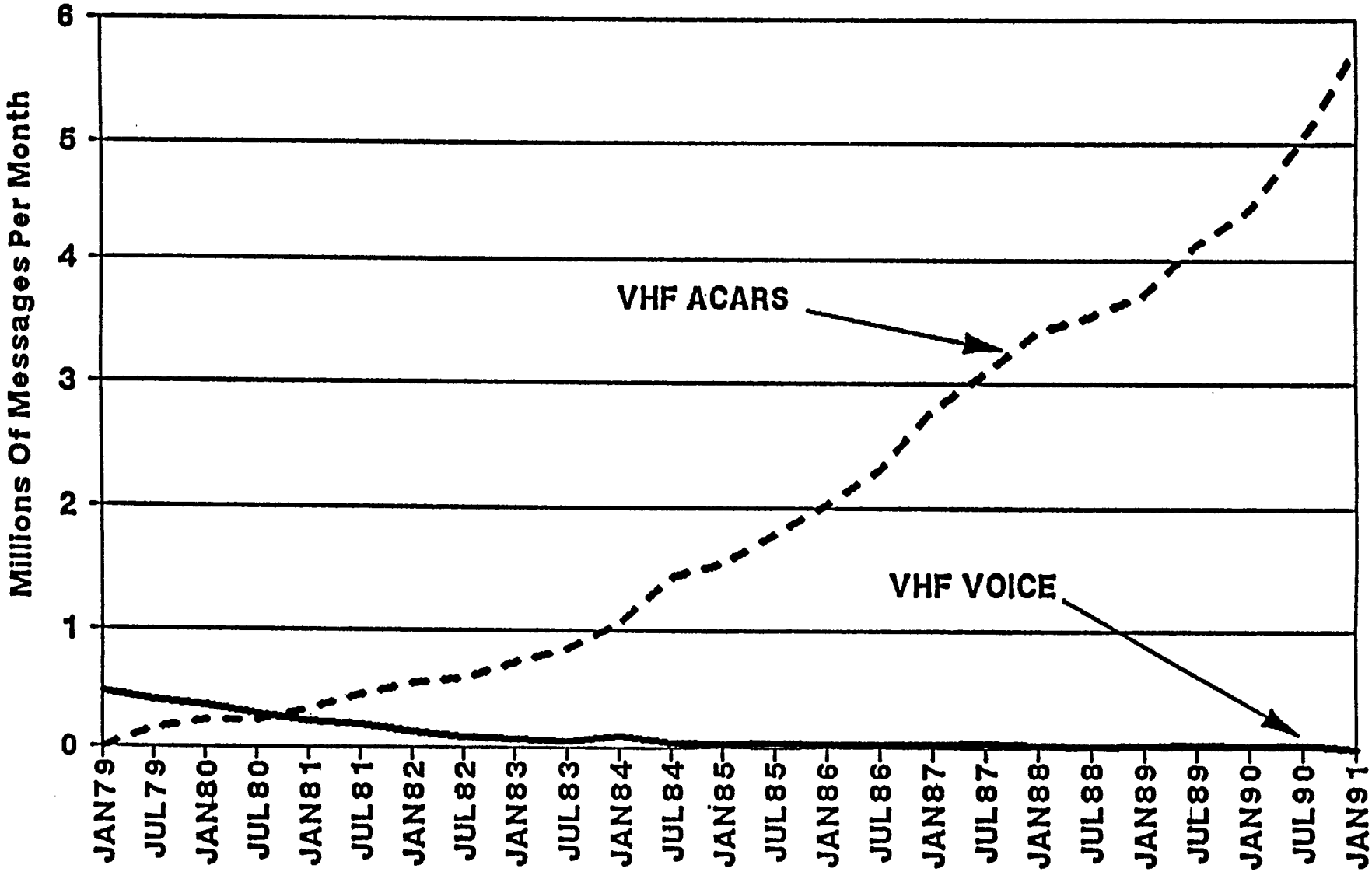
Further trials for air traffic control will commenced in August 1991. These trials are focusing on the implementation of data link for communicating tactical reclearances in the oceanic region.

CONCLUSION

It is easy to recognize the qualities of data link implementation over VHF/HF radio. Not only does data link offer benefits, but it also serves to eliminate drawbacks inherent to voice communications. When the comparison becomes focused on HF voice communications, data link becomes that much more impressive. Data link promises to reduce errors and flight deck workload. With its improved reliability and ability to drive end systems, it could lead to greatly enhanced error detection capabilities. With the right amount of attention and effort, data link could make such items as reduced separation standards, flexible routing and improved reclearances a reality.

In the airline operational control of aircraft, data link already has all but eliminated the use of voice. Figure 3 illustrates the historic trends of ACARS versus ARINC's domestic voice network. There will always be a need for voice in the airline operational environment, but mostly for non-routine or distress communications. In the air traffic control environment, data link has been very slow in implementation, but, according to FANS, it will become the primary means of oceanic communications. With the advent of SATCOM in the past year, the airline industry has come a long way toward the realization of this goal. There have been numerous studies, working groups, rapid prototypes, and trials to help direct these efforts. Data link has recently accomplished a major milestone in air traffic services applications. In August, 1991, the engineering trials included validation efforts for implementation of ATC data link in place of HF voice. The trials continue, utilizing several United 747-400's in the Pacific Ocean, communicating to the FAA through the ARINC network. For the first time, data link may be used in an operational environment to provide the primary means of oceanic communications.

References



VHF VOICE & VHF ACARS TRAFFIC

Figure 3

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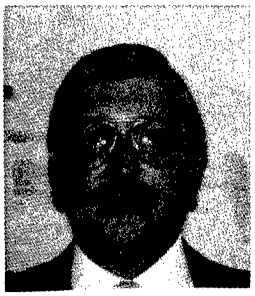
Richard E. Heinrich is the Senior Manager of Transmission and Management Systems Engineering at Aeronautical Radio where his responsibilities include the development of the satellite subnetwork to provide aeronautical satellite services. Rick has 13 years of experience in the design and development of communications equipment, systems, and networks in the military and commercial environment. He received his BSEE from Michigan Technological University in 1978.



SESSION FIVE: AIRLINE PROGRAM/OPERATIONS

Austin L. Snively
Systems Engineer
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Austin Snively has been with American Airlines for 23 years and has been responsible for the development of air\ground datalink at American. Austin's current responsibility consists of serving on industry activities for the development of future air\ground communications systems. Austin chairs several AEEC committees including the Datalink Subcommittee. He also participates in various RTCA, IATA and ICAO committees responsible for developing international standards and policies.

POTENTIAL USE OF VHF DATALINK (AVPAC) AS AN ALTERNATIVE TO SATCOM

Austin Snively

American Airlines, Tulsa, Okla.

INTRODUCTION

We hear much about the benefits of Aeronautical Telecommunications Network (ATN). Open Systems Interconnect (OSI) protocols is the way of the future for data communications. The addressability of OSI provides for connectivity between any two end systems connected to ATN. Byte and code independence no longer restricts the communications to character oriented data, thus permitting transfer of binary data, graphics, FAX and encoded data. Universal standards such as OSI provides for the standardization of the communications system worldwide.

However, one of the most important benefits of ATN is the freedom of choice that it offers in selecting subnetworks. In the aeronautical arena this permits choice of air/ground subnetwork usage. A primary objective in the development of ATN has been to ensure this freedom of choice. The connectivity of end systems on the ATN provides for subnetwork transparency to the end user.

SUBNETWORK CRITERIA

Several air/ground subnetworks have been identified for which standards are being developed. Others may be potential candidates in the future. Each of these have their own characteristics which will be considered when subnetwork selections are made.

SATCOM - SATCOM will be available worldwide with the exception of the polar regions. Performance of this air/ground subnetwork will be good, however due to its physical requirements, the cost for both equipage and use is high.

Mode-S Datalink - Mode-S datalink will be a civil aviation data communications system provided by the authorities for their usage. Its coverage will be restricted to land areas. Performance will be restricted due to the nature of the Mode-S scanners. However, the performance could be enhanced by the conversion to electronically scanned antennas which would be a very expensive undertaking.

AVPAC - AVPAC is the second generation VHF datalink being developed to operate within the ATN. VHF datalink, better known as ACARS, is currently provided by service providers such as ARINC, SITA, Air Canada and Japan. AVPAC will be available over land areas where ground station provision are implemented. Performance of AVPAC is expected to be high, but with relatively low cost.

Gatelink - Gatelink is being developed as a high volume datalink which will provide for efficient transfer of large databases between the aircraft and ground based end users. It will also provide for normal air/ground datalink functions while the aircraft is parked at the terminal. The performance of Gatelink will be very high but its usage will be restricted to parked aircraft where connectivity is provided.

HF - HF datalink is being evaluated as a future low cost air/ground subnetwork. Its coverage would be worldwide, however its performance may be marginal. It could have usage over the polar regions and as a potential backup to SATCOM.

SELECTION CRITERIA

Some areas of the world may have only one air/ground subnetwork available while others such as North America may have all to choose from. Obviously, the first criteria of choice will be availability. Where multiple air/ground subnetworks are available, other selection criteria will consist of performance, cost, and institutional considerations. Institutional decisions will be based on contractual agreements and end user preference among others.

VHF CRITERIA

The new generation VHF datalink, AVPAC, is expected to rate high in all categories of selectivity criteria. AVPAC will be supported in all areas where the current VHF datalink, ACARS, is supported. As these areas of coverage are continually being expanded, other potential providers of services may also enhance selectivity. Availability is currently dependent on contractual arrangements, however, end users may determine to implement their own systems in the future. Overall costs including equipage and usage have the potential of being the lowest of all air/ground subnetworks. Performance is expected to exceed all other with the exception of gatelink.

VHF DIGITAL RADIO ENHANCEMENTS

Along with the improvements in the protocols and capabilities of AVPAC, the VHF air/ground subnetwork will be further enhanced with the equipage of the new VHF Digital Radio, VDR, currently under development. The VDR will provide for a more reliable air/ground subnetwork. The transfer rate will approximate 24,000Bps in place of the current 2400, with the potential of future upgrades to higher data rates. The prekey is expected to be reduced to three milliseconds versus the 53 to 190 ms in the current system. The VDR will monitor all available ground stations and manage their usage in coordination with the ground system in order to provide optimum connectivity.

DIGITAL VOICE

The VDR is also being designed to allow for digital voice, although its primary advantage will be for datalink transmission. This digital voice capability is planned to be packetized rather than circuit mode voice. Packetized voice provides for two potentially revolutionary concepts to the aeronautical community. One is that an end user could pass voice communications thru the VHF ground service provider along with data. The other is that any end user implementing VDRs for voice communications would automatically have their own datalink system.

WHY VHF AT ADS/SATCOM SYMPOSIUM

Why should VHF datalink be discussed at the ADS/SATCOM symposium. Many areas of the world for which SATCOM is expected to be the sole air/ground datalink subnetwork to be available will have spotty VHF datalink coverage. Examples of this are the oceanic areas. The North Atlantic has Greenland and Iceland already available. The Pacific has islands scattered throughout which have or will potentially have VHF coverage. The Caribbean is another example. It is a known fact that VHF datalink will be significantly lower costs for usage. With the freedom of choice that ATN provides and the constant monitoring of connectivity by the VDR, AVPAC can and should be used in place of SATCOM for economic reasons as well as performance. This same concept applies equally well to land masses where accessibility is limited.

SUMMARY

AVPAC coupled with the VDR has the potential of being the most desirable air/ground datalink. It should be considered a companion to SATCOM or any other datalink air/ground subnetwork for ADS and all other datalink communications. AVPAC is becoming a worldwide officially recognized air/ground subnetwork for official usage. ICAO plans to commence an activity to develop Standards And Recommended Practices, SARPS, for AVPAC. Now is the time to consider VHF as a companion to all other datalink systems.

SESSION FIVE:
AIRLINE PROGRAM/OPERATIONS

PANEL DISCUSSION:

"What are the Airlines Doing?"

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THE FIRST ANNUAL INTERNATIONAL SATELLITE SURVEILLANCE AND COMMUNICATION SYMPOSIUM SEPTEMBER 24 - 26, 1991

DATA LINK HUMAN FACTORS TEAM

Remarks of William M. Russell, III
Director, Flight Technology
Air Transport Association of America

Recently a new Data Link Human Factors Team was established by the industry/government Human Factors Task Force and given a priority to focus on system requirements and developing tasks for the data link portion of the FAA draft National Plan for Aviation Human Factors. In taking this action to more effectively manage the efforts on data link, the Task Force expressed confidence that experts with a broad range of needed skills would participate. The Team has now met twice and has begun to make substantial progress.

The parent Human Factors Task Force is chartered to address steps needed to enhance safety and efficiency through improving the effectiveness of humans in aviation and the way they are used in the system. Functioning with participation from experts in flight operations, air traffic control, work station design, and human factors research, it has served to coalesce industry and government views on the needs for human factors. In 1989 it issued a National Plan to Enhance Aviation Safety through Human Factors Improvements which was instrumental in elevating the focus on aviation human factors in the government. More recently, the Task Force established an informal liaison with the FAA R, E and D Advisory Committee, through its Human Factors Working Group in order to facilitate communication.

Automatic Dependent Surveillance service, in addition to providing controllers with information on the position of aircraft, includes a means of communicating between the controller and the pilot. Currently, it is envisioned that this communication will be primarily via data link, although a voice backup is anticipated. The Data Link Human Factors Team is considering the data link portion of automatic dependent surveillance along with the rest of its work on data link. Further, it currently appears that ADS and satellite data link will be the next data link service to be implemented, and its schedule is a driving function in the planning of all data link human factors work. On the other hand, operators would prefer some assurance that early implementations of data link will be suitable for anticipated future domestic applications. The juxtaposition of these two factors results in a sense of urgency for definition of future data link services and their related human factors considerations.

We've mentioned that the Team was chartered to give priority consideration to two products. The first of these is to be a recommended statement of tasks to be added to the FAA draft National Plan for Aviation Human Factors. In the draft Plan, the ATC/Flight Deck portion (called an "environment") which covers data link is a generic approach to the conduct of a human factors research program. Yet there are numerous data link human factors issues which have been identified in various forums. In order to strengthen the Plan and provide a better road map for the data link work, the Team is developing more specific task statements which will describe the work to be done. This should be specific enough to support funding for the work. Currently the team is working with tasks in four areas, as follows:

Procedures
Errors
Human Interface Design
Situation Awareness

A number of tasks in these areas relate to the anticipated near term implementations of satellite data link.

The other area is system requirements. Systems analysis (or systems engineering) has become a viable tool for the development of systems such as data link when the human operators are considered part of the system. As data link is a large system with many nodes and end users, we have taken the view that a systems analysis should be conducted. However, in early work to address systems analysis, a problem developed. One of the first steps in conducting a systems analysis is to develop a statement of system requirements. In earlier work, we found great difficulty in establishing such a statement. If, for example, we chose a simplified near term requirement, it was criticized by those who said we would be implementing a system with known inadequacies when the anticipated future services become available. On the other hand, if requirements were attempted for the future, the large number of unknowns led to endless debates. At this time, the Team is focusing its initial work on developing the human requirements portion of the overall system requirements. It is hoped that through this process enough insight can be developed so that the risk of near term decisions can be reduced to an acceptable level. The product of this work is anticipated somewhat after the task statements discussed above.

In addition, the Team is addressing data link human factors issues for new aircraft designs and retrofit installations. Also, it recently initiated an activity to develop recommendations on message display formats.

It is clear that data link has significant potential for enhancing safety and efficiency of the airspace system through reducing voice congestion, and insuring error free transmission and delivery of messages to the proper recipient. On the other hand, it sidesteps a number of the mechanisms which have been used to overcome the errors in voice communications. If implemented incorrectly, data link also has the potential to reduce safety and efficiency in the event human participants do not get the right message, or should design features introduce additional errors, a possibility we all want to avoid. The Data Link Human Factors Team believes it can make a significant contribution by addressing means to avoid these potential undesireable conseqences. The products mentioned above should be a good start.

In closing, let me emphasize that the success of the Team is a result of the efforts of the participants from industry and government, many of whom are in this room today. Together, we can reach the goals of enhanced safety and efficiency.