U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: Installation of Terrain Awareness and Warning System (TAWS) Approved for Part 23 Airplanes

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1. PURPOSE. This advisory circular (AC) establishes an acceptable means, but not the only means, of obtaining Federal Aviation Administration's (FAA) airworthiness approval for the installation of a TAWS that has been approved under Technical Standard Order (TSO)-C151a, Terrain Awareness and Warning System, in a Part 23 airplane. The FAA's TSO process is a means for obtaining FAA design and performance approval for an appliance, system, or product; however, the TSO does not provide installation approval. This AC serves to provide guidance for designing an acceptable installation for a TAWS that complies with TSO-C151a. The guidance provided is specific to installations of these systems on airplanes certificated under Title 14 of the Code of Federal Regulations (14 CFR) Part 23 [commonly referred to as Part 23 of the Federal Aviation Regulations (FAR)]. It describes the airworthiness considerations for such installations as they apply to the unique features of the TAWS and the interface of the TAWS with other systems on the airplane.

Equipment that does not meet the minimum performance standards specified in TSO-C151a shall not be identified as TAWS equipment. Applicants that are not required to install TAWS and choose to install the system may deviate from the guidelines in this AC as necessary, provided the level of safety for the airplane's existing certification basis is not degraded.

Like all advisory material, this AC is not mandatory and does not constitute a regulation. It is issued for guidance purposes and to outline a method of compliance with applicable airworthiness requirements. Because the method of compliance presented in this AC is not mandatory, the terms "shall" and "must" used in this AC apply only to an applicant who chooses to follow this particular method and prescribed standards of TSO-C151a.

2. RELATED REGULATIONS AND DOCUMENTS.

a. Airworthiness Regulations. These acceptable means of compliance refer to the applicable sections of 14 CFR Part 23. The corresponding paragraphs of the former Civil Air Regulations (CAR) are shown in parenthesis for airplanes certificated under CAR.

§ 23.771 (3.381)	Pilot compartment.
§ 23.773 (3.382)	Pilot compartment view.
§ 23.777 (3.3841)	Cockpit controls.
§ 23.1301 (3.651 and 3.652)	Equipment: Function and installation.
§ 23.1303 (3.655(a))	Flight and navigation instruments.
§ 23.1309	Equipment, systems, and installations.
§ 23.1311	Electronic display instrument systems.
§ 23.1321 (3.661 and 3.662)	Arrangement and visibility.
§ 23.1322	Warning, caution, and advisory lights.
§ 23.1331 (3.668)	Instruments using a power source.
§ 23.1351 (3.681, 3.682, and 3.685)	Electrical Systems and Equipment: General.
§ 23.1353 (3.683)	Storage battery design and installation.

§ 23.1357 (3.690, 3.691, and 3.692)	Circuit protective devices.
§ 23.1359	Electrical system fire protection.
§ 23.1361 (3.688 and 3.689)	Master switch arrangement.
§ 23.1365 (3.693)	Electric cables and equipment.
§ 23.1367 (3.694 and 3.695)	Switches.
§ 23.1381 (3.696 and 3.697)	Instrument lights.
§ 23.1383 (3.698 and 3.699)	Taxi and landing lights.
§ 23.1431 (3.721)	Electronic equipment.
§ 23.1459	Flight recorders.
§ 23.1501 (3.735 and 3.737)	Operating Limitations and Information: General.
§ 23.1529	Instructions for Continued Airworthiness.
§ 23.1541 (3.755)	Markings and Placards: General.
§ 23.1543 (3.756)	Instrument markings: General.
§ 23.1545 (3.757)	Airspeed indicator.
§ 23.1559 (3.770)	Operating limitations placard.
§ 23.1581 (3.777)	Airplane Flight Manual and Approved Manual Material: General.
§ 23.1583 (3.761 and 3.778)	Operating limitations.

b. Operating Regulations. More specifics on these regulations are provided in paragraph 5.

§ 91.223	Terrain awareness and warning system
§ 121.354	Terrain awareness and warning system
§ 121.360	Ground proximity warning—glide slope deviation alerting system
§ 135.153	Ground proximity warning system
§ 135.154	Terrain awareness and warning system

c. AC, Orders, TSO, and Related Documents. Later revisions are acceptable. The following publications may be obtained free of charge from the U.S. Department of Transportation, Subsequent Distribution Office, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, MD 20785:

AC 20-115B	Radio Technical Commission for Aeronautics (RTCA), Inc., RTCA/DO-178B
AC 20-136	Protection of Aircraft Electrical/Electronic Systems Against the Indirect Effects of Lightning
AC 21-16D	RTCA Document DO-160D

AC 23-15	Small Airplane Certification Compliance Program
AC 23.1311-1A	Installation of Electronic Displays in Part 23 Airplanes
AC 23.1309-1C	Equipment, Systems, and Installations in Part 23 Airplanes
AC 20-112	Airworthiness and Operational Approval of Airborne Systems to be Used in Lieu of Ground Proximity Warning System
AC 20-130A	Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors
AC 20-138	Airworthiness Approval of Global Positioning System (GPS) Navigation Equipment for Use as a VFR and IFR Supplemental Navigation System
AC 90-45A	Approval of Area Navigation Systems for Use in the U.S. National Airspace System
FAA Order 8110.4B	Type Certification
FAA Order 8260.3B	United States Standard for Terminal Instrument Procedures (TERPS)
TSO-C10b	Altimeter, Pressure Actuated, Sensitive Type
TSO-C67	Airborne Radar Altimeter Equipment
TSO-C92c	Airborne Ground Proximity Warning Equipment
TSO-C106	Air Data Computer
TSO-C113	Airborne Multipurpose Electronic Displays
TSO-C115b	Airborne Area Navigation Equipment Using Multi-Sensor Inputs
TSO-C117a	Airborne Windshear Warning and Escape Guidance Systems for Transport Airplanes
TSO-C129a	Airborne Supplemental Navigation Equipment Using the Global Positioning System (GPS)

TSO-C145	Airborne Navigation Sensors Using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS)
TSO-C151a	Terrain Awareness and Warning System

The FAA technical reports listed below can be obtained from the National Technical Information Service in Springfield, Virginia 22161.

DOT/FAA/CT-96/1	Human Factors Design Guide
DOT/FAA/AAR-95/3	FAA Aircraft Certification Human Factors and Operations Checklist for Standalone GPS Receivers

d. Industry documents. Obtain RTCA, Inc. documents listed below from RTCA, Inc., 1140 Connecticut Avenue NW, Suite 1020, Washington, D.C. 20036-4001.

RTCA/DO-160D, Environmental Conditions and Test Procedures for Airborne Equipment

RTCA/DO-161A, Minimum Performance Standards - Airborne Ground Proximity Warning Equipment

RTCA/DO-178B, Software Considerations in Airborne Systems and Equipment Certification

RTCA/DO-200, Preparation, Verification and Distribution of User-Selectable Navigation Data Bases

RTCA/DO-200A, Standards for Processing Aeronautical Data

RTCA/DO-208, Minimum Operational Performance Standards for Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS)

e. Other document.

The FAA and Industry Guide to Product Certification, January 25, 1999. Available on internet: http://av-info.faa.gov/dst/CPIGUIDE.pdf

3. DEFINITIONS.

a. Alert: A visual, aural, or tactile stimulus presented to either attract attention or convey information regarding system status or condition, or both.

r. Terrain Awareness and Warning System (TAWS): A system that provides the flightcrew with sufficient information and alerting to detect a potentially hazardous terrain situation and so the flightcrew may take effective action to prevent a CFIT event.

s. Terrain Awareness Display: A display of the surrounding terrain or obstacle(s) relative to the airplane.

t. Terrain Database: Terrain or obstacle information stored within a TAWS.

u. Time-shared Display: A display that shows terrain information, plus additional information from other systems [for example, an Electric Flight Instrument System/Navigation Display/Multi-Function Display (EFIS/ND/MFD)].

v. Visual Alert: The use of projected or displayed information to present a condition, situation, or event to the flightcrew.

w. Warning Alert: An alert for a detected terrain threat that requires immediate flightcrew action.

4. BACKGROUND.

a. Regulations. Beginning in the early 1970's, a number of studies looked at the occurrence of "controlled flight into terrain" (CFIT) accidents, where a properly functioning airplane under the control of a fully qualified and certificated crew is flown into terrain (or water or obstacles) with no apparent awareness on the part of the crew.

Findings from these studies indicated that many such accidents could have been avoided if a warning device called a ground proximity warning system (GPWS) had been used. As a result of these studies and recommendations from the National Transportation Safety Board (NTSB), in 1974 the FAA required all Part 121 certificate holders (that is, those operating large turbine-powered airplanes) and some Part 135 certificate holders (that is, those operating large turbojet airplanes) to install TSO approved GPWS equipment (§§ 121.360 and 135.153) (39 FR 44439, December 18, 1974).

In 1978, the FAA extended the GPWS requirement to Part 135 certificate holders operating smaller airplanes: turbojet-powered airplanes with 10 or more passenger seats. These operators were required to install TSO-approved GPWS equipment or alternative ground proximity advisory systems that provide routine altitude callouts whether or not there is any imminent danger (§ 135.153) (43 FR 28176, June 29, 1978). This requirement was considered necessary because of the complexity, size, speed, and flight performance characteristics of these airplanes. The GPWS equipment was considered essential in helping the pilots of these airplanes to regain altitude quickly and avoid what could have been a CFIT accident.

Installation of GPWS's or alternative FAA-approved advisory systems was not required on turbo-propeller powered (turboprop) airplanes operated under Part 135 because, at that time, the general consensus was that the performance characteristics of turboprop airplanes made them less susceptible to CFIT accidents. For example, it was thought that turboprop airplanes had a greater ability to respond quickly in situations where altitude control was inadvertently neglected, as compared to turbojet

airplanes. However, later studies, including investigations by the NTSB, analyzed CFIT accidents involving turboprop airplanes and found that many of these accidents could have been avoided if GPWS equipment had been used.

Some of these studies also compared the effectiveness of the alternative ground proximity advisory system to the GPWS. GPWS was found to be superior in that it would warn only when necessary, provide maximum warning time with minimal unwanted alarms, and use command-type warnings.

Based on these reports and NTSB recommendations, in 1992 the FAA amended § 135.153 to require GPWS equipment on all turbine-powered airplanes with 10 or more passenger seats (57 FR 9944, March 20, 1992).

After these rules were issued, advances in terrain mapping technology permitted the development of a new type of ground proximity warning system that provides greater situational awareness for flightcrews. The FAA has approved certain installations of this type of equipment, known as the enhanced ground proximity warning system (EGPWS). However, in the proposed final rule, the FAA is using the broader term "terrain awareness and warning system" (TAWS) because the FAA expects that a variety of systems may be developed in the near future that would meet the improved standards contained in the proposed final rule.

The TAWS improves on existing GPWS systems by providing the flightcrew much earlier aural and visual warning of impending terrain, forward looking capability, and continued operation in the landing configuration. These improvements provide more time for the flightcrew to make smoother and gradual corrective action.

In 1998, the FAA issued Notice No. 98-11, Terrain Awareness and Warning System (63 FR 45628, August 26, 1998), proposing that all turbine-powered U.S.-registered airplanes type certificated to have six or more passenger seats (exclusive of pilot and copilot seating), be equipped with an FAA-approved terrain awareness and warning system. On March 23, 2000, the FAA issued Amendments 91-263, 121-273, and 135-75 (65 FR 16736, March 29, 2000) with an effective date of March 29, 2001. These amendments amended the operating rules to require that all U.S. registered turbine-powered airplanes with six or more passenger seats (exclusive of pilot and copilot seating) be equipped with an FAA approved TAWS. See paragraph 5 for more details.

b. TSO-C151a. On November 29, 1999, the FAA issued TSO-C151a and canceled TSO-C151. The FAA took this action to clarify and correct certain paragraphs and tables that appeared in TSO-C151. The FAA has determined that the changes to TSO-C151a are of a clarifying and corrective nature, and that these changes do not alter the original intent of the airworthiness requirements of the paragraphs or tables being changed. TSO-C151a prescribes the minimum design standards that a TAWS must meet to be identified with the TSO-C151a marking. The TAWS described in the TSO is representative of the "next generation" GPWS. In addition to the standards and test procedures required for the FLTA functions, the TAWS incorporates the standards and test procedures for basic GPWS equipment (as defined in TSO-C92c and in RTCA DO-161A). For further in-depth information concerning the TAWS' capabilities, refer to TSO-C151a.

c. Need for Guidance. The FAA's TSO process is a means of obtaining FAA design and performance approval for an appliance, system, or product. However, the TSO does not provide procedures for installation approval or procedures for design or implementation of an installation. With future rulemaking and heightened interest by manufacturers and operators to equip Part 23 airplanes with TAWS systems that are compliant with TSO-C151a, the FAA has recognized the need to establish guidance material for the design and test requirements for the installation of such systems. This AC has been developed as the means for providing such guidance for Part 23 airplanes. This AC describes the airworthiness considerations for designing a TAWS installation. The airworthiness considerations discussed apply only to the interface of the TAWS with other aircraft systems.

5. DISCUSSION.

a. Regulatory Basis. New requirements under 14 CFR Parts 91, 121, and 135 require the installation of the TAWS. Specifically:

(1) § 91.223 states that no person may operate a turbine-powered U.S.-registered airplane configured with six or more passenger seats, excluding any pilot seat, unless that airplane is equipped with an approved terrain awareness and warning system that meets the requirements of Class B equipment of TSO-C151. This section does not apply to: (a) Parachuting operations when conducted entirely within a 50 nautical mile radius of the airport from which such local flight operations began, (b) Fire fighting operations, and (c) Flight operations when incident to the aerial application of chemicals and other substances.

(2) § 121.354 states that no person may operate a turbine-powered airplane unless that airplane is equipped with an approved terrain awareness and warning system, including a terrain awareness display, that meets the requirements for Class A equipment of TSO-C151.

(3) § 135.154 states that no person may operate a turbine-powered U.S.-registered airplane configured with six to nine passenger seats, excluding any pilot seat, unless that airplane is equipped with an approved terrain awareness and warning system that meets the requirements of Class B equipment of TSO-C151. It also states that no person may operate a turbine-powered U.S.-registered airplane configured with 10 or more passenger seats, excluding any pilot seat, unless that airplane is equipped with a terrain awareness and warning system that meets the provisions of Class A equipment of TSO-C151.

(4) Part 121 and 135 regulations also mandate that GPWS be replaced with a TAWS approved under TSO-C151.

(5) For the compliance schedule, §§ 121.360 and 135.153 have an expiration date of March 29, 2005, for the use of current GPWS systems. U.S. registered airplanes manufactured after March 29, 2002, must be equipped with TAWS. Turbine-powered airplanes manufactured on or before March 29, 2002, must be equipped with TAWS by March 29, 2005.

6. SYSTEM DESCRIPTION. TAWS is intended to provide flightcrews with aural and visual alert aids aimed at preventing a CFIT accident through increased terrain awareness.

a. Class A TAWS equipment as defined in TSO-C151a.

(1) Class A TAWS equipment provides three principal alerting functions. These are:

(a) FLTA function, which includes:

- Reduced required terrain clearance.
- Imminent terrain impact.

(b) PDA function.

(c) Basic GPWS functions, as defined in TSO-C151a and RTCA DO-161A, which include:

- Excessive rates of descent.
- Excessive closure rate to terrain.
- Negative climb rate or altitude loss after take-off.
- Flight into terrain when not in landing configuration.
- Excessive downward deviation from and ILS glideslope.
- Descent of the airplane to 500 feet above the terrain or nearest runway elevation (voice callout "Five Hundred").

(2) The Class A TAWS system will require a display. The terrain display and terrain-threat alerting are made possible by the TAWS' acceptance of a variety of input parameters. Color displays are not required; monochromatic displays have been allowed and will continue to be allowed. These parameters are used in conjunction with a terrain and airport database(s) that reside within the TAWS computer. The Class A TAWS places an airplane symbol on a digital terrain map and applies terrain display algorithms. Terrain mapping information may be provided on either a weather radar (WXR) display, Electronic Flight Instrument System (EFIS) display, or other compatible display screens. Aircraft position information is provided by either the Flight Management Computer (FMC), Global Positioning System (GPS), or other source of positional information that meets the requirements specified in paragraph 7.f. of this AC.

(3) The Class A TAWS for operations under Part 135 (turbine-powered U.S.-registered airplane configured with 10 or more passenger seats, excluding any pilot seat) will be required to incorporate either an integral (internal) GPS or interface with an independent approved GPS for horizontal position information.

b. Class B TAWS equipment, as defined in TSO-C151a.

(1) Class B TAWS equipment provides three principal alerting functions. These are:

(a) FLTA function, which includes:

- Reduced required terrain clearance
- Imminent terrain impact

(b) PDA function

(c) Basic GPWS functions, as defined in TSO-C151a and RTCA DO-161A, which include:

- Excessive rates of descent
- Negative climb rate or altitude loss after take-off
- Descent of the airplane to 500 feet above the terrain or nearest runway elevation (voice callout "Five Hundred").

(2) The Class B TAWS will not require a display. If a display is installed with a Class B TAWS, it should meet the requirements of paragraph 7.h. of this AC.

(3) The Class B TAWS will be required to incorporate either an integral (internal) GPS or interface with an independent approved GPS for horizontal position information that meets the requirements specified in paragraph 7.f. of this AC.

(4) The Class B TAWS will not require an interface with a radio altimeter.

c. Note: The FAA is considering developing minimum operational performance standards intended for piston-powered and turbine-powered airplanes when configured with less than six passenger seats, excluding any pilot seats. At this time, the FAA is not considering a requirement for these installations. If standards are developed, they may be identified as Class C TAWS requirements. It is envisioned that Class C TAWS would only be an option that the operator may install for additional terrain situational awareness.

7. AIRWORTHINESS CONSIDERATIONS.

a. Initial Installation. For initial approval of a particular TAWS equipment installation, the scope of the applicant's program should be directed toward airworthiness approval through the Type Certificate (TC) or Supplemental Type Certificate (STC) process. The guidance provided in this AC also is appropriate for applicants who choose to exercise their Designated Alteration Station (DAS) authorization for STC approval. As part of the amended TC or STC program, the applicant should identify if the changes to the type certificated airplane constitute a significant change, but not one so extensive as to require a new TC in accordance with § 21.19 (Changes Requiring a New Type Certificate). If the design change is considered significant, the certification program should be coordinated with the responsible FAA Directorate, as described in FAA Order 8110.4B, Type Certification.

b. Follow-on Installations. For TAWS Class A and B equipment that has already obtained initial installation approval via the TC or STC process, approval may be obtained using either the STC, amended TC, or FAA Form 337 (Major Repair and Alteration) process.

(1) For TAWS Class B installations involving only simple altitude (vertical position source) and GPS data inputs, which utilize a format specified as acceptable in the TAWS equipment installation instructions, approval for return to service can be accomplished using FAA Form 337. The TAWS equipment manufacturer should provide a listing of acceptable altitude (vertical position source) and GPS equipment. Flight-testing should not be required for these installations.

(2) TAWS Class A and certain Class B installations that includes additional features beyond the minimum TAWS Class B equipment requirements (that is, terrain display, radio altitude or landing gear, flap, glideslope sensor inputs, etc.) will require a more extensive installation evaluation. Some flight-testing will likely be required for these installations as under Flight-Test Requirements.

(a) The installer should provide satisfactory evidence of similarity of the proposed TAWS installation to previously approved installations incorporating the same interfaces (sensors, displays, etc.). In any similarity evaluation, all changes to the system or its installation should be assessed for their effect on a system to meet the certification requirements.

(b) When using the STC or amended TC process, all required data pertaining to the installation should be submitted to the Aircraft Certification Office (ACO). These data should include the manufacturer's operating and installation instructions, fault analysis for the installation, installation details, structural substantiation, and system wiring diagrams. The ACO will define necessary ground and flight-tests.

(c) When using the FAA Form 337 process, all required data pertaining to the installation should be submitted to the Flight Standards District Office (FSDO). These data should include the manufacturer's operating and installation instructions, fault analysis for the installation, installation details, structural substantiation, system wiring diagrams, and results of required ground and flight-test evaluations. Limitations associated with the equipment should be

copied from the installation instructions to the Airplane Flight Manual (AFM), Airplane Flight Manual Supplement (AFMS), or Supplemental AFM. In situations where additional FAA evaluation is necessary, required flight evaluations will be conducted by the cognizant ACO or, when authorized, by a Flight-Test Pilot Designated Engineering Representative (DER) in accordance with the procedures used by the ACO. These evaluations should be conducted to verify that the design and installation performs its intended function under the expected operating conditions, that there are no adverse interactions between the TAWS and existing aircraft systems, and that prior approvals of present aircraft equipment have not been compromised. The approval for return to service must be signed by one of the entities noted in 14 CFR Part 43 (that is, repair station, manufacturer, holder of an inspection authorization).

c. Project Specific Certification Plan. On January 25, 1999, the FAA, in coordination with the Aerospace Industries Association (AIA) and the General Aviation Manufacturers Association (GAMA), introduced "The FAA and Industry Guide to Product Certification." This aid communicates the design and production certification process for aircraft. It describes how to plan, manage, and document an effective and efficient product certification process. The applicant should use this guide to develop their Project Specific Certification Plan (PSCP). The applicant should develop a comprehensive PSCP that includes the following:

(1) Project Description. A summary of the project.

(2) System Description.

(a) A comprehensive system description that includes a brief summary of the product as it relates to existing flight deck displays, sensors, added sensors, switches, annunciator lights, control panels, electrical components, interior arrangement, other interfaces, product part number, etc.

(b) A layout and description of any changes to the flight instrument panels.

(c) Information regarding software aspects of certification and any application-specific integrated circuits (ASIC) approved under TSO-C151a should be referenced and made available upon request. Additional documentation may be required for added features that were not approved under TSO-C151a.

(3) Project Schedule.

(a) A detailed project schedule that identifies all major milestones and schedules for any required deliverables (that is, test plans).

(b) Schedules for operational and maintenance aspects, as well as foreign authority validation requirements.

(4) Certification Basis and Means of Compliance.

(a) A certification matrix that identifies the applicable regulations, AC's, current policies, certification basis, and the procedures or methods that will be used to comply with those regulations.

(b) Any testing or analyses applicable to the project that have been previously approved by the FAA under an STC, TC, TSO, or Parts Manufacturer Approval (PMA) held by the applicant. The approval date, letter reference number, and references as to how the specific approval was granted (that is, STC, TSO, letter of approval, etc.) should be included in this section.

(5) Communication and Coordination.

(a) If applicable, identification of all Designated Engineering Representatives (DER) Designated Airworthiness Representatives (DAR), Designated Manufacturing Inspection Representative (DMIR) or DAS specialists working on the program.

(b) Identification of all delegated functions, which should include any stipulations, coordination, and limitations that are placed upon those delegations.

(6) Testing Plan. This section should contain the requirements for the planning, preparation, and adequacy of conducting the FAA required testing, including any delegations. The applicant should address human factors issues and provide human factors support for decisions regarding the flightcrew interface issues resulting from the TAWS installation.

(7) Conformity Plan. This section should describe the activities associated with conformity of parts, simulators, and aircraft installations.

(8) Continued Airworthiness Plan. This section should provide the instructions for continued airworthiness for the TAWS installation in accordance with § 23.1529.

(9) Compliance Documentation. This section should describe the procedures for submittal and processing of compliance documentation.

d. System Safety Assessment.

(1) A system safety assessment (SSA) should be performed that establishes the hazards associated with the proposed installation. The SSA should be developed in accordance with AC 23.1309-1C.

(2) The FAA expects an SSA for the installation to establish, by quantitative or qualitative analysis, the probability of system failure, false alerts, and unannunciated failures. The presentation of hazardously misleading information (HMI) on the terrain display, or the unannunciated loss of the terrain warning functions as a result of TAWS computer failure, is considered a major failure condition by TSO-C151a. TSO-C151a requires major failure condition (10^{-5}) for unannunciated failure, HMI, and false alerts at the TAWS computer level. The box, as installed, should meet the following criteria:

(a) The probability of failure conditions of the installed system that would lead to the loss of all the functions, as described in paragraph 6.a. and 6.b. above, should be less than or equal to 10^{-3} per flight hour.

(b) The probability of a failure condition for either a false caution or warning alert, or both, should be less than or equal to 10^{-4} per flight hour due to undetected or latent failures.

(c) The probability of a failure condition for an unannunciated failure of the system to provide the required alerting functions should be less than or equal to 10^{-4} per flight hour due to undetected or latent failures.

(d) The probability of a failure condition for the system to provide hazardously misleading information (HMI) to the TAWS display should be less than or equal to10^{-4} per flight hour due to undetected or latent failures.

(e) Failure of the installed TAWS should not degrade the integrity of any installed system with the TAWS interfaces that could have either hazardous or catastrophic failure conditions as defined by AC 23.1309-1C.

e. Software. The applicant should submit data that the TAWS software meets the requirements of TSO-C151a and that it meets the appropriate software levels for any added feature (s). Software implementing the TAWS functions defined in TSO-C151a should be developed at least to Level C, as defined in RTCA DO-178B, or an acceptable alternative approved by the FAA.

f. Position Sources. TAWS uses the estimated position of the airplane with reference to either the terrain or obstacle to determine when an alert should be annunciated. The applicant should provide evidence that the TAWS horizontal and vertical position sources are suitable for each phase of flight (that is, enroute, terminal, approach, and departure) as provided by TSO-C151a (Appendix 1, Section 10) for which approval is sought.

(1) Horizontal Position Source.

(a) TAWS that interface with previously approved navigation systems. Previously approved Area Navigation (RNAV) and GPS systems that are used for navigation are generally considered suitable for TAWS horizontal position inputs. An RNAV system must meet the requirements of TSO-C115 or be installed in accordance with AC 90-45A. A GPS must meet the requirements of TSO-C129a or be installed in accordance with AC 20-130A or AC 20-138. If a Wide Area Augmentation System (WAAS) is used as a position source it must meet the requirements TSO-C145. A means for testing the position source for accuracy and reliability is unnecessary for these systems.

(i) Class A TAWS equipment installed in airplanes operated under Part 121 may use approved RNAV, which may include GPS.

(ii) Class A TAWS for operations under Part 135 (turbine-powered U.S.-registered airplane configured with 10 or more passenger seats, excluding any pilot seat) are required to interface with an independent approved GPS for horizontal position information.

(iii) The Class B TAWS equipment is required to interface with an independent approved GPS for horizontal position information.

(b) TAWS equipment with internal GPS position source. Class A and Class B TAWS equipment that use a GPS internal to the TAWS for horizontal position information must use a GPS that is capable of detecting a positional error that exceeds the appropriate alarm limit for the existing phase of flight, in accordance with TSO-C129a or equivalent. When this alarm limit is activated, the GPS-computed position is considered unsuitable for the TAWS. The applicant must be able to demonstrate that the TAWS, as installed on the aircraft, provides the appropriate position information (latitude/longitude) for the TAWS functions.

(c) Degraded Horizontal Position Source. TAWS functions should be automatically disabled when the horizontal position source has degraded to a point where its accuracy can no longer support these functions (that is, IRU, dead reckoning). Annunciation of the loss of the TAWS function is required. If the installation does not provide this automatic feature, then an indication should be provided to the flightcrew that the TAWS function is no longer available and the appropriate crew action noted in the AFM or AFMS.

(2) Vertical Position Source. The following sources are considered suitable for use in establishing vertical position. The applicant is required to demonstrate that the TAWS, as installed in the aircraft, provides the appropriate vertical information for the TAWS functions.

(a) Barometric Altitude. Vertical position information provided by a barometric altitude source that meets the accuracy specified in TSO-C10b, or later versions, is considered acceptable as a source of vertical position information.

(b) Radio Altimeter. Vertical position information provided by a radio altimeter that meets the accuracy specified in TSO-C67, or later versions, is considered acceptable as a source of vertical position information for height above ground only. Radio altitude by itself is not adequate as the source of vertical position information for all phases of flight. Class B equipment does not require a radio altitude input.

(c) Air Data Computers. Vertical position information provided by an air data computer that meets the accuracy specified in TSO-C106, or later versions, is considered acceptable as a source of vertical position information.

(d) GPS. Vertical position information provided by GPS may be used in combination with other sources of vertical position (that is, barometric altitude). In this implementation, the GPS must meet the accuracy and integrity requirements of TSO-C129a. If GPS data is used as the only means for the determination of vertical position, then it must meet the accuracy and

integrity requirements of TSO-C145, or later versions. Either of these implementations is considered acceptable as a source of vertical position information.

g. Terrain Database. The terrain database for TAWS has been validated via the TSO-C151a authorization process, so there is no need to revalidate the database during the installation process. However, there are two areas of concern that must be addressed during the installation process:

(1) Updates. The installed system must be capable of accepting updated terrain databases (and obstacle databases as well, if included). The TAWS manufacturers must have a procedure in place whereby the manufacturer can inform either the airplane owner or operator, or both, about updates or how they can learn about updates. The procedure must contain sufficient information to enable them to make a logical safety decision as to whether it is appropriate to purchase and install the update. This information should be contained in the instructions for continued airworthiness.

(2) Valid Regional Data. The instructions for continued airworthiness should identify the procedures for determining the status of the terrain database. Operators should use this information to determine if the current terrain database is appropriate for the area of intended operation. The area of intended operation should be identified in the AFM or AFMS.

h. Display Presentation.

(1) Terrain Display.

(a) The TAWS equipment approved under TSO-C151a must be capable of providing terrain and alerting data to display hardware. The display hardware may be stand-alone or interfaced with existing equipment, such as a weather radar (WXR), Navigation displays, or other compatible display system. The actual display presentation format that the flightcrew sees will depend on the onboard display hardware, the options made available by the TSO-C151a manufacturer, and the features desired by either the customer or the user. Regardless of whatever format is used, the display presentation should enhance the flightcrew's terrain situational awareness.

(b) The terrain display system is an output from the TAWS; therefore, the possibility of failure of that system should be no greater than 10^{-3} per average flight hour, and the possibility of misleading information on the display due to undetected or latent failures should be no greater than 10^{-4} per average flight hour. For a Class A TAWS, the software development assurance level should be at least to Level C as defined in RTCA DO-178B or an acceptable alternative approved by the FAA. For Class B TAWS, the software development assurance level should be at least to Level D providing the required alerts and visual annunciations are independent of the terrain display(s). If the required alerts and visual annunciations are integrated on the displays, the software development assurance should be at least Level C. **NOTE:** A terrain display is not mandatory for Class B equipment.

(c) During the development of the TAWS equipment, the applicant should use a representative sample of pilots to participate in the design and evaluation process for the proposed presentation format.

(d) The applicant should consider the selection of terrain display where the display is utilized for multiple functions. In these cases, a means should be provided to select and de-select the display of terrain.

(2) Terrain Display Presentation. TAWS equipment shall be designed to interface with a terrain display, either color or monochromatic. The terrain display should be capable of providing the following terrain-related information:

(a) The terrain should be depicted relative to the airplane's position such that the pilot may estimate the relative bearing to the terrain of interest.

(b) The terrain should be depicted relative to the airplane's position such that the pilot may estimate the distance to the terrain of interest.

(c) The terrain depicted should be oriented to either the heading or track of the airplane. In addition, a north-up orientation may be added as a selectable format. A north-up orientation should only be used for strategic (flight planning) purposes.

(d) Variations in terrain elevation depicted relative to the airplane's elevation (above and below) should be visually distinct. Terrain that is more than 2,000 feet below the airplane's elevation need not be depicted.

(e) Terrain that generates alerts should be displayed in a manner to distinguish it from non-hazardous terrain, consistent with the caution and warning alert level.

(f) The terrain display presentation should be clear, unambiguous, and readily usable by the flightcrew during day and night operations under all ambient lighting conditions expected in service.

(g) The terrain display should be viewable in direct and reflected sunlight, and at least one display should be viewable by the minimum required flightcrew.

(h) An inhibited, failed, or inoperative TAWS should be indicated to the flightcrew in a manner consistent with the flight deck design philosophy.

(i) The terrain display presentation should complement and be compatible with the terrain alerting function of the TAWS.

(j) Terrain mapping should allow the flightcrew to determine relative terrain elevation.

(k) The terrain display should be designed so that the flightcrew can readily determine if terrain is a threat to the airplane.

(l) Either the colors or textures, or both, used for threat terrain should be intuitive and indicate the immediacy of the threat. For warnings and cautions, § 23.1322 provides specific requirements for the assignment of red and amber for visual annunciations. Red should be used as

the warning annunciation for emergency operational conditions when immediate flightcrew recognition is required, and immediate correction or compensatory action may be required. Amber should be used for the cautionary annunciation for abnormal operational conditions when immediate flightcrew awareness is required and subsequent flightcrew action may be required. White, or another unique color, should be used for advisory annunciations of operational conditions that require flightcrew awareness and when action may be required. Green should be used for indication of safe operating conditions. For color terrain displays, an acceptable method for color allotment is as follows: (1) red for terrain or obstacle threat warning area when the airplane is well below the threat, (2) yellow or amber for terrain or obstacle threat caution area when the airplane is about the same altitude as the threat, (3) green for terrain obstacle area when the airplane is well above the threat, and (4) black for no significant terrain or obstacle. For monochromatic displays, the intensity of the data, such as the use of dot density or brightness, shows the relationship between terrain and the airplane altitude.

(m) If the terrain is presented on a shared display, the pilot may select the information to be displayed at any given time. Terrain mode and terrain information should be easily distinguishable from weather and other features.

(n) For color displays, the selected colors should complement the discreet visual and aural alerts that are presented to the flightcrew. Accordingly, any colors that are used for the threat terrain display should match the colors used for the discreet visual alerts.

(3) Pop-Up Mode-Switching Functionality.

(a) General Considerations. If implemented, an automatic pop-up feature should incorporate the following considerations in its design:

- The pop-up functionality should automatically display in a heading up or track up orientation.
- The pop-up functionality should automatically display TAWS-related information when a TAWS warning or caution alert occurs.
- The display system should be designed so that it is very evident that an automatic pop-up has occurred.
- The terrain display mode should be annunciated on the display. If this annunciation is not feasible then a mode annunciation light should be installed near the terrain display.
- Manually switching back to the original mode of operation should require minimal effort.
- Automatic switching back to the original mode of operation after the caution or warning ceases should not be allowed unless it is part of the aircraft design philosophy.

(b) Pop-Up Inhibit Feature. When dual terrain displays are provided in conjunction with pop-up functionality, the terrain map and alerts should automatically be presented on at least one of the displays.

(c) Prioritizing Pop-Up Displays Between Systems. In installations where the TAWS and the Predictive Windshear System (PWS) share the same display, and automatic pop-up functionality is employed, the display priorities indicated in Table 1, below, are recommended:

TABLE 1. Prioritization of pop-up displays where the TAWS and the PWS share the same display

Priority		Description
Highest	1	Terrain Awareness Warning
	2	Predictive Windshear Warning
	3	Terrain Awareness Caution
	4	Predictive Windshear Caution
	5	Standard Terrain Display
Lowest	6	Weather Radar

If the system provides alerting for obstacle threats, the prioritization for warnings and cautions should be the same as those for terrain. The priorities are listed in the table above.

(4) Auto-Range Switching Mode. An auto-ranging function during alerts is not required. However, if provided, an auto-ranging display should be designed so that it is very evident to the flightcrew that the range has been automatically selected. The range selected for auto-ranging should provide a usable depiction of the terrain or obstacle threat on the display. Switching back to a manually-selected range should require minimal effort.

i. Alerts. Alerts should be clear, concise, and unambiguous. The alerting system should be:

(1) Consistent with the alerting philosophy of the airplane flight deck in which the TAWS equipment is installed; and

(2) Within the flightcrew's primary field of view

(3) Generation of aural and visual alerts should not be dependent upon display of terrain data.

j. Alert Prioritization.

(1) Installations of TAWS on aircraft also equipped with a Reactive Windshear System (RWS), Predictive Windshear System (PWS), and Traffic Alert and Collision Avoidance System (TCAS) should include an aural prioritization scheme such that:

(a) Only one aural alert is given at any one time, and

(b) Aural alerts for situations requiring immediate action by the flightcrew have priority in situations where conditions for multiple alerts may occur. **Note:** In older aircraft the system architecture may preclude the prioritization of aural alerts for multiple alerting systems. If such is the case, an aural

prioritization scheme is not required. However, if simultaneous alerts can be given, then the alerts must be understandable and distinguishable.

(2) Implementing this voice prioritization scheme within the TAWS equipment is acceptable. An example of the recommended voice prioritization is shown in Table 2 for Class A TAWS, and Table 3 for Class B TAWS, if provided, but it is not required.

TABLE 2. Recommended voice prioritization between the Class A TAWS and other systems installed

Priority		Description For Class A TAWS
Highest	1	Reactive Windshear System Warning
	2	Sink Rate Pull-Up Warning *(Excessive Rates of Descent)*
	3	Terrain Closure Pull-Up Warning *(Excessive Closure Rates)*
	4	Terrain Awareness Pull-Up Warning *(FLTA)*
	5	Predictive Windshear System Warning
	6	Minimums (Voice Callouts)
	7	Terrain Awareness Caution *(FLTA)*
	8	Too Low Terrain *(Flight Into Terrain When Not in Landing Configuration)*
	9	PDA ("Too Low Terrain") Caution
	10	Altitude Callouts (Voice callouts)
	11	Too Low Gear *(Flight Into Terrain When Not in Landing Configuration)*
	12	Too Low Flaps *(Flight Into Terrain When Not in Landing Configuration)*
	13	Sink Rate *(Excessive Rates of Descent)*
	14	Don't Sink *(Negative Climb Rate or Altitude Loss After Take-off)*
	15	Glideslope *(Excessive Downward Deviation From an ILS Glideslope)*
	16	Predictive Windshear System Caution
	17	Approaching Minimums *(Voice Callouts)*
	18	Bank Angle *(Voice Callouts)*
	19	Reactive Windshear System Caution
	20	TCAS RA ("Climb," "Descend," etc.)
Lowest	21	TCAS TA ("Traffic, Traffic")

TABLE 3. Recommended voice prioritization between the Class B TAWS and other systems installed

Priority		Description for Class B TAWS
Highest	1	Reactive Windshear System Warning
	2	Sink Rate Pull-Up Warning *(Excessive Rates of Descent)*
	3	Terrain Awareness Pull-Up Warning *(FLTA)*
	4	Predictive Windshear System Warning
	5	Minimums (Voice Callouts)
	6	Terrain Awareness Caution *(FLTA)*
	7	PDA ("Too Low Terrain") Caution
	8	Altitude Callouts *(Voice callouts)*
	9	Sink Rate *(Excessive Rates of Descent)*
	10	Don't Sink *(Negative Climb Rate or Altitude Loss After Take-off)*
	11	Predictive Windshear System Caution
	12	Approaching Minimums *(Voice Callouts)*
	13	Bank Angle *(Voice Callouts)*
	14	Reactive Windshear System Caution
	15	TCAS RA ("Climb," "Descend," etc.)
Lowest	16	TCAS TA ("Traffic, Traffic")

k. System Inhibit.

(1) Inhibiting the FLTA and PDA functionality should not impact the basic GPWS functions. Appropriate annunciation of the inhibited functions should be provided to the flightcrew. Flightcrew procedures for disabling various TAWS functions should be identified in the AFM or AFMS. System inhibit should include a means such that it can not be operated instinctively, inadvertently, or by habitual reflexive action. Provisions for a guarded switch could be a possible means of compliance.

(2) System Self-Test. Self-test features should be inhibited in flight unless provisions are made to ensure the self-test cycle does not interfere with normal operations.

l. Flight Data Recorder. For those applications that require crash-survivable flight data recording in accordance with the requirements of § 23.1459 (Flight recorders), a means should be provided to record the FLTA alerts in the same manner as is currently done for the basic GPWS. It is not necessary to distinguish between basic GPWS and the new FLTA and PDA alerts. A means also should be provided to record either a FLTA or PDA-inhibit, or both.

m. Systems Evaluations. Aircraft simulators, mock-ups, system integration tools, etc., independently or in conjunction with computer generated test scenarios developed by the TAWS manufacturer, may be used to evaluate specific installations of TAWS equipment. If these tools are used to evaluate a particular TAWS installation, they should adequately represent the target aircraft configuration. The level of fidelity required will depend on the type of credit being sought. Some of the characteristics of a TAWS installation and flight deck integration that may be evaluated are displays, alert prioritization, mode transitions, pop-up displays, auto-ranging, self test, operational workload issues, accessibility and usability of the TAWS controls, and systems failure modes.

n. Ground Test Requirements. A ground test should be conducted for each TAWS installation. The level of testing required will be determined by the scope of the installation (whether an initial installation of the model versus a follow-on installation). In addition to system evaluations noted above, ground test should evaluate the location of TAWS controls, displays, and visual alerts, aural alerts, self-test functions, identified failure modes, all discrete inputs and sensors interfaced with the TAWS equipment, electro-magnetic interference (EMI)/electro-magnetic compatibility (EMC) testing, and electrical transient effects. The visibility and characteristics of any provided display should be evaluated under all anticipated cockpit lighting conditions. Ground tests conducted using computer generated test equipment accepted by the TAWS manufacturer may be used in place of flight-testing for basic Class B TAWS equipment. Similar testing may be used to minimize the extent of flight-testing required for Class A TAWS equipment.

o. Flight-Test Requirements. The level of flight-test required to validate a particular TAWS installation will be based on the type of airplane, airplane system architecture (digital, hybrid digital-analog discrete inputs, or analog discrete inputs), and credit given for previously certified installations, system evaluation, and ground testing. Airplanes incorporating digital or hybrid digital-analog discrete data interface architectures may require flight-testing to ensure proper data transfer among various systems. The actual requirement for a flight-test needs to be evaluated for each installation. If ground testing is not adequate to verify proper function of all interfaced equipment, additional flight-testing for TAWS functions may be necessary.

(1) Flight-Test Matrix. Table 4 shows TAWS functions that should have a flight-test evaluation for the following examples. These examples are intended to assist in determining the extent of flight-testing for some potential or likely TAWS configurations:

TABLE 4. Flight-Test Matrix

TAWS Functions	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6
FLTA	X	X	X	X		X
PDA	X	X			X or	X
Basic GPWS	X	X		X	X	
Terrain Display	X		X	X		X
TAWS Horizontal Position Source	X			X		X

(a) Example 1. This is the first time the manufacturer's equipment has been installed in any airplane for the purpose of receiving initial TC or STC approval. If such is the case, then a complete and thorough ground and flight-test program should be conducted to verify the adequacy of the installation.

(b) Example 2. This involves a follow-on installation of a previously approved TAWS in which a required sensor input has not been previously approved for the specific manufacturer's equipment. For example, if the sensor that provides barometric altitude (or equivalent) to the TAWS equipment has not been previously approved, the flight-test evaluation should focus on the TAWS functions affected by barometric altitude such as FLTA and PDA.

(c) Example 3. This involves a follow-on installation of a previously approved TAWS in which the terrain display has not been previously approved. In this case, the focus of the flight-test evaluation should be on display related issues and tests specified in paragraph 7.o.(6), below, of this AC.

(d) Example 4. This involves a follow-on installation of a previously approved TAWS in which the horizontal position source sensor input has not been previously approved for the specific manufacturer's equipment. In this case, the focus of the flight-test evaluation should be on the adequacy of the horizontal position source and the display of the terrain as determined by that horizontal position source. Verification of the function and proper interface installation may require additional flight-testing for the FLTA, PDA, and basic GPWS.

(e) Example 5. This involves a follow-on installation of a previously approved TAWS in which the vertical position source to the TAWS equipment has not been previously approved. In this case, the focus of the flight-test evaluation should be on the TAWS functions affected by the vertical position source such as one of the basic GPWS modes, FLTA, or PDA functions. Only one test is required to assure that the vertical position source input is properly installed to the TAWS.

(f) Example 6. This involves a follow-on installation of a particular manufacturer's TAWS in an airplane that was previously approved with the same manufacturer's basic GPWS equipment (per TSO-C92c). The TAWS installation uses the same interfaces used for the previous GPWS installation plus those additional interfaces associated with the TAWS installation. If such is the case, then basic GPWS testing may not be necessary. Flight-tests can be limited to the interfaces, features and functions (including basic GPWS) added with the TAWS installation. For example, interfaces that enable additional GPWS functions or features, such as position based alerting desensitization, altitude callouts, bank angle limits, etc., would be evaluated along with TAWS functions.

(2) FLTA Flight-Test Requirements. Flight-testing to verify the proper operation of the FLTA function can be conducted in an area where the terrain or obstacle elevation for the test runs is known within approximately 300 feet. This test may have a potential hazard. Test runs are recommended to be level flight at approximately 500 feet above the terrain/obstacle of interest. The test runs should verify that all alerts (caution and warnings) are given at an appropriate point in the test run, that all pop-up, auto-range, or other display features are working correctly, and that the display depicts the terrain accurately.

> **NOTE:** The terrain selected should be at least 15 NM from the nearest airport to conduct the test as described. If this is not practical, the fly-over altitude will have to be lowered to 300 feet or less above either the terrain or obstacle, or both, in order to generate a TAWS alert.

(3) PDA Flight-Test Requirements. Flight-testing to verify the proper operation of the PDA function can be conducted in any airport area within 10 NM of the nearest runway. The airplane should be configured for landing at approximately 1500 feet AGL along the final approach segment of the runway at approximately 10 NM from the runway. At the 10 NM point, a normal three degree flight path angle descent can be initiated and maintained until the PDA alert occurs.

> **NOTE:** The runway selected for this test should be relatively free from either terrain or obstacles to preclude activation of the FLTA function. If not feasible, then increase the barometric altitude by 1 inch of mercury (hg) to allow radio altitude inputs to trigger a PDA alert. Approximately level terrain along the final approach segment will exercise the PDA function. This test may also exercise the 500 foot voice callout. The adequacy of the PDA aural alert should be verified during this test. This test will also verify the adequacy of the airport data base, the navigation source input and either the barometric or radio altitude inputs to TAWS, or both.

(4) Basic GPWS Flight-Test Requirements. Flight-testing to verify the proper operation of basic GPWS functions can be conducted in any area where the terrain elevation is known to the flightcrew. The following information is intended to provide guidance for conducting flight-tests to exercise and verify the proper operation of each GPWS function. The

need to conduct flight-testing for follow-on TAWS installations will depend upon the nature of the new or modified sensors and their impact on that particular GPWS function.

(a) Excessive Rates of Descent. This test can be conducted at any location, but descents toward near level terrain are recommended for best results and ease of correlation with RTCA DO-161 envelopes. For Class A equipment, exercising this test verifies the proper inputs to the TAWS of barometric altitude (and the corresponding computation of barometric altitude rate) and radio altitude. For Class B equipment, exercising this test verifies the proper inputs to the TAWS of barometric altitude, the height above terrain as determined from the GPS position and the corresponding terrain elevation from the terrain data base. Only one test run is required to determine proper installation.

(b) Excessive Closure Rate To Terrain. This test must be conducted in an area of known rising terrain. It is recommended that one level test run at an altitude between 500-1000 feet above the terrain elevation be conducted. For Class A equipment only, this test will verify the proper input to the TAWS of the radio altitude.

(c) Negative Climb Rate or Altitude Loss After Takeoff. This test is conducted immediately after takeoff before climbing above 700 AGL or above runway elevation. For Class A equipment, exercising this test verifies the proper inputs to the TAWS of barometric altitude, barometric altitude rate and radio altitude. For Class B equipment, exercising this test verifies the proper input of barometric altitude and height above terrain as determined from the GPS position and the corresponding terrain elevation from the terrain data base.

(d) Flight Into Terrain When Not In Landing Configuration. This test should be conducted while on a visual approach to a runway and include evaluation of the flap override function. For Class A equipment only, exercising this test verifies the proper input to the TAWS of barometric altitude, barometric altitude rate and radio altitude as well as the gear and flap sensor inputs to TAWS.

(e) Excessive Downward Deviation From an ILS Glideslope. This test should be conducted during an ILS approach and include evaluation of the glideslope cancel function. For Class A equipment only, this test will verify the proper installation of the ILS Glideslope input to TAWS.

(f) Voice Callout "Five Hundred." This test is conducted during an approach to a runway. For Class A and B equipment, this test will verify the proper input to the TAWS of barometric altitude, radio altitude, and height above terrain as determined by either radio altitude or by access to the terrain data base.

(5) Terrain Display Flight-Test Requirements. Flight-testing to verify the proper operation of the terrain display should be conducted while verifying all the other required TAWS functions. Emphasis should be placed on verifying compliance with the requirements specified in paragraph 7.h.(2) of this AC during normal airplane maneuvering during all phases of flight. Pop-up and auto-ranging features should be evaluated if applicable. It is recommended to perform

sustained turns to evaluate symbol stability, flicker, jitter, display update rate, color cohesiveness, readability, the use of color to depict relative elevation data, caution and warning alert area depictions, map masking and overall suitability of the display.

(6) TAWS Horizontal Position Source Flight-Test Requirements. For TAWS equipment interfaced with an approved GPS (WAAS) navigation system, no additional horizontal position source testing is necessary. (For TAWS equipment incorporating an internal GPS (WAAS) position source, a suitable ground or flight-test to validate positional accuracy is necessary.) A low level overflight of a known ground reference point, reference AC 20-130A or AC 20-138, is acceptable. In addition, a 360 degree turn at 30 degrees of bank is necessary to show continuity of position data. Note: Additional test equipment will likely be required to observe the GPS data.

(7) Pressure Altitude Variations in Cold Weather Flight-Test Requirements. The TAWS may be designed to account for the effects of cold weather on barometric altitude while determining vertical position. Flight-testing may be required for the initial installation approval only, unless a suitable ground verification procedure is conducted. Testing requirements will depend on the design of the cold weather compensation.

(8) Added Features Flight-Test Requirements. Flight-testing may be required to verify the proper operation of added features such as Windshear Detection, Bank Angle, Altitude Call Outs "Approaching Minimums," or other features not required by TSO-C151a.

p. AFM or AFMS. An AFM or AFMS containing the limitations, restricted areas of operation, and operational considerations for either Normal or Abnormal Procedures should be provided for each installation. The applicant should make an evaluation to determine if there are any limitations of the system and, if so, how they will affect aircraft operations. Any limitations affecting operations shall be included in the AFM or AFMS. As a minimum, the applicant should provide instructions in the Limitations Section of the AFM or AFMS that include the following:

(1) Limitations. The following instructions should be included in the Limitations Section of all AFM or AFMS:

(a) Navigation must not be predicated upon the use of the TAWS.

NOTE: The terrain display is intended to serve as a situational awareness tool only. It may not provide either the accuracy or fidelity, or both, on which to solely base decisions and plan maneuvers to avoid terrain or obstacles.

(b) To avoid giving unwanted alerts, the TAWS must be inhibited when landing at an airport that is not included in the airport database.

(c) The use of the terrain awareness warning and terrain display functions is prohibited during QFE (atmospheric pressure at airport elevation) operations.

NOTE: This limitation may not apply to systems that use other sources of altitude measurement to determine the airplanes vertical position.

(d) The ABC Model XXX TAWS Pilot's Guide, P/N *<insert part number>*, dated *<insert date>* (or later appropriate revision) should be immediately available to the flightcrew. The software status stated in the pilot's guide should match that displayed on the equipment.

(e) Pilots are authorized to deviate from their current ATC clearance to the extent necessary to comply with TAWS warnings.

(f) Terrain database. The area of intended operation should be identified in the AFM or AFMS (that is, North America, Europe, etc.)

(2) Restricted Areas of Operation. Known areas or other factors within the approved areas of operation that adversely affect navigation performance to the extent that the TAWS will be potentially unreliable or misleading, should be identified in the AFM or AFMS. Areas of operation where the terrain data base resolution or accuracy leads to nuisance alerts should also be identified.

This situation may occur if:

- The data are not properly analyzed,
- There is not enough data to map the terrain adequately,
- The resolution of the data is not adequate for the type of approved position source, or
- There are changes in the area (volcanoes, earthquakes, construction) that have not been noted.

NOTE: For Class A TAWS equipment and where operational procedures require a route structural analysis (RSA), airports or runways that are susceptible to nuisance alerts should be identified. This analysis can be accomplished by computer simulation. Engine-out procedures also should be considered when developing the RSA.

(3) Operational Considerations for either Normal or Abnormal Procedures, or both. In addition to the GPWS operational procedures, consider the following:

(a) Terrain Awareness Caution. When a terrain awareness CAUTION occurs take positive corrective action until the alert ceases. Stop descending or initiate either a climb or a turn, or both, as necessary, based on analysis of all available instruments and information.

(b) Terrain Awareness Warning. If a terrain awareness WARNING occurs, immediately initiate and continue a climb that will provide maximum terrain clearance, or any similar approved vertical terrain escape maneuver, until all alerts cease. Only vertical maneuvers are recommended, unless either operating in visual meteorological conditions (VMC), or the pilot

determines, based on all available information, that turning in addition to the vertical escape maneuver is the safest course of action, or both.

(c) NOTE: Cold Weather Operations. For those systems that do not provide extreme cold temperature compensation of barometric altitude (corrected altitude), the AFM, AFMS, or Supplemental AFM should include the following note: "Operations at extreme cold temperatures, for example, -30 degrees Celsius, will result in a significant reduction in terrain clearance provided by TAWS alerts." To reduce or eliminate errors potentially induced in barometric altitude temperature extremes, the design should include features such as corrected altitude or special operational procedures. For operations in cold weather, either the system should be able to account for variations in extreme cold weather temperatures, for example, –30 degrees Celsius, or additional flightcrew procedures should be considered to address pressure altitude limits for vertical position determination.

(d) GPWS Mode 4. A procedure must be established for the operation of the inhibition of Mode 4 warnings based on flaps being in other than the landing configuration. The GPWS Mode 4 function may be deactivated to prevent nuisance warnings when following approved procedures that specify landing with flaps not in normal landing position or landing gear up.

(e) GPWS Mode 5. The GPWS should provide a capability to inhibit or cancel the below-glideslope alert for an approach.

Michael K. Dahl
Acting Manager, Small Airplane Directorate
Aircraft Certification Service

U.S. Department
of Transportation

**Federal Aviation
Administration**

800 Independence Ave., S.W.
Washington, D.C. 20591

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