



Department of Transportation  
**Federal Aviation Administration**  
Aircraft Certification Service  
Washington, D.C.

**TSO-C151c**

Effective  
Date: 6/27/12

# Technical Standard Order

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**Subject: Terrain Awareness and Warning System (TAWS)**

- 1. PURPOSE.** This technical standard order (TSO) is for manufacturers applying for a TSO authorization (TSOA) or letter of design approval (LODA). In it, we (the Federal Aviation Administration (FAA)) tell you what minimum performance standards (MPS) your Terrain Awareness and Warning System (TAWS) equipment must first meet for approval and identification with the applicable TSO marking.
- 2. APPLICABILITY.** This TSO affects new applications submitted after its effective date.

  - a.** All prior revisions to this TSO are no longer effective. Generally, we will not accept applications for the previous revision after the effective date of this TSO. We may do so, however, up to six months after it, if we know that you were working against the prior MPS before the new change became effective.
  - b.** TAWS approved under a previous TSOA may still be manufactured under the provisions of its original approval.
- 3. REQUIREMENTS.** New models of TAWS equipment identified and manufactured on or after the effective date of this TSO must meet the MPS qualification and documentation requirements in appendix **1** of this TSO for Class A and B equipment and appendix **3** of this TSO for Class C equipment. This equipment is intended for fixed-wing aircraft only.

  - a. Functionality.** This TSO's standards apply to equipment intended to provide the flight crew with terrain awareness as well as aural and visual alerts on a display to help prevent an inadvertent controlled flight into terrain (CFIT) event. Class A and B TAWS equipment is required by Title 14 of the Code of Federal Regulations (14 CFR) parts 91, 121, and 135. Class C TAWS equipment is intended for voluntary installations on airplanes not covered by the TAWS requirements in 14 CFR parts 91, 121, and 135.
  - b. Failure Condition Classifications.**

(1) Failure of the function defined in paragraph **3.a** due to a TAWS computer malfunction resulting in false terrain warnings, un-annunciated loss of function, or presentation of hazardingly misleading information as defined in paragraph 2.12 of appendix 1 is a major failure condition.

(2) Loss of the function defined in paragraph **3.a** is a minor failure condition.

(3) Design the system to at least these failure condition classifications.

**c. Functional Qualification.** Demonstrate the required functional performance under the test conditions specified in appendix 2 of this TSO for Class A and B equipment or appendix 3 of this TSO for Class C equipment.

**d. Environmental Qualification.** Demonstrate the required performance under the test conditions specified in appendix 2 of this TSO for Class A and B equipment or appendix 3 of this TSO for Class C equipment using standard environmental conditions and test procedures appropriate for airborne equipment.

**Note:** The use of RTCA/DO-160D (with Changes 1 and 2 only, incorporated) or earlier versions is generally not considered appropriate and will require substantiation via the deviation process as discussed in paragraph **3.g.** of this TSO.

**e. Software Qualification.** If the article includes software, develop the software according to RTCA, Inc. document RTCA/DO-178B, *Software Considerations in Airborne Systems and Equipment Certification*, dated December 1, 1992 to the software level consistent with the failure condition classifications defined in paragraph **3.b.** of this TSO.

**Note:** The certification liaison process objectives will be considered satisfied after FAA review of the applicable life cycle data.

**f. Electronic Hardware Qualification.** If the article includes complex custom airborne electronic hardware, develop the component according to RTCA, Inc. document *RTCA/DO-254, Design Assurance Guidance for Airborne Electronic Hardware* to the design assurance level consistent with the failure condition classifications defined in paragraph **3.b.** of this TSO.

**Note:** The certification liaison process objectives will be considered satisfied after FAA review of the applicable life cycle data.

**g. Deviations.** We have provisions for using alternate or equivalent means of compliance to the criteria in the MPS of this TSO. If you invoke these provisions, you must show that your equipment maintains an equivalent level of safety. Apply for a deviation under the provision of

14 CFR § 21.618.

**4. MARKING.**

**a.** Mark at least one major component permanently and legibly with all the information in 14 CFR § 45.15(b). The marking must include the serial number.

**b.** Also, mark the following permanently and legibly, with at least the manufacturer's name, subassembly part number, and the TSO number:

(1) Each component that is easily removable (without hand tools); and,

(2) Each subassembly of the article that you determined may be interchangeable.

**c.** If the article includes software and/or airborne electronic hardware, then the article part numbering scheme must identify the software and airborne electronic hardware configuration. The part numbering scheme can use separate, unique part numbers for software, hardware, and airborne electronic hardware.

**d.** You may use electronic part marking to identify software or airborne electronic hardware components by embedding the identification within the hardware component itself (using software) rather than marking it on the equipment nameplate. If electronic marking is used, it must be readily accessible without the use of special tools or equipment.

**5. APPLICATION DATA REQUIREMENTS.** You must give the FAA aircraft certification office (ACO) manager responsible for your facility a statement of conformance, as specified in 14 CFR § 21.603(a)(1), and one copy each of the following technical data to support your design and production approval. LODA applicants must submit the same data (excluding paragraph **5.g.**) through their civil aviation authority.

**a.** A Manual(s) containing the following:

(1) Operating instructions and equipment limitations sufficient to describe the equipment's operational capability. The operating instructions must include information on the effects of loss of GPS on the TAWS function if the TAWS relies on GPS. Additionally, the instructions must contain processes by which the terrain database can be updated.

(2) Detailed description of any deviations.

(3) Installation procedures and limitations sufficient to ensure that the TAWS, when installed according to the installation or operational procedures, still meets this TSO's requirements. Limitations must identify any unique aspects of the installation. The limitations must include a note with the following statement:

“This article meets the minimum performance and quality control standards required by a technical standard order (TSO). Installation of this article requires separate approval.”

(4) For each unique configuration of software and airborne electronic hardware, reference the following:

- (a) Software part number including revision and design assurance level;
- (b) Airborne electronic hardware part number including revision and design assurance level; and,
- (c) Functional description.

(5) A summary of the test conditions used for environmental qualifications for each component of the article. For example, a form as described in RTCA/DO-160G, *Environmental Conditions and Test Procedures for Airborne Equipment*, Appendix A.

(6) Schematic drawings, wiring diagrams, and any other documentation necessary for installation of the TAWS.

(7) List of replaceable components, by part number, that makes up the TAWS. Include vendor part number cross-references, when applicable.

**b.** Instructions covering periodic maintenance, calibration, and repair for the continued airworthiness of TAWS. Include recommended inspection intervals and service life, as appropriate.

**c.** If the article includes software: a plan for software aspects of certification (PSAC), software configuration index, and software accomplishment summary.

**d.** If the article includes simple or complex custom airborne electronic hardware: a plan for hardware aspects of certification (PHAC), hardware verification plan, top-level drawing, and hardware accomplishment summary (or similar document, as applicable).

**e.** A drawing depicting how the article will be marked with the information required in paragraph 4 of this TSO.

**f.** Identify functionality or performance contained in the article not evaluated under paragraph 3 of this TSO (that is, non-TSO functions). Non-TSO functions are accepted in parallel with the TSO authorization. For those non-TSO functions to be accepted, you must declare these functions and include the following information with your TSO application:

(1) Description of the non-TSO function(s), such as performance specifications, failure condition classifications, software, hardware, and environmental qualification levels. Include a

statement confirming that the non-TSO function(s) don't interfere with the article's compliance with the requirements of paragraph 3.

(2) Installation procedures and limitations sufficient to ensure that the non-TSO function(s) meets the declared functions and performance specification(s) described in paragraph 5.f.(1).

(3) Instructions for continued performance applicable to the non-TSO function(s) described in paragraph 5.f.(1).

(4) Interface requirements and applicable installation test procedures to ensure compliance with the performance data defined in paragraph 5.f.(1).

(5) Test plans, analysis and results, as appropriate, to verify that performance of the hosting TSO article is not affected by the non-TSO function(s).

(6) Test plans, analysis and results, as appropriate, to verify the function and performance of the non-TSO function(s) as described in paragraph 5.f.(1).

g. The quality system description required by 14 CFR § 21.608, including functional test specifications. The quality system should ensure that you will detect any change to the approved design that could adversely affect compliance with the TSO MPS, and reject the article accordingly. (Not required for LODA applicants.)

h. Material and process specifications list.

i. List of all drawings and processes (including revision level) that define the article's design.

j. Manufacturer's TSO qualification report showing results of testing accomplished according to paragraph 3.c. of this TSO.

**6. MANUFACTURER DATA REQUIREMENTS.** Besides the data given directly to the responsible ACO, have the following technical data available for review by the responsible ACO:

a. Functional qualification specifications for qualifying each production article to ensure compliance with this TSO.

b. Article calibration procedures.

c. Schematic drawings.

d. Wiring diagrams.

e. Material and process specifications.

**f.** The results of the environmental qualification tests conducted according to paragraph **3.d.** of this TSO.

**g.** If the article includes software, the appropriate documentation defined in RTCA/DO-178B, including all data supporting the applicable objectives in RTCA/DO-178B, *Annex A, Process Objectives and Outputs by Software Level*.

**h.** If the article includes complex custom airborne electronic hardware, the appropriate hardware life cycle data in combination with design assurance level, as defined in RTCA/DO-254, appendix A, table A-1.

**i.** If the article contains non-TSO functions, you must also make available items **6.a.** through **6.h.** as they pertain to the non-TSO functions.

## **7. FURNISHED DATA REQUIREMENTS.**

**a.** If furnishing one or more articles manufactured under this TSO to one entity (such as an operator or repair station), provide one copy or on-line access to the data in paragraphs **5.a.** and **5.b.** of this TSO. Add any other data needed for the proper installation, certification, use, or for continued compliance with this TSO, of the TAWS.

**b.** If the article contains declared non-TSO function(s), include one copy of the data in paragraphs **5.f.(1)** through **5.f.(4)**.

## **8. HOW TO GET REFERENCED DOCUMENTS.**

**a.** Order RTCA documents from RTCA Inc., 1150 18th Street NW, Suite 910, Washington, D.C. 20036. Telephone (202) 833-9339, fax (202) 833-9434. You can also order copies online at [www.rtca.org](http://www.rtca.org).

**b.** Order copies of 14 CFR parts 21, 45, 91, 121, and 135, from the Superintendent of Documents, Government Printing Office, P.O. Box 979050, St. Louis, MO 63197. Telephone (202) 512-1800, fax (202) 512-2250. You can also order copies online [www.access.gpo.gov](http://www.access.gpo.gov). Select "Access," then "Online Bookstore." Select "Aviation," then "Code of Federal Regulations."

**c.** You can find a current list of technical standard orders and advisory circulars on the FAA Internet website Regulatory and Guidance Library at <http://rgl.faa.gov/>. You will also find the TSO Index of Articles at the same site.



Susan J. M. Cabler  
Assistant Manager, Aircraft Engineering  
Division

**APPENDIX 1. FEDERAL AVIATION ADMINISTRATION MINIMUM  
PERFORMANCE STANDARD FOR A TERRAIN AWARENESS AND WARNING  
SYSTEM FOR CLASSES A AND B**

**1.0 INTRODUCTION.**

**1.1 PURPOSE.** This standard provides the MPS for a Terrain Awareness and Warning System (TAWS).

**1.2 SCOPE.** This appendix sets forth the standard for two classes of TAWS equipment. Class A equipment is required for certain 14 CFR part 121 and part 135 operators. Class B equipment is required for certain 14 CFR part 135 and part 91 operators. See table 7 and the appropriate operating rules for specific details.

**1.3 SYSTEM FUNCTION AND OVERVIEW.** The system must provide the flight crew with sufficient information and appropriate alerts to detect a potentially hazardous terrain situation that, in turn, prevents a CFIT event. The basic TAWS functions for all TAWS systems approved under this TSO include the following:

**a.** A forward looking terrain avoidance (FLTA) function. The FLTA function looks ahead of the airplane along and below the airplane's lateral and vertical flight path and provides suitable alerts if a potential CFIT threat exists.

**b.** A premature descent alert (PDA) function. The PDA function of the TAWS uses the airplane's current position and flight path information, as determined from a suitable navigation source and airport database, to determine if the airplane is hazardously below the normal (typically three-degree) approach path for the nearest runway as defined by the alerting algorithm.

**c.** An appropriate visual and aural discrete signal for both caution and warning alerts.

**d.** Class A TAWS equipment must provide terrain information, which is presented on a display system.

**e.** Class A TAWS equipment must provide indications of imminent contact with the ground for the following conditions as further defined in RCTA/DO-161A, *Minimum Performance Standards-Airborne Ground Proximity Warning Equipment*, dated May 27, 1976, and section 3.3 of this appendix. Deviations from RTCA/DO-161A are acceptable providing the nuisance alert rate is minimized, the deviation is approved under the provision of 14 CFR § 21.618, and an equivalent level of safety for the following conditions is provided.

- **Mode 1:** Excessive rates of descent
- **Mode 2:** Excessive closure rate to terrain
- **Mode 3:** Negative climb rate or altitude loss after takeoff

- **Mode 4:** Flight into terrain when not in landing configuration
- **Mode 5:** Excessive downward deviation from an Instrument Landing System (ILS) glideslope, Localizer Performance and Vertical Guidance (LPV), or Global Navigation Satellite System (GNSS) Landing System (GLS) glidepath.

**Note:** RTCA/DO-161A glideslope requirements are incorporated for GLS and LPV glidepaths for TAWS Class A systems, reference paragraph 3.3f. It is desirable to provide a glidepath/glideslope warning function on any approach with vertical guidance.

- **Altitude Callout:** A voice callout (“Five Hundred”) when the airplane descends to 500 feet above terrain or nearest runway elevation. All TAWS equipment must provide a 500 foot voice call out.

**Note:** The altitude callout is not defined in RTCA/DO-161A but is a requirement for the TAWS system. The altitude callout requirements are defined in paragraph 3.3.c. of this appendix.

f. Class B equipment basic TAWS functions include functions listed in paragraphs 1.3.a through 1.3.c and it must provide indications of imminent contact with the ground during the following airplane operations as defined in paragraph 3.4 of this appendix:

- **Mode 1:** Excessive rates of descent
- **Mode 3:** Negative climb rate or altitude loss after takeoff
- **Altitude Callout:** A voice callout (“Five Hundred”) when the airplane descends to 500 feet above the nearest runway elevation. All TAWS equipment must provide the 500 foot voice call out.

**1.4 ADDED FEATURES.** If the manufacturer elects to add features to the TAWS equipment, those features must at least meet the same qualification testing, software verification, and validation requirements as provided under this TSO. Additional information such as human-made obstacles may be added as long as they do not adversely alter the terrain functions.

**1.5 OTHER TECHNOLOGIES.** Although this TSO envisions a TAWS based on the use of on-board terrain and airport databases, other technologies such as the use of radar are not excluded. Other concepts and technologies may be approved under this TSO’s provisions for non-TSO functionality.

## **2.0 DEFINITIONS.**

**2.1 Advisory Alerts.** The level or category of alert for conditions that require flight crew awareness and may require subsequent flight crew response.

**2.2 Alert.** A visual, aural, or tactile stimulus presented to attract attention and convey information regarding system status or condition.

**2.3 Aural Alert.** A discrete sound, tone, or verbal statement used to annunciate a condition, situation, or event.

**2.4 Caution Alert.** The level or category of alert for conditions that require immediate flight crew awareness and subsequent flight crew response.

**2.5 Controlled Flight Into Terrain (CFIT).** An accident or incident in which an aircraft, under the full control of the pilot, is flown into terrain, obstacles, or water.

**2.6 Failure.** The inability of the equipment or any sub-part of that equipment to perform within previously specified limits.

**2.7 False Alert.** An inappropriate alert that occurs as result of a failure within the TAWS or when the design alerting thresholds of the TAWS are not exceeded.

**2.8 Forward Looking Terrain Avoidance (FLTA).** Looks ahead of the airplane along and below the airplane's lateral and vertical flight path and provides suitable alerts if a potential CFIT exists.

**2.9 Global Navigation Satellite System (GNSS).** A world-wide position, velocity, and time determination system that includes one or more satellite constellations, receivers, and system integrity monitoring, augmented as necessary to support the required navigation performance for the actual phase of operation.

**2.10 Ground Based Augmentation System (GBAS) Landing System (GLS).** GLS provides precision navigation guidance for exact alignment and descent of aircraft on approach to a runway. GLS uses the Ground Based Augmentation System (GBAS) to augment the Global Navigation Satellite System(s) and to provide locally relevant information to the aircraft, including the definition of the approach path.

**2.11 Hazard.** A state or set of conditions that together with other conditions in the environment can lead to an accident.

**2.12 Hazardously Misleading Information (HMI).** An incorrect depiction of the terrain threat relative to the airplane during an alert condition (excluding source data).

**2.13 Localizer Performance with Vertical Guidance (LPV).** A wide area augmentation system (WAAS) approach that provides vertical guidance to as low as 200 feet above ground level (AGL).

**2.14 Nuisance Alert.** An inappropriate alert, occurring during normal safe procedures, which is the result of a design performance limitation of TAWS.

**2.15 Required Obstacle Clearance (ROC).** Required vertical clearance expressed in feet between an aircraft and an obstruction. (Per Order 8260.3B Change 20)

**2.16 Search Volume.** A volume of airspace around the airplane's current and projected path that is used to define a TAWS alert condition.

**2.17 Terrain Cell.** A grid of terrain provided by the TAWS database which identifies the highest terrain elevation within a defined geographical area. Terrain cell dimensions and resolution can vary depending on the needs of the TAWS system and availability of data. If a supplier desires, obstacle height can be included in the terrain elevation.

**2.18 Visual Alert.** The use of projected or displayed information to present a condition, situation, or event.

**2.19 Warning Alert.** The level or category of alert for conditions that require immediate flight crew awareness and immediate flight crew response.

### **3.0 REQUIRED TAWS FUNCTIONS.**

**3.1 Class A and Class B Requirements for FLTA.** The majority of CFIT accidents occur because flight crews do not have adequate situational information regarding the terrain in the vicinity of the airplane and its projected flight path. Class A and Class B equipment is required to look ahead of the airplane, within the design search volume, and provide timely alerts in the event terrain is predicted to penetrate the search volume. The FLTA function should be available during all airborne phases of flight including turning flight. The search volume consists of a computed look ahead distance, a lateral distance on both sides of the airplane's flight path, and a specified look down distance based upon the airplane's vertical flight path. This search volume should vary as a function of phase flight, distance from runway, and the required obstacle clearance (ROC) in order to perform its intended function and to minimize nuisance alerts. The lateral search volume should expand as necessary to accommodate turning flight. The TAWS search volumes should consider the accuracy of the TAWS navigation source. The TAWS lateral search area should be less than the protected area defined by the United States Standard for Terminal Instrument Procedures (TERPS), FAA Order 8260.3B and International Civil Aviation Organization (ICAO) Procedures for Air Navigation Services-Aircraft Operations (PAN-OPS) 8168, volume 2, in order to prevent nuisance alerts.

**3.1.1 Reduced Required Terrain Clearance (RTC).** Class A and Class B equipment must provide suitable alerts when the airplane is above the terrain in the airplane's projected flight path, but the projected amount of terrain clearance is considered unsafe for the particular phase of

flight. The required obstacle (terrain) clearance (ROC), as specified in TERPS and the Aeronautical Information Manual (AIM), has been used to define the minimum requirements for obstacle/terrain clearance (ROC) appropriate to the FLTA function. These requirements are specified in table 3.1.1. The FLTA function must be tested to verify that the alerting algorithms meet the test conditions specified in appendix 2, Tables A, B, C, D, E, and F.

**Table 3.1.1**

<b>TAWS REQUIRED TERRAIN CLEARANCE (RTC) BY PHASE OF FLIGHT</b>			
<b>Phase of Flight</b>	<b>TERPS (ROC)</b>	<b>TAWS (RTC) Level Flight</b>	<b>TAWS (RTC) Descending</b>
Enroute	1000 feet	700 feet	500 feet
Terminal (Intermediate Segment)	500 feet	350 feet	300 feet
Approach	250 feet	150 feet	100 feet
Departure (See Note 1)	48 feet/nautical mile (NM)	100 feet	100 feet

**Note 1:** During the departure phase of flight, the FLTA function of Class A and B equipment must alert if the airplane is projected to be within 100 feet vertically of terrain. However, Class A and Class B equipment should not alert if the airplane is projected to be more than 400 feet above the terrain.

**Note 2:** As an alternate to the stepped down reduction from the terminal to approach phase as shown in table 3.1.1, a linear reduction of the RTC as the aircraft comes closer to the nearest runway is allowed, provided the requirements of table 3.1.1 are met.

**Note 3:** During the visual segment of a normal instrument approach (typically about 1 NM from the runway threshold), the RTC should be defined/reduced to minimize nuisance alerts. Below a certain altitude or distance from the runway threshold, logic may be incorporated in order to inhibit the FLTA function. Typical operations below minimum descent altitude (MDA), decision altitude (DA), decision height (DH), or the visual descent point (VDP) should not generate nuisance alerts.

**Note 4:** The specific RTC values are reduced slightly for descending flight conditions to accommodate the dynamic conditions and pilot response times.

**3.1.2 Imminent Terrain Impact.** Class A and Class B equipment must provide suitable alerts when the airplane is below the elevation of a terrain cell along the airplane's lateral projected

flight path and, based upon the vertical projected flight path, the equipment predicts that the terrain clearance will be less than the value given in the RTC column of table 3.1.1. See appendix 2 for test conditions that must be conducted (Table G).

**3.1.3 FLTA Turning Flight.** Class A and Class B equipment must provide suitable alerts for the functions specified in paragraphs 3.1.1 and 3.1.2 when the airplane is in turning flight.

**3.2 Class A and Class B Equipment Requirements for Detection and Alerting for Premature Descent Along the Final Approach Segment.** Class A and Class B equipment must provide a suitable alert when it determines that the airplane is significantly below the normal approach flight path to a runway. Approximately one-third of all CFIT accidents occur during the final approach phase of flight, when the airplane is properly configured for landing and descending at a normal rate. For a variety of reasons, which include poor visibility, nighttime operations, loss of situational awareness, operating below minimums without adequate visual references, and deviations from the published approach procedures, many airplanes have crashed into the ground short of the runway. Detection of this condition and alerting the flight crew is an essential safety requirement of this TSO, and there are numerous ways to accomplish these overall objectives. Alerting criteria may be based upon height above runway elevation and distance to runway. It may be based upon height above the terrain and distance to runway or other suitable means. This TSO will not define the surfaces for which alerting is required. Instead, it specifies some general requirements for alerting and some cases when alerting is inappropriate. See appendix 2, table H for test requirements.

- a. The PDA function must be available for all types of instrument approaches. This includes both straight-in approaches and circling approaches.
- b. The TAWS equipment must not generate PDA alerts for normal visual flight rules (VFR) operations in the airport area. Airplanes routinely operate at traffic pattern altitudes of 800 feet above field/runway elevation when within 5 NM of the airport.
- c. Airplanes routinely operate in VFR conditions at 1000 feet above ground level (AGL) within 10-15 NM of the nearest airport, and these operations must not generate alerts.
- d. Airplanes routinely operate in the visual segment of a circling approach within 2 NM of the airport/runway of intended landing, with 300 feet of obstacle clearance. Operations at circling minimums must not cause PDA or FLTA alerts.

**3.3 Class A Requirements for Ground Proximity Warning System (GPWS) Alerting.** In addition to the TAWS FLTA and PDA functions, the equipment must provide the Mode 1 through Mode 5 GPWS functions listed below in accordance with TSO-C92c and the altitude callout function in accordance with paragraph 3.3.c. of this appendix. However, it is essential to retain the independent protective features provided by both the GPWS and FLTA functions. In each case, all of the following modes must be covered. Some GPWS alerting thresholds may be adjusted or modified to be more compatible with the FLTA alerting function and to minimize GPWS nuisance alerts. Modifications to the GPWS requirements require an approved deviation in accordance with 14 CFR § 21.618. The failure of the TSO-C92c equipment functions, except

for power supply failure, input sensor failure, or failure of other common portions of the equipment, must not cause a loss of the FLTA, PDA, or terrain display.

- **Mode 1:** Excessive rate of descent
- **Mode 2:** Excessive closure rate to terrain
- **Mode 3:** Negative climb rate or altitude loss after takeoff
- **Mode 4:** Flight into terrain when not in landing configuration
- **Mode 5:** Excessive downward deviation from an ILS glideslope, LPV, and/or GLS glidepath
- **Altitude Callout:** Five Hundred Foot Voice Callout

**a. Flap Alerting Inhibition.** A separate, guarded control may be provided to inhibit Mode 4 alerts based on flaps being other than landing configuration.

**b. Speed.** Airspeed or groundspeed must be included in the logic that determines basic GPWS alerting time for “excessive closure rate to terrain” and “flight into terrain when not in landing configuration” to allow maximum time for the flight crew to react and take corrective action.

**c. Altitude Callouts.** Class A equipment must provide a voice callout of “five hundred” or equivalent when descending through 500 feet above terrain or 500 feet above the nearest runway elevation during nonprecision approaches, but are recommended for all approaches. Additional altitude callouts, such as “one hundred” or “two hundred” are acceptable, but not required. This voice callout will not be made at ascent, for example on a missed approach or departure.

**d. Sweep Tones “Whoop-Whoop.”** If a two-tone sweep is used to comply with RTCA/DO-161A, paragraph 2.3, the complete cycle of two-tone sweeps plus annunciation may be extended from “1.4” to “2” seconds.

**e. Mode 5 Glidepath Deviation Alerting.** Class A TAWS equipment must provide Mode 5 alerting for localizer performance with vertical guidance (LPV) glidepath and GNSS landing system (GLS) glidepath, as well as the ILS glideslope. The LPV and GLS envelope, deactivation, reactivation, arming, disarming, alert requirements must follow the Mode 5 requirements in RTCA/DO-161A. The FAA recommends that the glidepath aural alert for LPV and GLS approaches say “glidepath” or equivalent, but the use of “glideslope” is also acceptable. Follow test guidance in RTCA/DO-161A.

### 3.4 Class B Requirements for GPWS Alerting.

**a.** Class B equipment must provide alerts for excessive descent rates. The Mode 1 alerting envelope of RTCA/DO-161A was modified to accommodate a larger envelope for both caution and warning alerts. Height above terrain may be determined by using the terrain database elevation and subtracting it from the QNH (corrected) barometric altitude, or GNSS altitude (or equivalent). In addition, since the envelopes are not limited by a radio altitude measurement to a maximum of 2500 feet AGL, the envelopes are expanded to include higher vertical speeds. The equipment must meet either the requirements set forth in appendix 2, paragraph 7.0, or those specified in RTCA/DO-161A.

**b.** Class B equipment must provide alerts for “negative climb rate after takeoff or missed approach” or “altitude loss after takeoff,” as specified in RTCA/DO-161A. The alerting envelopes are identical to the Mode 3 alerting envelopes in RTCA/DO-161A. Height above terrain may be determined by comparison of aircraft altitude (GNSS or barometric) with runway threshold elevation or by radio altimeter.

**c.** This feature also has an important CFIT protection function. In the event the airplane is operated unintentionally close to terrain when not in the airport area or the area for which PDA protection is provided, this voice callout will alert the flight crew to hazardous conditions. The equipment must meet the requirements specified in appendix 2, section 9.0. Class B TAWS equipment must provide a 500 foot voice call out when descending through 500 feet above the runway threshold elevation for landing. This feature is primarily intended to provide situational awareness to the flight crew when the airplane is being operated properly, per normal procedures. During a normal approach, it is useful to provide the flight crew with a voice callout at 500 feet, relative to the runway threshold elevation for the runway of intended landing. The Class B TAWS equipment must also provide a 500 foot voice call out above terrain when not landing. This 500 foot voice call out above terrain when not landing is an important CFIT protection function. In the event the airplane is operated unintentionally close to terrain when not in the airport area or the area for which PDA protection is provided, this voice callout will indicate to the flight crew to hazardous conditions.

**3.5 Class A Equipment Requirements for a Terrain Display.** Class A equipment must be designed to interface with a color terrain display, and may be designed to also interface to a monochromatic terrain display. Class A equipment for TAWS must also be capable of providing the following terrain-related information to a display system:

**a.** The terrain must be depicted relative to the airplane’s position such that the pilot can estimate the relative bearing to the terrain of interest.

**b.** The terrain must 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 must be oriented to either the heading or the track of the airplane. In addition, a north-up orientation may be added as a selectable format.

d. Variations in terrain elevation must be depicted relative to the airplane's current or projected elevation (above and below) and be visually distinct. Terrain that is more than 2000 feet below the airplane's elevation can be excluded.

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

**3.6 Class B Equipment Requirements for a Terrain Display.** Operators required to install Class B equipment are not required to include a terrain display. However, Class B TAWS equipment must be capable of driving a terrain display function in the event the installer wants to include the terrain display function.

#### **4.0 AURAL AND VISUAL ALERTS.**

**4.1** The TAWS is required to provide aural and visual alerts for each of the functions described in section **3.0** of this appendix.

**4.2** The TAWS must provide the required aural and visual alerts in a manner that clearly indicates to the flight crew that they represent a single event. The TAWS may accomplish the entire alerting function, or provide alert inputs to an external aircraft alerting system. Exceptions to this requirement are allowed when suppression of aural alerts is necessary to protect pilots from nuisance aural alerting, but a visual alert is still appropriate.

**4.3** Each aural alert must identify the reason for the alert, such as "too low terrain," "glideslope," or another acceptable annunciation.

**4.4** The system must remove the visual and aural alert once the situation has been resolved.

**4.5** The system must be capable of accepting and processing airplane performance-related data or airplane dynamic data and providing the capability to update aural and visual alerts at least once per second.

**4.6** The aural and visual outputs as defined in Table **4-1** must be compatible with the standard cockpit displays and auditory systems.

**4.7** The aural and visual alerts should be selectable to accommodate operational commonality among airplane fleets.

**4.8** The visual display of alerting information must be immediately and continuously displayed until the situation is resolved or no longer valid.

**4.9** At a minimum, the TAWS must be capable of providing aural alert messages described in Table **4-1**. In addition to this minimum set, other voice alerts may be provided.

#### **Table 4-1**

<b>STANDARD SET OF VISUAL AND AURAL ALERTS</b>		
<b>Alert Condition</b>	<b>Caution</b>	<b>Warning</b>
<p><b>FLTA Functions</b></p> <p>Reduced Required Terrain Clearance and Imminent Impact with Terrain</p> <p>Class A &amp; Class B</p>	<p><b><u>Visual Alert</u></b> Amber text message that is obvious, concise, and must be consistent with the aural message.</p> <p><b><u>Aural Alerts</u></b> Minimum selectable voice alerts: “Caution, Terrain; Caution, Terrain” <b>and</b> “Terrain Ahead; Terrain Ahead”</p>	<p><b><u>Visual Alert</u></b> Red text message that is obvious, concise and must be consistent with the aural message.</p> <p><b><u>Aural Alerts</u></b> Minimum selectable voice alerts: “Terrain, Terrain; Pull-Up, Pull-Up” <b>and</b> “Terrain Ahead, Pull-Up; Terrain Ahead, Pull-Up”</p>
<p>Premature Descent Alert (PDA)</p> <p>Class A &amp; Class B</p>	<p><b><u>Visual Alert</u></b> Amber text message that is obvious, concise, and must be consistent with the aural message.</p> <p><b><u>Aural Alert</u></b> “Too Low Terrain”</p>	<p><b><u>Visual Alert</u></b> None Required</p> <p><b><u>Aural Alert</u></b> None Required</p>
<p>Ground Proximity Envelope 1, 2, or 3 Excessive Descent Rate Mode 1</p> <p>Class A &amp; Class B</p>	<p><b><u>Visual Alert</u></b> Amber text message that is obvious, concise, and must be consistent with the aural message.</p> <p><b><u>Aural Alert</u></b> “Sink Rate”</p>	<p><b><u>Visual Alert</u></b> Red text message that is obvious, concise, and must be consistent with the Aural message.</p> <p><b><u>Aural Alert</u></b> “Pull-Up”</p>
<p>Ground Proximity Excessive Closure Rate (Flaps not in Landing Configuration) Mode 2A</p> <p>Class A</p>	<p><b><u>Visual Alert</u></b> Amber text message that is obvious, concise, and must be consistent with the aural message.</p> <p><b><u>Aural Alert</u></b> “Terrain, Terrain”</p>	<p><b><u>Visual Alert</u></b> Red text message that is obvious, concise, and must be consistent with the aural message.</p> <p><b><u>Aural Alert</u></b> “Pull-Up”</p>
<p>Ground Proximity Excessive Closure Rate (Landing Configuration) Mode 2B</p> <p>Class A</p>	<p><b><u>Visual Alert</u></b> Amber text message that is obvious, concise, and must be consistent with the aural message.</p> <p><b><u>Aural Alert</u></b> “Terrain, Terrain”</p>	<p><b><u>Visual Alert</u></b> Red text message that is obvious, concise, and must be consistent with the aural message for gear up.</p> <p><b><u>Aural Alert</u></b> “Pull-Up”—for gear up None Required—for gear down</p>
	<b><u>Visual Alert</u></b>	<b><u>Visual Alert</u></b>

<b>STANDARD SET OF VISUAL AND AURAL ALERTS</b>		
<b>Alert Condition</b>	<b>Caution</b>	<b>Warning</b>
Ground Proximity Altitude Loss after Takeoff Mode 3 Class A & Class B	Amber text message that is obvious, concise, and must be consistent with the aural message.  <b><u>Aural Alerts</u></b> “Don’t Sink” and “Too Low Terrain”	None Required  <b><u>Aural Alert</u></b> None Required
Ground Proximity Envelope 1 (Gear and/or flaps other than landing configuration) Mode 4  Class A	<b><u>Visual Alert</u></b> Amber text message that is obvious, concise, and must be consistent with the aural message.  <b><u>Aural Alerts</u></b> “Too Low Terrain” <b>and</b> “Too Low Gear”	<b><u>Visual Alert</u></b> None Required  <b><u>Aural Alert</u></b> None Required
Ground Proximity Envelope 2 Insufficient Terrain Clearance (Gear and/or flaps other than landing configuration) Mode 4  Class A	<b><u>Visual Alert</u></b> Amber text message that is obvious, concise, and must be consistent with the aural message.  <b><u>Aural Alerts</u></b> “Too Low Terrain” <b>and</b> “Too Low Flaps”	<b><u>Visual Alert</u></b> None Required  <b><u>Aural Alert</u></b> None Required
Ground Proximity Envelope 3 Insufficient Terrain Clearance (Gear and/or flaps other than landing configuration) Mode 4  Class A	<b><u>Visual Alert</u></b> Amber text message that is obvious, concise, and must be consistent with the aural message.  <b><u>Aural Alert</u></b> “Too Low Terrain”	<b><u>Visual Alert</u></b> None Required  <b><u>Aural Alert</u></b> None Required
Ground Proximity Excessive Glideslope or Glidepath Deviation Mode 5  Class A	<b><u>Visual Alert</u></b> Amber text message that is obvious, concise, and must be consistent with the aural message.  <b><u>Aural Alert</u></b> “Glideslope” or “Glidepath”	<b><u>Visual Alert</u></b> None Required  <b><u>Aural Alert</u></b> None Required
Ground Proximity Altitude Callout (See Note1)	<b><u>Visual Alert</u></b> None Required	<b><u>Visual Alert</u></b> None Required

STANDARD SET OF VISUAL AND AURAL ALERTS		
Alert Condition	Caution	Warning
Class A & Class B (See Note 3)	<u>Aural Alert</u> “Five Hundred”	<u>Aural Alert</u> None Required

**Note 1:** The call out for ground proximity altitude is considered advisory.

**Note 2:** Visual alerts may be put on the terrain situational awareness display, if doing so fits with the overall human factors alerting scheme for the flight deck. This does not eliminate the visual alert color requirements, even in the case of a monochromatic display. Typically in such a scenario, adjacent colored annunciator lamps meet the alerting color requirements.

**Note 3:** Additional callouts can be made by the system, but the system is required to make the 500 foot voice callout.

#### 4.10 Prioritization.

**a. Class A Equipment.** Class A Equipment must have an interactive capability with other external alerting systems so that an alerting priority can be executed automatically. This prevents confusion or chaos on the flight deck during multiple alerts from different alerting systems. Typical alerting systems that may be interactive with TAWS include predictive windshear (PWS), reactive windshear (RWS), and traffic alert collision and avoidance system (TCAS). The TAWS system must include an alert prioritization scheme for Class A equipment. Table 4-2 provides an example prioritization scheme for Class A equipment. If the PWS, RWS, or TCAS functions are provided within TAWS, the alert prioritization scheme in table 4-2 also applies. The FAA will consider alert prioritization schemes other than the one included in table 4-2.

#### **b. Class B Equipment.**

**1.** Class B Equipment does not require prioritization with external systems such as TCAS, RWS, and PWS. If prioritization with those functions is provided, the prioritization scheme should be in accordance with the scheme in table 4-2.

**2.** Class B Equipment must establish an internal priority alerting system (scheme) for each of the functions. The priority scheme must ensure that the more critical alerts override alerts of lesser priority. Table 4-3 provides a example internal priority scheme for Class B equipment. Class B Equipment need only consider the TAWS functions required for Class B Equipment.

**Table 4-2**

**Legend: W = Warning      C = Caution      I = Non Alert Information**

<b>ALERT PRIORITIZATION SCHEME</b>			
<b>Priority</b>	<b>Description</b>	<b>Level</b>	<b>Comments</b>
1	Reactive Windshear Warning	W	
2	Sink Rate Pull-Up Warning	W	Continuous
3	Excessive Closure Pull-Up Warning	W	Continuous
4	RTC Terrain Warning	W	
5	V <sub>1</sub> Callout	I	
6	Engine Fail Callout	W	
7	FLTA Pull-up Warning	W	Continuous
8	PWS Warning	W	
9	RTC Terrain Caution	C	Continuous
10	Minimums	I	
11	FLTA Caution	C	7 s period
12	Too Low Terrain	C	
13	PDA (“Too Low Terrain”) Caution	C	
14	Altitude Callouts	I	
15	Too Low Gear	C	
16	Too Low Flaps	C	
17	Sink Rate	C	
18	Don’t Sink	C	
19	“Glideslope” or “Glidepath”	C	3 s period
20	PWS Caution	C	
21	Approaching Minimums	I	
22	Bank Angle	C	
23	Reactive Windshear Caution	C	
Mode 6	TCAS RA (“ <i>Climb,</i> ” “ <i>Descend,</i> ” etc.)	W	Continuous
Mode 6	TCAS TA (“ <i>Traffic, Traffic</i> ”)	C	Continuous

**Note:** These alerts can occur simultaneously with TAWS voice callout alerts.

**Table 4-3**

<b>TAWS INTERNAL ALERT PRIORITIZATION SCHEME</b>	
<b>Priority</b>	<b>Description</b>
1	Sink Rate Pull-Up Warning
2	Terrain Awareness Pull-Up Warning
3	Terrain Awareness Caution
4	PDA (“ <i>Too Low Terrain</i> ”) Caution
5	Altitude Callout “500”
6	Sink Rate

7	Don't Sink (Mode 3)
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**4.11** During ILS glideslope, LPV, GLS glidepath, or other localizer-based approach operations, TAWS should not cause an alert for a terrain/obstacle located outside the TERPS protected airspace. Special design considerations may be necessary to address this issue.

**5.0 TAWS Position Requirements.** TAWS relies on horizontal position, vertical position, velocity, and vertical rate information. This information can be generated internally to the TAWS, or acquired by interfacing to other installed avionics on the aircraft.

**5.1 External Sources.** When the TAWS interfaces to external sources for position, velocity, or rate information, the TAWS installation manual must define the performance requirements for the interface.

**5.2 Internal Sources.** When the TAWS includes internal sources for position, velocity, or rate information, these sources must meet the performance requirements in the applicable TSO, if an applicable TSO exists. The performance of the internal source must be sufficient for the TAWS to meet its intended function. Examples of applicable TSOs include:

**a. GNSS equipment:** TSO-C129a, *Airborne Supplemental Navigation Equipment Using the Global Positioning System* (or subsequent), or any revision of TSO-C145, *Airborne Navigation Sensors Using the Global Positioning System Augmented by the Satellite Based Augmentation System*, TSO-C146, *Stand-Alone Airborne Navigation Equipment Using the Global Positioning System Augmented by the Satellite Based Augmentation System*, or TSO-C196, *Airborne Supplemental Navigation Sensors for Global Positioning System Equipment Using Aircraft-Based Augmentation*.

**b. Barometric altitude equipment:** TSO-C10b, *Altimeter, Pressure Actuated, Sensitive Type*, or TSO-C106, *Air Data Computer*.

**c. Radio altimeter equipment:** TSO-C87 *Airborne Low-Range Radio Altimeter*, ETSO-2C87, *Low Range Radio Altimeters*, or RTCA/DO-155, *Minimum Performance Standards Airborne Low-Range Radar Altimeters*.

**d. Vertical velocity equipment:** TSO-C8, *Vertical Velocity Instruments*, or TSO-C106, *Air Data Computer*.

**5.3 Primary Horizontal Position Sources.** Horizontal position for TAWS must come from a GNSS source meeting TSO-C129a or any revision of TSO-C145, TSO-C146, or TSO-C196. As an exception, TAWS equipment intended for installation in aircraft operating under 14 CFR § 121 may be configurable to operate solely on a non-GNSS position source.

**5.4 Alternate Horizontal Position Sources.** Retaining TAWS functionality during GNSS outage or unavailability provides a safety benefit. It is acceptable and recommended to incorporate a secondary, non GNSS position source, to provide horizontal position when the GNSS is not available or reliable.

**5.5 Vertical Position Sources.** Vertical position for TAWS may come from a barometric source such as an altimeter or an air data computer, or from a geometric source, such as GNSS. GNSS vertical accuracy, at a minimum, must meet RTCA/DO-229D section 2.2.3.3.4. Designs that cross check barometric and geometric altitude are recommended. Class A TAWS also requires a radio altimeter.

**5.6 Position Source Faults.** If a position source generates a fault indication or any flag indicating the position is invalid or does not meet performance requirements, the TAWS must stop utilizing that position source. The TAWS may revert to an alternate position source, and must provide indications, as appropriate, regarding loss of function associated with the loss of the position source. The TAWS must inhibit FLTA and PDA alerts when the position source in use is faulted or invalid.

## **6.0 CLASS A AND CLASS B REQUIREMENTS FOR A TERRAIN AND AIRPORT DATABASE.**

**6.1 Minimum Geographical Consideration.** At a minimum, terrain and airport information must be provided for the expected areas of operation, airports, and routes flown.

**6.2 Development and Methodology.** The manufacturer must present the development methodology used to validate and verify the terrain and airport information. RTCA/DO-200A/ED-76, *Standards for Processing Aeronautical Data*, should be used as a guideline.

**6.3 Resolution.** Terrain and airport information must be accurate and of acceptable resolution in order for the system to perform its intended function. Terrain data should be gridded at 30 arc seconds with 100-foot resolution within 30 NM of all airports with runway lengths of 3500 feet or greater, and whenever necessary (particularly in mountainous environments), 15 arc seconds with 100-foot resolution (or even 6 arc seconds) within 6 NM of the closest runway. It is acceptable to have terrain data gridded in larger segments over oceanic and remote areas around the world.

**Note:** Class B equipment may require information relative to airports with runways less than 3500 feet whether public or private. Small airplane owners and operators, as well as small non-scheduled part 135 operators, will likely be the largest market for Class B equipment and they frequently use airports of less than 3500 feet. Those TAWS manufacturers who desire to sell to this market must be willing to customize their terrain databases to include selected airports used by their customers.

**6.4 Continued Airworthiness Updates.** The system must be capable of accepting updated terrain and airport information. Updating of terrain, obstacle, and airport databases does not require a change to the TSO authorization.

**7.0 CLASS A AND CLASS B FAILURE INDICATION.** Class A and Class B equipment must include a failure monitor function that provides reliable indications of equipment condition during operation. It must monitor the equipment itself, input power, input signals, and aural and visual outputs. A means to inform the flight crew whenever the system has failed or can no longer perform the intended function must be provided.

**8.0 CLASS A AND CLASS B REQUIREMENTS FOR SELF-TEST.** Class A and Class B equipment must have a self-test function to verify system operation and integrity. It must monitor the equipment itself, input power, input signals, and aural and visual outputs. Failure of the system to successfully pass the self-test must be annunciated.

**Note:** Flight crew verification of the aural and visual outputs during a self-test is an acceptable method for monitoring aural and visual outputs.

**9.0 CLASS A EQUIPMENT REQUIREMENTS FOR INHIBITING THE FLTA FUNCTION, THE PREMATURE DESCENT ALERT FUNCTION, AND THE TERRAIN DISPLAY.**

**9.1 Manual Inhibit.** The TAWS system must have a capability (e.g., a control switch to the flight crew) to manually inhibit the TAWS (FLTA/PDA) aural alerts, visual alerts, and the terrain display. The switch must not inhibit any of the GPWS alerts defined in section 1.3.e. If the TAWS system incorporates an automatic inhibit function that automatically inhibits TAWS (FLTA/PDA) aural alerts, visual alerts, and terrain display when a position source is faulted or unavailable, then the manual inhibit may be designed to only inhibit aural and visual alerts. This alternate manual inhibit functionality will allow pilots to disable the TAWS (FLTA/PDA) alerting without removing the terrain display when landing at a site not included in the database or landing at a site that generates known nuisance alerts. Inhibit status must be annunciated to the flight crew.

**9.2 Automatic Inhibit.** The capability of automatically inhibiting Class A functions within TAWS equipment is acceptable when utilizing the conditions described in paragraph 7.0. If auto inhibit capability is provided, the “inhibit status” must be annunciated to the flight crew.

**10.0 CLASS A and B PHASE OF FLIGHT DEFINITIONS.** The TAWS equipment search volumes and alerting thresholds should vary as necessary in order to be compatible with TERPS and other operational considerations. For this reason, a set of definitions is offered for enroute, terminal, approach and departure phases of flight. Other definitions for enroute, terminal, and approach may be used by TAWS provided they are compatible with TERPS and standard instrument approach procedures and comply with the test criteria specified in appendix 2. If other definitions for enroute, terminal, and approach are used by TAWS, that information must be approved by the ACO.

**10.1 Enroute Phase.** The enroute phase exists when the airplane is more than 15 NM from the nearest airport or whenever the conditions for terminal, approach, and departure phases are not met.

**10.2 Terminal Phase.** The terminal phase exists when the airplane is 15 NM or less from the nearest runway while the range to the nearest runway threshold is decreasing and the airplane is at or lower than a straight line drawn between the two points specified in table 10 relative to the nearest runway.

**Note:** If the aircraft is accomplishing a procedure turn as part of an instrument approach procedure, the system may remain in the terminal phase, even though the distance to the runway threshold may be temporarily increasing and the conditions for the approach phase may be temporarily met.

**Table 10**

<b>HEIGHT ABOVE RUNWAY VERSUS DISTANCE TO RUNWAY</b>	
<b>Distance to Runway</b>	<b>Height above Runway</b>
15 NM	3500 Feet
5 NM	1900 Feet

**10.3 Approach Phase.** The approach phase exists when the distance to the nearest runway threshold is equal to or less than 5 NM; and the height above the nearest runway threshold location and elevation is equal to or less than 1900 feet; and the distance to the nearest runway threshold is decreasing.

**10.4 Departure Phase.** The departure phase should be defined by some reliable parameter that initially determines that the airplane is on the ground upon initial power-up. If, for example, the equipment can determine that the airplane is “on the ground” by using some logic such as ground speed less than 35 knots and altitude within +/- 75 feet of field elevation or nearest runway elevation and “airborne” by using some logic such as ground speed greater than 50 knots and altitude 100 feet greater than field elevation, then the equipment can reliably determine that it is in the “Departure Phase.” Other parameters to consider are climb state and distance from departure runway. Once the airplane reaches 1500 feet above the departure runway, the departure phase is ended.

**10.5 Nearest Airport or Runway.** The enroute phase considers distance to the nearest airport, and the terminal and approach phases consider distance to the nearest runway in determining the appropriate phase of flight, and thus the appropriate terrain alerting requirements. The phase of flight may also be determined by basing the phase of flight on the intended landing airport or runway, if the TAWS has the intended landing airport or runway information available. The phase of flight determination may also exclude airports or runways which are unsuitable for landing of a particular type of aircraft. For example, the TAWS could be configurable at installation on a large transport category aircraft to only change the phase of flight based on runways of a certain minimum length.

**11.0 CLASS A AND CLASS B SUMMARY REQUIREMENTS.** A summary table of requirements is provided in table 11 for convenience and general information only. Official regulatory requirements are contained in the Federal Aviation Regulations.

**Table 11**

CLASS A AND B SUMMARY REQUIREMENTS								
TAWS Class	Operating Rule	Pax Seats (Min)	FLT A	PDA	Basic GPWS Functions	FMS/RNAV or GPS	Terrain Display Mandatory	Terrain/Airport Database
A	121	See Note	YES	YES	Paragraph 1.3.e.	FMS or GPS	YES	YES
A	135	>9	YES	YES	Paragraph 1.3.e.	GPS	YES	YES
B	135	6-9	YES	YES	Paragraph 1.3.f.	GPS	NO	YES
B	91	= or >6	YES	YES	Paragraph 1.3.f.	GPS	NO	YES

**Note 1:** There is no seat threshold for 14 CFR part 121. All 14 CFR part 121 airplanes affected by the TAWS rules must install TAWS regardless of the number of seats.

**Note 2:** The GPWS equipage requirements in 14 CFR § 121.360 and 135.153 expired and are superseded by the TAWS requirements in 14 CFR § 121.354 and 135.154. TSO-C151c Class A equipment must meet the TSO-C92c requirements, but a separate TSO authorization for TSO-C92c is not required.

## APPENDIX 2. TEST CONDITIONS

**1.0 FORWARD LOOKING TERRAIN AVOIDANCE—REDUCED REQUIRED TERRAIN CLEARANCE (RTC) TEST CONDITIONS.** These conditions exist when the airplane is currently above the terrain, but the combination of current altitude, height above terrain, and projected flight path indicates that there is a significant reduction in the RTC.

**1.1 Phase of Flight Definitions.** For the following test conditions, refer to appendix 1, paragraph 10.0, for an expanded explanation of the definitions of the phases of flight.

**1.2 Enroute Descent Requirement.** A terrain alert must be provided in time to ensure that the airplane can level off (L/O) with a minimum of 500 feet altitude clearance over the terrain/obstacle when descending toward the terrain/obstacle at any speed within the operational flight envelope of the airplane. The test conditions assume a descent along a flight path with terrain that is 1000 feet below the expected L/O altitude. If the pilot initiates the L/O at the proper altitude, no TAWS alert is expected. However, if the pilot is distracted or otherwise delays the L/O, a TAWS alert is required to permit the pilot to recover to level flight in a safe manner.

**Note:** The L/O initiation height of 20 percent of the vertical speed was chosen (as a minimum standard for nuisance alarm-free operations) because it is similar to typical autopilot or flight director L/O (altitude capture) algorithms. In contrast, the technique of using 10 percent of the existing vertical speed as a L/O initiation point is usually considered a minimum, appropriate only to manual operations of smaller general aviation (GA) airplanes. With high rates of descent, experienced pilots often use a manual technique of reducing the vertical speed by one-half when reaching 1000 feet above/below the L/O altitude. This technique will significantly reduce the likelihood of nuisance alerts. In the event that using 20 percent of the vertical speed as a minimum standard for nuisance-free operations is shown not to be compatible with the installed autopilot or flight director L/O (altitude capture) algorithms, consideration should be given to setting the alert logic closer to the 10 percent vertical speed criteria to minimize nuisance alerts.

**a.** Table A, column A represents the test condition. Columns B, C, and D are for information purposes only. Column E represents the minimum altitude for which TAWS alerts must be posted to perform their intended function. Column F represents the maximum altitude for which TAWS alerts may be provided in order to meet the nuisance alert criteria. See appendix 2, paragraph 4.0.

**b.** For each of the descent rates specified below, recovery to level flight at or above 500 feet terrain clearance is required.

## c. Test conditions for enroute descent requirement:

Assumed pilot response time	3.0 seconds (minimum)
Assumed constant G pull-up	0.25 g's
Minimum allowed terrain clearance	500 feet AGL
Descent rates	1000, 2000, 4000, and 6000 feet per minute (FPM)
Assumed pilot task for column F	L/O at 1000 feet above the terrain per TERPS ROC

**Note 1:** The actual values for the airplane altitude, distance and time from the terrain cell when caution and warning alerts are posted and the minimum terrain clearance altitude must be recorded.

**Note 2:** Enroute operations are considered to exist beyond 15 NM from the departure runway until 15 NM from the destination airport. Use of the nearest runway logic is permissible provided suitable logic is incorporated to ensure that the transitions to the terminal logic will typically occur only when the airplane is in terminal airspace.

**Note 3:** The values shown in column E may be reduced by 100 feet (to permit a L/O to occur at 400 feet above the obstacle) provided that it can be demonstrated that the basic TAWS Mode 1 alert (sink rate) is issued at or above the altitude specified in column E for typical terrain topographies.

**Note 4: Class B Equipment Considerations.** The values shown in Column F are appropriate for autopilot or flight director operations with an altitude capture function typical of many 14 CFR part 25-certified airplanes (Transport Category Aircraft). The values are based upon 20 percent of the airplanes vertical velocity. If TAWS is installed on an airplane without such an autopilot or flight director function, consideration should be given to computing the alerts based upon 10 percent of the vertical velocity, which is more appropriate to manual flight and small, GA airplane operations.

**TABLE A**

ENROUTE DESCENT ALERTING CRITERIA					
A	B	C	D	E	F
VERT SPEED (FPM)	ALT LOST WITH 3 SEC PILOT DELAY	ALT REQ'D TO L/O WITH 0.25G	TOTAL ALT LOST DUE TO RECOVERY MANEUVER	MINIMUM TAWS WARNING ALERT HEIGHT (ABOVE TERRAIN)	MAXIMUM TAWS CAUTION ALERT HEIGHT (ABOVE TERRAIN)
1000	50	17	67	567	1200
2000	100	69	169	669	1400
4000	200	278	478	978	1800

**1.3 Enroute Level Flight Requirement.** During level flight operations (vertical speed is +/- 500 FPM), a terrain alert should be posted when the airplane is within 700 feet of the terrain and is predicted to be equal to or less than 700 feet within the prescribed alerting time or distance. See Table B for test criteria.

**Note 1:** The actual values for the airplane altitude, distance and time from the terrain cell when caution and warning alerts are posted must be recorded.

**TABLE B**

ENROUTE LEVEL FLIGHT ALERTING CRITERIA			
GROUND SPEED (KT)	HEIGHT OF TERRAIN CELL Mean Sea Level (MSL)	TEST RUN ALTITUDE (MSL)	ALERT CRITERIA
200	5000	6000	NO ALERT
250	5000	5800	NO ALERT
300	5000	5800	NO ALERT
200	5000	5700 (+0/-100)	MUST ALERT
250	5000	5700 (+0/-100)	MUST ALERT
300	5000	5700 (+0/-100)	MUST ALERT
400	5000	5700 (+0/-100)	MUST ALERT
500	5000	5700 (+0/-100)	MUST ALERT

**1.4 Terminal Area (Intermediate Segment) Descent Requirement.** A terrain alert must be provided in time to ensure that the airplane can L/O with a minimum of 300 feet altitude clearance over the terrain/obstacle when descending toward the terrain/obstacle at any speed within the operational flight envelope of the airplane. The test conditions assume a descent along a flight path with terrain that is 500 feet below the expected L/O altitude. If the pilot initiates the L/O at the proper altitude, no TAWS alert is expected. However, if the pilot is

distracted or otherwise delays the L/O, a TAWS alert is required to permit the pilot to recover to level flight in a safe manner.

a. Table C, column A represents the test condition. Columns B, C, and D are for information purposes only. Column E represents the minimum altitude for which TAWS alerts must be posted to perform their intended function. Column F represents the maximum altitude for which TAWS alerts may be provided in order to meet the nuisance alert criteria. See appendix 2, paragraph 4.0.

b. For each of the descent rates specified below, recovery to level flight at or above 300 feet terrain clearance is required.

c. Test conditions for terminal area descent requirement:

Assumed pilot response time	1.0 second (minimum)
Assumed constant G pull-up	0.25 g's
Minimum allowed terrain clearance	300 feet AGL
Descent rates	1000, 2000, and 3000 FPM
Assumed pilot task for column F	L/O at 500 feet above the terrain per TERPS ROC

**Note 1:** The actual values for the airplane altitude, distance, and time from the terrain cell when caution and warning alerts are posted and the minimum terrain clearance altitude must be recorded.

**Note 2: For Class B Equipment Considerations.** The values shown in Column F are appropriate for autopilot or flight director operations with an altitude capture function typical of many 14 CFR part 25 certificated airplanes (Transport Category Aircraft). The values are based upon 20 percent of the airplanes vertical velocity. If TAWS is installed on an airplane without such an autopilot or flight director function, consideration should be given to computing the alerts upon 10 percent of the vertical velocity, which is more appropriate to manual flight and small, GA airplane operations.

**Table C**

TERMINAL DESCENT AREA ALERTING CRITERIA					
A	B	C	D	E	F
VERT SPEED (FPM)	ALT LOST WITH 1 SEC PILOT DELAY	ALT REQ'D TO L/O WITH 0.25G	TOTAL ALT LOST DUE TO RECOVERY MANEUVER	MINIMUM TAWS WARNING ALERT HEIGHT (ABOVE TERRAIN)	MAXIMUM TAWS CAUTION ALERT HEIGHT (ABOVE TERRAIN)
1000	17	17	34	334	700
2000	33	69	102	402	900
3000	50	156	206	506	1100

**1.5 Terminal Area (Intermediate Segment) Level Flight Requirement.** During level flight operations (vertical speed less than +/- 500 feet per minute), a terrain alert should be posted when the airplane is less than 350 feet above the terrain and is predicted to be within less than 350 feet within the prescribed alerting time or distance. See Table D for test criteria.

**Note:** The actual values for the airplane altitude, distance, and time from the terrain cell when caution and warning alerts are posted must be recorded.

**Table D**

TERMINAL AREA LEVEL FLIGHT ALERTING CRITERIA			
GROUND SPEED (KT)	HEIGHT OF TERRAIN CELL (MSL)	TEST RUN ALTITUDE (MSL)	ALERT CRITERIA
150	1000	1500	NO ALERT
200	1000	1500	NO ALERT
250	1000	1500	NO ALERT
100	1000	1350	MUST ALERT
150	1000	1350	MUST ALERT
200	1000	1350	MUST ALERT
250	1000	1350	MUST ALERT

**1.6 Final Approach Segment Descent Requirement.** A terrain alert must be provided in time to ensure that the airplane can L/O with a minimum of 100 feet altitude clearance over the terrain/obstacle when descending toward the terrain/obstacle at any speed within the operational flight envelope of the airplane.

a. Table E, column A represents the test condition. Columns B, C, and D are for information purposes only. Column E represents the minimum altitude for which TAWS alerts must be posted to perform their intended function. Column F represents the maximum altitude for which

TAWS alerts may be provided in order to meet the nuisance alert criteria. See appendix 2, paragraph 4.0.

b. For each of the descent rates specified below, recovery to level flight at or above 100 feet terrain clearance is required.

c. Test conditions for final approach segment descent requirement:

Assumed pilot response time	1.0 seconds (minimum)
Assumed constant G pull-up	0.25 g's
Minimum allowed terrain clearance	100 feet AGL
Descent rates	500, 750, 1000, and 1500 FPM
Assumed pilot task for column F	L/O at 250 feet above the terrain per TERPS ROC

**Note 1:** The actual values for the airplane altitude, distance, and time from the terrain cell when caution and warning alerts are posted and the minimum terrain clearance altitude must be recorded.

**Note 2: For Class B Equipment Considerations.** The values shown in column F are appropriate for autopilot or flight director operations with an altitude capture function typical of many 14 CFR part 25 certificated airplanes (Large Airplanes). The values are based upon 20 percent of the airplanes vertical velocity. If TAWS is installed on an airplane without such an autopilot or flight director function, consideration should be given to computing the alerts based upon 10 percent of the vertical velocity, which is more appropriate to manual flight and small, GA airplane operations.

**Table E**

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<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>	<b>F</b>
VERT SPEED (FPM)	ALT LOST WITH 1 SEC PILOT DELAY	ALT REQ'D TO L/O WITH 0.25G	TOTAL ALT LOST DUE TO RECOVERY MANEUVER	MINIMUM TAWS WARNING ALERT HEIGHT (ABOVE TERRAIN)	MAXIMUM TAWS CAUTION ALERT HEIGHT (ABOVE TERRAIN)
500	8	4	12	112	350
750	12	10	22	122	400
1000	17	18	35	135	450
1500	25	39	64	164	550

**1.7 Final Approach Level Flight Requirement.** During level flight operations at the minimum descent altitude (MDA), a terrain alert should be posted when the airplane is within 150 feet of the terrain and is predicted to be within less than 150 feet within the prescribed alerting time or distance. See Table F for test criteria.

**Note:** The actual values for the airplane altitude, distance, and time from the terrain cell when caution and warning alerts are posted must be recorded.

**Table F**

<b>FINAL APPROACH LEVEL FLIGHT ALERT CRITERIA</b>				
<b>GROUND SPEED (KT)</b>	<b>HEIGHT OF TERRAIN CELL (MSL)</b>	<b>DISTANCE TERRAIN FROM RWY (NM)</b>	<b>TEST RUN ALTITUDE (MSL)</b>	<b>ALERT CRITERIA</b>
120	400	2.0	650	NO ALERT
140	400	2.0	650	NO ALERT
160	400	2.0	650	NO ALERT
120	400	2.0	600	MAY ALERT
140	400	2.0	600	MAY ALERT
160	400	2.0	600	MAY ALERT
100	400	2.0	550	MUST ALERT
120	400	2.0	550	MUST ALERT
140	400	2.0	550	MUST ALERT
160	400	2.0	550	MUST ALERT

**2.0 FORWARD LOOKING TERRAIN AVOIDANCE IMMINENT TERRAIN IMPACT TEST CONDITIONS.** The following test conditions must be conducted to evaluate level flight performance during all phases of flight:

**Note 1:** The actual values for the airplane altitude, distance and time from the terrain cell when caution and warning alerts are posted must be recorded.

**Note 2:** Based upon a one-second pilot delay and a 0.25g incremental pull to constant 6.0 degree climb gradient, compute and record the airplane altitude at the terrain cell, the positive (or negative) clearance altitude, and the airplane position and time (after the alert), when the alert envelope is cleared.

**2.1 Test Criteria.** For each of the test cases below, a positive clearance of the terrain cell of interest is required.

**2.2 Additional Test Criteria.** Repeat each of the test cases below with the altitude error of -200 feet). A positive clearance of the terrain cell of interest is required.

**Table G**

<b>IMMINENT TERRAIN IMPACT ALERTING CRITERIA</b>				
<b>GROUND SPEED (KT)</b>	<b>HEIGHT OF TERRAIN CELL (MSL)</b>	<b>DISTANCE TERRAIN FROM RWY (NM)</b>	<b>TEST RUN ALTITUDE (MSL)</b>	<b>ALERT CRITERIA</b>
200	10000	30	9000	MUST ALERT
250	10000	30	9000	MUST ALERT
300	10000	30	9000	MUST ALERT
400	10000	30	8000	MUST ALERT
500	10000	30	8000	MUST ALERT
150	2000	10	1500	MUST ALERT
200	2000	10	1500	MUST ALERT
250	2000	10	1500	MUST ALERT
100	600	5	500	MUST ALERT
120	600	5	500	MUST ALERT
140	600	5	500	MUST ALERT
100	600	4	200	MUST ALERT
120	600	4	200	MUST ALERT
140	600	4	200	MUST ALERT
160	600	4	200	MUST ALERT
160	600	5	500	MUST ALERT

**3.0 PDA TEST CONDITIONS.** The purpose of this test is to verify that the pilot will be alerted to a “low altitude condition” at an altitude defined by the specific design PDA alert surface. This TSO does not define specific pass/fail criteria since, as stated in paragraph 3.2 of appendix 1, it does not define the surface for which alerting is required. The applicant must

provide the proposed pass/fail criteria along with the proposed recovery procedures for the specific alerting criteria proposed by the applicant. In developing the test plan, the applicant should refer to paragraph 3.2 of appendix 1 for general requirements for alerting (if alerting is applicable). The applicant may also want to consider the recovery procedures specified in paragraphs 1.2, 1.4, and 1.6 of paragraph 1 of appendix 2. The following test conditions must be conducted to evaluate PDA performance:

Descent rates (FPM)	750, 1500, and 2000, 3000
Assumed runway elevation	Sea level, Level terrain

**Note:** For each test condition listed in table H, compute and record the PDA alert altitude and the recovery altitude to level flight.

**Table H**

PREMATURE DESCENT ALERTING CRITERIA				
GROUND SPEED (KT)	VERT. SPEED (FPM)	DISTANCE FROM RWY THRESHOLD (Touchdown) (NM)	PDA ALERT HEIGHT (MSL)	RECOVERY ALTITUDE (MSL)
80	750	15		
100	1500	15		
120	750	15		
140	1500	15		
160	750	15		
200	1500	15		
250	2000	15		
80	750	12		
100	1500	12		
120	750	12		
140	1500	12		
160	750	12		
80	750	4		
100	1500	4		
120	750	4		
140	1500	4		
80	750	2		
100	1500	2		
120	750	2		
140	1500	2		

**4.0 NUISANCE ALERT TEST CONDITIONS—GENERAL.** The following test conditions must be conducted to evaluate TAWS performance during all phases of flight. The following general criteria apply:

**4.1 4000 FPM.** Descent must be possible at 4000 FPM in the enroute airspace and pilots must be able to L/O 1000 feet above the terrain using a normal L/O procedure (leading by 20 percent of the vertical speed) without a caution or warning alert. See Table A.

**4.2 2000 FPM.** Descent must be possible at 2000 FPM in the terminal area and pilots must be able to L/O 500 feet above the terrain using the normal L/O procedure described in paragraph 4.1 above, without a caution or warning alert. See Table C.

**4.3 1000 FPM.** Descent must be possible at 1000 FPM in the final approach segment and pilots must be able to L/O at the MDA using the normal L/O procedure described in paragraph 4.1 above, without a caution or warning alert. See Table E.

**5.0 NUISANCE TEST CONDITIONS FOR HORIZONTAL AND VERTICAL FLIGHT TECHNICAL ERRORS.** It must be shown by analysis, simulation, or flight testing, that the system will not produce nuisance alerts when the airplane is conducting normal flight operations in accordance with published instrument approach procedures. This assumes the normal range in variation of input parameters.

**5.1 Test Cases.** At a minimum, the following cases listed in table I must be tested twice: one set of runs conducted with no lateral or vertical errors while another set is conducted with both lateral and vertical flight technical errors (FTE). Certain conditions must be simulated, such as: a lateral FTE of 0.3 NM and a vertical FTE of –100 feet (such as when the aircraft is closer to terrain) up to the final approach fix (FAF), as well as a lateral FTE of 0.3 NM and a vertical FTE of –50 feet from the FAF to the missed approach point (MAP). For all listed VHF omnidirectional range navigation system (VOR), VOR/distance measuring equipment (DME) and localizer-based approaches, from the FAF to the MAP, the airplane descends at 1000 FPM until reaching either MDA (run #1) or MDA-50 feet (run #2). The airplane then levels off and flies level until reaching the MAP. Localizer updating of lateral position errors (if provided) may be simulated.

**Table I**

<b>NUISANCE ALERT TEST CONDITIONS FOR HORIZONTAL AND VERTICAL FLIGHT TECHNICAL ERRORS</b>		
<b>Case</b>	<b>Location</b>	<b>Operation</b>
1	Quito, Ecuador	VOR 'QIT'-ILS Rwy 35
2	Katmandu, Nepal	VOR-DME Rwy 2
3	Windsor Locks, CT	VOR Rwy 15
4	Calvi, France	LOC DME Rwy 18/Circle

5	Tegucigalpa, Honduras	VOR DME Rwy 1/Circle
6	Eagle, CO	LOC DME-C
7	Monterey, CA	LOC DME Rwy 28L
8	Juneau, AK	LDA-1 Rwy 8
9	Chambery, France	ILS Rwy 18

**6.0 TEST CONDITIONS USING KNOWN ACCIDENT CASES.** The aircraft configuration and flight trajectory for each case may be obtained from the FAA Regulatory and Guidance Library site. Click “Technical Standards and Orders and Index,” click “Current,” and then click “TSO-C151c.”

**6.1 Test Report.** The test report should include as many of the following parameters as possible used to recreate the events: (1) latitude; (2) longitude; (3) altitude; (4) time from terrain at caution and warning alerts; (5) distance from terrain at caution and warning alerts; (6) ground speed; (7) true track; (8) true heading; (9) radio altitude (height above terrain); (10) gear position; and (11) flap position.

**6.2 Computation and Recording.** In addition to the parameters above, when the warning is posted for each test case, based upon a one second pilot delay and a 0.25 g incremental pull to a constant 6.0 degree climb gradient, do the following: compute and record the airplane altitude at the terrain cell, the positive (or negative) clearance altitude, and the airplane position and time (after the alert) when the alert envelope is cleared.

**Note:** The terrain cell of interest is the one associated with the accident and not necessarily the terrain cell that caused the warning.

**6.3 Test Criteria.** For each of the test cases below in table J, demonstrate that the airplane profile clears the terrain of interest.

**Table J**

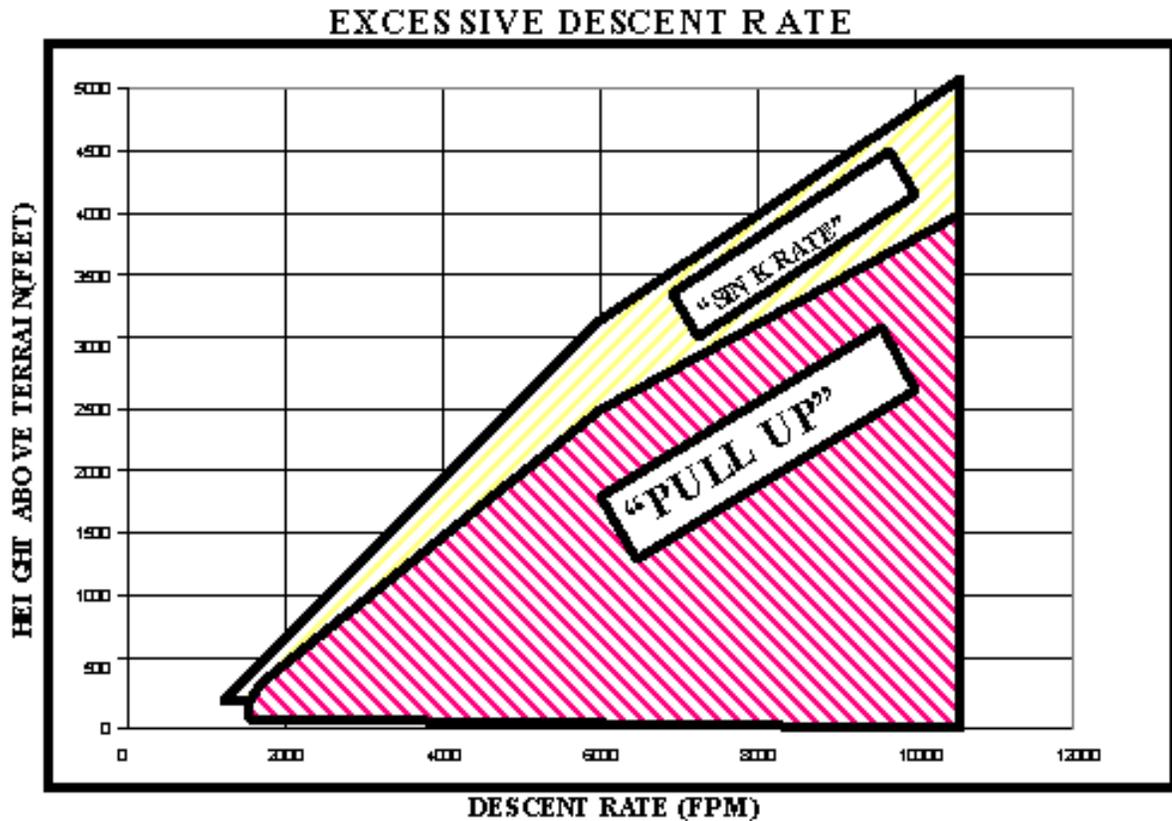
LOCATION	DATE	AIRCRAFT REGISTRATION NUMBER
La Paz, Bolivia	1/1/1985	N819EA
Flat Rock, NC	8/23/1985	N600CM
Windsor, MA	12/10/1986	N65TD
Eagle, CO	3/27/1987	N31SK

Tegucigalpa, Honduras	10/21/1989	N88705
Halawa Point, HI	10/28/1989	N707PV
San Diego, CA	3/16/1991	N831LC
Rome, GA	12/11/1991	N25BR
Gabriels, NY	1/3/1992	N55000
Alamogordo, NM	6/24/1992	N108SC
E. Granby, CT	11/12/1995	N566AA
Buga, Columbia	12/20/1995	N651AA
Nimitz Hill, Guam	8/6/1997	H7468

**7.0 CLASS B EQUIPMENT TEST REQUIREMENTS FOR EXCESSIVE DESCENT RATE.** Use the following performance envelopes down to a “height above terrain” value of 100 feet. If a radar altimeter input is unavailable, determine the height of terrain by subtracting the terrain elevation (as obtained from the terrain database) from the current QNH (corrected) barometric altitude, the GNSS altitude, or an equivalent source. GNSS vertical accuracy must meet RTCA/DO-229D section 2.2.3.3.4. The curve in figure 1 represents the minimum heights at which alerting must occur.

**Note:** Class B equipment may be designed to meet the requirements of RTCA/DO-161A Mode 1 for excessive descent rate in lieu of the requirements of paragraph **7.0**.

**Figure 1**



**8.0 CLASS B EQUIPMENT TEST REQUIREMENTS FOR NEGATIVE CLIMB RATE OR ALTITUDE LOSS AFTER TAKEOFF.** Use the existing performance envelopes specified in RTCA/DO-161A based upon a “height above runway” using barometric altitude, GNSS altitude, or equivalent, and runway elevation in lieu of radio altimeter inputs, if radio altimeter inputs are unavailable.

### **9.0 ALTITUDE CALLOUT TEST REQUIREMENTS**

**9.1 CLASS A EQUIPMENT ALTITUDE CALLOUT TEST REQUIREMENTS.** With the landing gear in landing configuration test for approach to an airport with a 1500 FPM descent rate. Ensure the TAWS provides a single aural callout of “Five Hundred” or equivalent within one second of the aircraft descending through 500 feet above terrain or the runway threshold elevation (when comparing the aircraft’s barometric or geometric altitude against the database runway elevation).

**9.2 CLASS B EQUIPMENT ALTITUDE CALLOUT TEST REQUIREMENTS.** Instead of using height of terrain as determined by a radio altimeter, determine height above runway by subtracting the runway elevation (from the airport database) from the current barometric altitude,

GNSS altitude, or equivalent, if a radio altimeter input is unavailable. When the height above the runway value first reaches 500 feet, a single voice callout (“Five Hundred”) or equivalent must be provided.

**APPENDIX 3. FEDERAL AVIATION ADMINISTRATION MINIMUM  
PERFORMANCE STANDARD (MPS) FOR A TERRAIN AWARENESS AND  
WARNING SYSTEM FOR CLASS C**

**1.0 INTRODUCTION.**

**1.1** This appendix describes modifications to this TSO for the GA category of aircraft that is not required to have TAWS equipment installed. Class C equipment is intended for small GA airplanes that are not required to install Class B equipment.

**1.2** This appendix contains only modifications to existing requirements in this TSO. It is intended that Class C meet all Class B requirements that are not modified or addressed here. The paragraph numbers below relate directly to the paragraphs in appendices **1** and **2**.

**2.0** Class C TAWS equipment must meet all of the requirements of a Class B TAWS with the modifications described herein. If the equipment is designed only to function as Class C, per these modifications, it should be appropriately marked as Class C so that it can be uniquely distinguished from the Class A and Class B TAWS required by 14 CFR parts 91, 135, and 121.

**MODIFICATIONS TO APPENDIX 1 FOR CLASS C TAWS.**

**Minimum Performance Standards, MPS**

**1.1 Phase of Flight Definitions.** For appendix **3**, the terms “takeoff,” “cruise,” and “landing” are used instead of “departure,” “enroute,” and “approach” because they are more suitable to the GA environment.

- *Takeoff*—positive ROC, inside traffic area, distance to nearest runway threshold is increasing, and airplane is below 1,000 feet.
- *Cruise*—anytime the airplane is outside the airport traffic control area.
- *Landing*—inside traffic area and distance to nearest runway threshold is decreasing, and airplane is below 1,000 feet.

**1.2 Altitude Accuracy and Display.** A means must be provided to compute an actual MSL aircraft altitude value that is immune to temperature errors and manual correction mis-sets that would otherwise prevent the TAWS from performing its intended function. This type of altitude is derived primarily from geometric sources such as GPS, and referenced to MSL typically via a database correction. If the TAWS includes a terrain display, this reference altitude value used for the TAWS alerts should also be indicated to the pilot on the display. The altitude value should be labeled according to AC 20-163, *Displaying Geometric Altitude Relative to Mean Sea Level*, which recommends "GSL."

**1.3 (f)(3) System Function and Overview.** This data is pilot selectable for both “altitude” and “inhibit.”

**3.1.1 Reduced Required Terrain Clearance (RTC).** The required terrain clearance in the alternate table 3.1.1 applies to small aircraft flying visually, and the TERPS criteria need not apply to TAWS. Thus, ROC numbers that are more appropriate to low level flight have been chosen.

**Alternate Table 3.1.1**

<b>TAWS REQUIRED TERRAIN CLEARANCE (RTC) BY PHASE OF FLIGHT</b>			
<b>Phase of Flight</b>	<b>Small Aircraft ROC</b>	<b>TAWS (RTC) Level Flight</b>	<b>TAWS (RTC) Descending</b>
Cruise	500 Feet	250 Feet	200 Feet
Takeoff	48 Feet/NM	100 Feet	100 Feet
Landing (See Note 1)	250 Feet	150 Feet	100 Feet

**Note 1:** During the takeoff phase of flight, the FLTA function must alert if the aircraft is projected to be within 100 feet vertically of terrain. However, the equipment should not alert if the aircraft is projected to be more than 250 feet above the terrain.

**3.3.c Voice Callouts.** This data is pilot selectable for both “altitude” and “inhibit.”

**4.0 Aural and Visual Alerts**

**Table 4-1**

<b>STANDARD SET OF VISUAL AND AURAL ALERTS</b>		
<b>Alert Condition</b>	<b>Caution</b>	<b>Warning</b>
<b>FLTA Functions</b>  Terrain Awareness Reduced Required Terrain Clearance and Terrain Awareness Imminent Impact with Terrain	<u><b>Visual Alert</b></u> Amber text message that is obvious, concise, and consistent with the aural message.  <u><b>Aural Alert</b></u> Minimum selectable voice alert: “Caution, Terrain; Caution, Terrain”	<u><b>Visual Alert</b></u> Red text message that is obvious, concise, and consistent with the aural message.  <u><b>Aural Alert</b></u> Minimum selectable voice alert: “Terrain; Terrain”
Terrain Awareness Premature Descent Alert (PDA)	<u><b>Visual Alert</b></u> Amber text message that is obvious, concise, and must be consistent with the aural message.  <u><b>Aural Alert</b></u> “Too Low; Too Low”	<u><b>Visual Alert</b></u> None Required  <u><b>Aural Alert</b></u> None Required
Ground Proximity Excessive Descent Rate	<u><b>Visual Alert</b></u> Amber text message that is obvious, concise, and must be consistent with	<u><b>Visual Alert</b></u> Red text message that is obvious, concise, and must be consistent with

<b>STANDARD SET OF VISUAL AND AURAL ALERTS</b>		
<b>Alert Condition</b>	<b>Caution</b>	<b>Warning</b>
	the aural message.  <b><u>Aural Alert</u></b> “Sink Rate”	the aural message.  <b><u>Aural Alert</u></b> “Pull-Up”
Ground Proximity Altitude Loss after Takeoff	<b><u>Visual Alert</u></b> Amber text message that is obvious, concise, and must be consistent with the aural message.  <b><u>Aural Alert</u></b> “Don’t Sink”	<b><u>Visual Alert</u></b> None Required  <b><u>Aural Alert</u></b> None Required
Ground Proximity Voice Callout (See Note 1)	<b><u>Visual Alert</u></b> None Required  <b><u>Aural Alert</u></b> “Five Hundred” or selected altitude	<b><u>Visual Alert</u></b> None Required  <b><u>Aural Alert</u></b> None Required

**Note 1:** The aural alert for ground proximity voice callout is considered advisory.

**Note 2:** Visual alerts may be put on the terrain situational awareness display, if this fits with the overall human factors alerting scheme for the flight deck. This does not eliminate the visual alert color requirements, even in the case of a monochromatic display. Typically in such a scenario, adjacent colored enunciator lamps meet the alerting color requirements. Audio alerts are still required regardless of terrain display visual alerts.

### **MODIFICATIONS TO APPENDIX 2, TEST CONDITIONS.**

**Note 1:** Paragraph 1.1 of this TSO is not applicable; for small aircraft, only the “takeoff,” “cruise,” and “final approach to landing” phases of flight are considered.

**Note 2:** Paragraph 1.2 of this TSO is changed to specify altitude levels, test speeds, and pull-ups more appropriate for small aircraft.

**1.2 Cruise Descent Requirements.** A terrain alert must be provided in time to ensure that the airplane can L/O with a minimum of 200 feet altitude clearance over the terrain/obstacle when descending toward the terrain/obstacle at any speed within the operational flight envelope of the airplane. The test conditions assume a descent along a flight path with terrain that is 500 feet below the expected L/O altitude. If the pilot initiates the L/O at the proper altitude, no TAWS

alert is expected. However, if the pilot is distracted or otherwise delays the L/O, a TAWS alert is required to permit the pilot to recover to level flight in a safe manner.

**a.** Table A, column A, represents the test condition. Columns B, C, and D are for information purposes only. Column E represents the minimum altitude for which TAWS alerts must be posted in order to perform their intended function. Column F represents the maximum altitude for which TAWS alerts may be provided in order to meet the nuisance alert criteria. See appendix 2, paragraph 4.0.

**b.** For each of the descent rates specified below, recovery to level flight at or above 200 feet terrain clearance is required.

**c.** Test Conditions for cruise descent requirements:

Assumed pilot response time	3.0 seconds (minimum)
Assumed constant G pull-up	1.0 g
Minimum allowed terrain clearance	200 feet AGL
Descent rates	500, 1000, and 2000 FPM
Assumed pilot task for column F	L/O at 500 feet above the terrain per appendix 3, table 3.1.1 (ROC Column)

**Note 1:** The actual values for the airplane altitude, distance and time from the terrain cell when caution and warning alerts are posted, and the minimum terrain clearance altitude must be recorded.

**Note 2:** Cruise operations are considered to exist beyond the airport control area until inside the destination airport control area for VFR operations. Distances may extend to 10 NM from the airport (takeoff and landing) for IFR operations. Use of the nearest runway logic is permissible provided suitable logic is incorporated to ensure that the transitions to the terminal logic will typically occur only when the airplane is in terminal airspace.

**Note 3:** The values shown in column E may be reduced by 50 feet (to permit a L/O at 150 feet above the obstacle) provided that it demonstrates that the basic TAWS Mode 1 alert (sink rate) is issued at or above the altitude specified in column E for typical terrain topographies.

**Note 4:** The values shown in column F are appropriate for an airplane without an autopilot or flight director function, and are based upon 10-15 percent of the vertical velocity, which is appropriate to manual flight and small, GA airplane operations.

**Table A**

### ENROUTE DESCENT ALERTING CRITERIA

Alerting for Premature Descent during Cruise					
A	B	C	D	E	F
VERT SPEED (FPM)	ALT LOST WITH 3 SEC PILOT DELAY	ALT REQ'D TO L/O WITH 1 G PULLUP	TOTAL ALT LOST DUE TO RECOVERY MANEUVER	MINIMUM TAWS WARNING ALERT HEIGHT (ABOVE TERRAIN)	MAXIMUM CAUTION ALERT HEIGHT (ABOVE TERRAIN)
500	25	1	26	226	550
1000	50	4	54	254	600
2000	100	17	117	317	800

**Note:** Paragraph 1.3 in this TSO is changed to specify altitude levels, test speeds, and pull-ups more appropriate to small aircraft.

**1.3 Cruise Level Flight Requirement.** During level flight operations (vertical speed is  $\pm 200$  feet per minute), a terrain alert should be posted when the airplane is within 250 feet of the terrain and is predicted to be equal to or less than 200 feet within the prescribed test criteria. See Table B for test criteria.

**Note:** The actual values for the airplane altitude, distance and time from the terrain cell when caution and warning alerts are posted must be recorded.

**Table B**

LEVEL CRUISE FLIGHT ALERTING CRITERIA			
GROUND SPEED (KT)	HEIGHT OF TERRAIN CELL (MSL)	TEST RUN ALTITUDE (MSL)	ALERT CRITERIA
100	5000	5340 (+0/-50)	NO ALERT
150	5000	5340 (+0/-50)	NO ALERT
200	5000	5340 (+0/-50)	NO ALERT
100	5000	5240 (+0/-50)	MUST ALERT
150	5000	5240 (+0/-50)	MUST ALERT
200	5000	5240 (+0/-50)	MUST ALERT

**1.4 Terminal Area (Intermediate Segment) Descent Requirement.** Not applicable.

**1.5 Terminal Area (Intermediate Segment) Level Flight Requirement.** Not applicable.

**1.6 Final Approach Descent Requirements.** Revised to specify altitude levels, test speeds, and pull-ups more appropriate to small aircraft:

a. Table E, column A, represents the test conditions. Columns B, C, and D are for information purposes only. Column E represents the minimum altitude for which TAWS alerts must be posted in order to perform their intended function. Column F represents the maximum altitude for which TAWS alerts may be provided in order to meet the nuisance alert criteria. See appendix 2, paragraph 4.0.

b. For each of the descent rates specified below, recovery to level flight at or above 100 feet terrain clearance is required.

c. Test conditions for 1.6:

Assumed pilot response time	1.0 seconds (minimum)
Assumed constant G pull-up	1.0 g
Minimum allowed terrain clearance	100 feet AGL
Descent rates	500, 750, and 1000 FPM
Assumed pilot task for column F	L/O at 250 feet above the terrain per appendix 3, table 3.1.1 (ROC Column)

**Note 1:** The actual values for the airplane altitude, distance and time from the terrain cell when caution and warning alerts are posted, and the minimum terrain clearance altitude must be recorded.

**Note 2:** The values shown in column F are appropriate for an airplane without an autopilot or flight director function, and are based upon 10 percent of the vertical velocity that is appropriate for manual flight and small, GA airplane operations.

**Table E**

APPROACH DESCENT ALERTING CRITERIA					
A	B	C	D	E	F

VERT SPEED (FPM)	ALT LOST WITH 1 SEC PILOT DELAY	ALT REQ'D TO L/O WITH 1 G PULLUP	TOTAL ALT LOST DUE TO RECOVERY MANEUVER	MINIMUM TAWS WARNING ALERT HEIGHT (ABOVE TERRAIN)	MAXIMUM TAWS CAUTION ALERT HEIGHT (ABOVE TERRAIN)
500	8	1	9	109	300
750	12	2	14	114	325
1000	17	4	21	121	350

**1.7 Landing Flight Requirements.** Applies as written.

**2.0 through 2.2 FORWARD LOOKING TERRAIN AVOIDANCE IMMINENT IMPACT TEST CONDITIONS.** Apply using Table G for speed cases of 100 through 250 knots; however, change the incremental pull from 0.25g to 1.0g as described in note 2.

**3.0 through 3.1 PREMATURE DESCENT ALERT TEST CONDITIONS.** Apply as written.

**4.0 NUISANCE ALERT TEST CONDITIONS—GENERAL.** Apply as written.

**4.1 4000 FPM.** Not applicable.

**4.2 2000 FPM.** Descent must be possible at 2000 FPM and pilots must be able to L/O at 500 feet above the terrain using a normal L/O procedure (leading by 10 percent of the vertical speed), without a caution or warning alert.

**4.3 1000 FPM.** Descent must be possible at 1000 FPM in a final approach segment and pilots must be able to L/O at 250 feet using the normal L/O procedure described in 4.2 above, without a caution or warning alert.

**5.0 NUISANCE TEST CONDITIONS FOR HORIZONTAL AND VERTICAL FLIGHT TECHNICAL ERRORS.** Applicable as written.

**5.1 Test Cases.** Is applicable as written; however, test cases are limited to locations 3, 6, 7, and 8 in table I.

**6.0 TEST CONDITIONS USING KNOWN ACCIDENT CASES.** Paragraphs 6.0 through 6.3 of Appendix 2 are to be determined by the applicant using actual National Transportation Safety Board (NTSB) GA accidents. Since detailed data is usually not available, reasonable constructed scenarios matching the actual known accident data may be demonstrated. Pulls of up to 1.0g may be used instead of the 0.25g as specified in paragraph 6.2, computation and recording.

**7.0 CLASS C EQUIPMENT TEST REQUIREMENTS FOR EXCESSIVE DESCENT RATE.** Apply Class B as written.

**8.0 CLASS C EQUIPMENT TEST REQUIREMENTS FOR NEGATIVE CLIMB RATE OR ALTITUDE LOSS AFTER TAKEOFF.** Apply Class B as written.

**9.0 CLASS C EQUIPMENT TEST REQUIREMENTS FOR THE ALTITUDE CALLOUTS.** Apply Class B as written.