CHAPTER 3
AIRWORTHINESS STANDARDS
TRANSPORT CATEGORY ROTORCRAFT

MISCELLANEOUS GUIDANCE (MG)

AC 29 MG 18 HELICOPTER TERRAIN AWARENESS AND WARNING SYSTEM (HTAWS)

a. Background

(1) General. Approximately 60% of helicopter accidents in recent years have been attributed to Helicopter Controlled Flight Into Terrain (CFIT) incidents, resulting in hull loss and fatalities. The original Ground Proximity Warning System (GPWS) was first introduced on helicopters in 1997. The GPWS is a computer-based system that provides the flight crew with warning (both aural and visual) of pending collision of the aircraft with the terrain, considering such items as crew recognition and reaction times.

(2) The helicopter GPWS has since been upgraded to "HTAWS" that incorporates a terrain and obstacle database with GPS vertical and horizontal position to provide enhanced terrain and obstacle awareness. This is achieved by employing a look-ahead function that provides cautions, warnings, and optional terrain/obstacle display(s).

(3) TSO-C151b**.** Technical Standard Order (TSO)-C151b, Terrain Awareness and Warning System, prescribes the minimum design standards that a Terrain Awareness and Warning System (TAWS) must meet to be identified with the TSO-C151b marking. The requirements contained in TSO-151b were developed for airplanes and many of the operational modes are not appropriate for helicopter installation. The recommended changes to the TSO requirements for a system to be installed in a helicopter are presented in paragraph **s** of this guidance. These additional performance considerations should be complied with for helicopter installations. *Note: The issuance of a Technical Standard Order Authorization (TSOA) against TSO/JTSO C-151b (or further amendments) does not constitute an installation approval*.

b. Purpose. This guidance material describes an acceptable means for obtaining FAA/AUTHORITY airworthiness approval for the installation of a Helicopter Terrain Awareness and Warning System (HTAWS). This information provides guidance for the design and installation for an HTAWS for helicopters. The guidance provided is specific to installations of these systems on helicopters certificated under FAR/JAR 29. It describes the airworthiness considerations for such installations as they apply to the unique features of the HTAWS and the interface of the HTAWS with other systems on the helicopter. The HTAWS certification should address the complete process, form source and integrity of the database to the required sensors and their effect on operational credit for the installation. There are five basic aspects for certification for HTAWS that are discussed throughout this document: equipment qualification,

installation, credit validation, testing considerations, and Instructions for Continued Airworthiness (ICA).

c. Related Regulations and Documents

(1) Regulations. FAR/JAR:

§ 29.1301 Function and installation
§ 29.1303 Flight and navigation instruments
§ 29.1309 Equipment, systems, and installations
§ 29.1321 Arrangement and visibility
§ 29.1322 Warning, caution, and advisory lights
§ 29.1351 Electrical systems and equipment—General
§ 29.1357 Circuit protective devices
§ 29.1381 Instrument lights
§ 29.1459 Flight recorders
§ 29.1529 Instructions for Continued Airworthiness
§ 29.1541 Markings and placards—General
§ 29.1581 Flight manual—General
§ 29.1585 Operating procedures

(2) Advisory Circulars (AC), Orders, and Technical Standard Orders TSO/JTSO

TSO-C92c, Ground Proximity Warning/Glide slope Deviation Alerting Equipment:
Technical Standards Authorization, Part 37.201
TSO C-151b, Terrain Awareness and Warning System

(3) Industry documents. The Radio Technical Commission for Aeronautics (RTCA) documents listed below are available from RTCA, Inc., 1140 Connecticut Avenue N.W., Suite 1020, Washington, D.C. 20036-4001; DO-160D, Environmental Conditions and Test Procedures for Airborne Equipment.

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

DO-200A, Standards for Processing Aeronautical Data.

Society of Automotive Engineers (SAE) Aerospace Recommended Practice (ARP) 4754, Certification Considerations for Highly Integrated or Complex Aircraft Systems.

d. Definitions

(1) Alerts: A visual, aural, or tactile stimulus presented either to attract attention or to convey information regarding system status or condition, or both.

HTAWS Alerts:

Aural Alert: A discrete sound, tone, or verbal statement used to enunciate a condition, situation, or event.

Caution Alert: An alert requiring flight crew awareness. Subsequent corrective action will normally be necessary.

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

Warning Alert: An alert for a detected terrain or obstacle threat that requires immediate flight crew attention and decision.

(2) Class (A) HTAWS Equipment: This class of equipment provides Ground Proximity Warning System (GPWS), Forward Looking Terrain Avoidance (FLTA), and an optional display capability, as defined in paragraphs **e** and **j**.

(3) Class (B) HTAWS Equipment: This class of equipment provides FLTA, as defined in paragraph **e** and **j**.

(4) Controlled Flight Into Terrain (CFIT): An accident or incident in which the aircraft, under the flight crew's control, is inadvertently flown into terrain, obstacles, or water.

(5) Failure: The inability of the equipment or any subpart of that equipment to perform its intended function within previously specified limits.

(6) False Alert: A warning or caution that occurs when the design terrain or obstacle warning or caution threshold of the system is not exceeded.

(7) Forward-Looking Terrain Avoidance (FLTA): An HTAWS functional requirement to provide look-ahead terrain and obstacle protection along and below the aircraft’s lateral and vertical flight path.

(8) Hazard: A state or set of conditions that, together with other conditions in the environment, could result in a safety impact.

(9) Hazardously Misleading Information (HMI): An incorrect depiction of the terrain or obstacle threat relative to the aircraft during an alert condition (excluding source data).

(10) Integrity: Attribute of a system or a component that can be relied upon to function as required by the criticality determined by the Functional Hazard Assessment (FHA).

(11) Low Altitude Mode: A reduced warning algorithm state that allows operation at less than en route altitudes with minimal alerts.

(12) Maneuver: An appropriate change in the flight path of the aircraft initiated by the flight crew in response to an HTAWS alert to include climbs, descents (inappropriate for most situations), and turning procedures.

(13) Nuisance Alert: An alert that occurs when there is no threat or is unnecessary for the intended operation.

(14) Obstacle: A human-made structure that is in the flight path of the aircraft.

(15) Operational Credit: To give approval for an HTAWS installation that adds to, replaces, or intervenes in the aircraft's operating requirements or operational procedures based on the installation and operation of the HTAWS system.

(16) QFE**:** Corrected Barometric Altitude relative to field elevation.

(17) QNH: Corrected Barometric Altitude relative to sea level.

(18) Required Terrain Clearance (RTC): The minimum requirements for obstacle or terrain clearance as defined by United States Standard for Terminal Instrument Procedures (TERPS) FAA Order 8260.3B and the Aeronautical Information Manual (AIM).

(19) Helicopter Terrain Awareness and Warning System (HTAWS): A generic term used to describe an alerting system that provides the flight crew with sufficient information and time to detect potentially hazardous terrain or obstacle.

(20) Terrain Awareness Display (TAD): A display of the surrounding terrain and obstacle(s) relative to the aircraft.

(21) Terrain Database: Terrain and obstacle information stored within an HTAWS.

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

e. SYSTEM DESCRIPTION

HTAWS is intended to provide flight crews with aural and visual alert aids aimed at preventing a CFIT accident by providing increased terrain and obstacle awareness. Like airplane TAWS, as described in TSO-151b, HTAWS equipment may be divided into two classes of complexity which, in general, may relate to aircraft size or complexity.

(1) Class (A) HTAWS equipment as defined here.

(i) Class (A) HTAWS equipment provides two principal alerting functions. These are:

(A) Forward-Looking Terrain-Avoidance (FLTA) function, which includes:

- Reduced required terrain clearance.
- Imminent terrain or obstacle impact.

(B) Basic Ground Proximity Warning System (GPWS) functions, which includes:

- Excessive rates of descent. (Optional)
- Excessive closure rate to terrain.
- Excessive altitude loss after takeoff.
- Flight into terrain when not in landing configuration.
- Excessive downward deviation from and ILS glide slope.

(ii) The Class (A) HTAWS system does not require a display, unless the installation is required by an operating rule. If a display is installed, it should meet the requirements of paragraph j. The terrain and obstacle display and threat alerting are made possible by the HTAWS' acceptance of a variety of input parameters. These parameters are used in conjunction with a terrain, obstacle and airport database(s) that reside within the HTAWS computer. The Class (A) HTAWS places an aircraft position symbol on a terrain and obstacle map and applies terrain display algorithms. Terrain and obstacle mapping information may be provided on either a weather radar (WX) display, Electronic Flight Instrument System (EFIS) display, or other compatible display screens.

(iii) Aircraft position information should be provided by a Global Positioning System (GPS or GPS-based equivalent) that meets the provisions specified in paragraph **h** (Position Source).

(iv) Class (A) HTAWS equipment may provide automatic autorotation detection when Excessive Descent Rate warning functions are included. A detected autorotation state should inhibit Excessive Rate Warnings and other warnings that may distract a flight crew during an emergency procedure. Altitude advisories and gear (not extended) warning may be added during this autorotation state if desired. The altitude

for the optional gear warning should be based on the specific helicopter autorotation rate of descent and gear extension time to insure gear down prior to the landing.

(v) Class (A) HTAWS equipment should provide a Low Altitude Mode to allow VFR operations at less than en route altitudes with minimal nuisance alerts.

(2) Class (B) HTAWS equipment, as defined here.

(i) Class (B) HTAWS equipment provides two principal alerting functions. These are:

- Imminent terrain or obstacle impact
- Excessive altitude loss after takeoff

(ii) Class (B) HTAWS does not require a display. If a display is installed with a Class (B) HTAWS, it should meet the provisions of paragraph **j** (Display Presentation).

(iii) Class (B) HTAWS equipment is required to interface with an approved GPS (or GPS-based equivalent) for horizontal position information that meets the provisions specified in paragraph **h** (Position Source).

(iv) Class (B) HTAWS does not require an interface to a radio altimeter.

(v) Class (B) HTAWS equipment should provide a Low Altitude Mode to allow VFR operations at less than en route altitudes with minimal alerts.

f. Airworthiness Considerations

(1) The scope of the applicant's program should be directed toward airworthiness approval through the Type Certification (TC), Amended Type Certification (ATC), or Supplemental Type Certification (STC) processes. The significant differences between the airplane (TAWS) and helicopter (HTAWS) systems and the lack of specific TSO requirements for the helicopter system necessitate greater engineering and flight test involvement than normally provided during the field approval process. The applicant must identify if the changes made to the helicopter during installation of the HTAWS constitute a significant (engineering) change. However, the installation of the HTAWS alone should not require application of the Changed Product Rule, § 21.101.

(2) The remainder of this document describes in detail specific airworthiness considerations that applicants should consider as part of the certification process.

g. Certification Requirements:

(1) General. For first time approvals, the manufacturer/applicant should provide detailed systems description and design features that can be verified by certification engineers and project pilots. Flight-testing should concentrate on the adequacy of the interface, basic functionality of the system, location and visibility of the display, adequacy of the visual and aural alerts, day and night lighting, ease of use, understanding of the terrain and obstacle display, and potential interference with other installed equipment. In general, each mode of operation of the system should be evaluated in flight.

(2) System Safety Assessment. The applicant should perform a Functional Hazard Assessment (FHA) and System Safety Assessment (SSA) to establish the HTAWS criticality and hazards associated with the proposed installation. The integrity level of the system must be commensurate with the assessed criticality, and compliance with this criticality level must be demonstrated during certification. These assessments should consider the probability of such failures as: unannunciated failures, false caution or warning alerts due to undetected (or latent) failures, failure of the system to provide the required alerting functions due to undetected (or latent) failures, effects of HTAWS failures on other aircraft systems, nuisance alerts, etc.

(3) Software Qualification. The software for the enhanced features should be developed in accordance with RTCA DO-178B, Software Considerations in Airborne Systems and Equipment Certification, or an FAA/AUTHORITY-accepted equivalent. The most significant aspects of the enhanced features are the terrain and obstacle database stored in the HTAWS computer and the algorithms used by the EPGWS computer. Coupled with this are the evasive maneuvers that will be employed to avoid terrain and obstacle. Software for the enhanced features should be developed as a minimum to DO-178B level C. Failure rates for the system will be commensurate with the failure condition category determined during the safety assessment process. This analysis should include unannunciated failure or malfunction (false warning) of the HTAWS aural or visual warnings.

(4) Environmental Qualification. The HTAWS with its installation should be shown to be suitable to its airborne environment. A desirable way to qualify the system component is to obtain approval to the appropriate TSO. If the equipment is not TSO-approved, it should be shown through testing that it complies with the requirements of SAE Document AS-8034, latest revision of RTCA Document DO-160, and other appropriate standards at the time of qualification. This will include testing in accordance with the appropriate categories of the latest revision of RTCA Document DO-160, JEDEC Publication No. 64D (Protection from Ionizing Radiation).

(5) System Performance Validation. The applicant should demonstrate that the performance of the HTAWS, with regards to the position of the aircraft relative to the terrain or obstacle, is sufficiently adequate to preclude creation of a hazardously misleading situation. The integrity of the navigation source has a significant effect on acceptable performance of the system. The applicant should demonstrate that the performance of the HTAWS navigation source is suitable for each phase of flight

(en route, terminal, approach, and low altitude mode) for which approval is sought. The HTAWS navigation source may be the same as the primary navigation system for the aircraft.

(6) Database Considerations. Since 6 arc-second terrain data currently are not available for all regions of the world, it may be years before a complete database is developed. It may be impossible to perform 100 percent verification of the accuracy of the terrain database. There currently are no specific FAA/AUTHORITY certification standards for airborne terrain and obstacle databases; therefore, the completeness and integrity of those databases available may vary significantly. To ensure no erroneous data that could result in misleading information, the HTAWS system operating software should be developed in accordance with RTCA DO-178B, or an FAA/AUTHORITY accepted equivalent. The applicant should present and verify the process by which the database is developed and the methodology used to validate the database. The applicant should demonstrate that the accuracy and resolution of the database is suitable for the intended operation. The DO-200A, Standard for Processing Aeronautical Data, may be used as a guideline. The process should at least show how raw data is used, how it will be implemented into the database, and how it will be verified.

(7) Alerts. Alerts should be clear, concise, and unambiguous. If there is a failure mode where the display may be inoperative but the HTAWS is operative or vice versa, some type of annunciation should be provided to the flight crew of the failure mode; e.g. “HTAWS display inop”, “HTAWS inop”, etc. This annunciation should be clear, unambiguous, and distinguishable from other failures. The alerting system should be consistent with the basic alerting philosophy of the GPWS.

(8) Displays. The current state of the art of HTAWS may make use of existing aircraft display systems such as the weather radar, or Multiple Function Display (MFD); therefore, implementation of the HTAWS presentation requires the integration with existing display systems. The use of the HTAWS display should must not unacceptably detract from the usability of existing functions. Although a display is not specifically required, the full benefit of an HTAWS will only be provided when a display of the terrain and obstacle information is provided. Refer to paragraph **j** for Display Presentation Considerations.

h. Position Source. HTAWS uses the estimated position, based on GPS, of the aircraft with reference to the terrain/obstacle to determine when an alert should be annunciated. The applicant should provide evidence that the HTAWS position source (horizontal and vertical) is suitable for each phase of flight (i.e., en route, terminal, low alt mode, and approach, for which approval is sought).

(1) Horizontal and Vertical Position Source.

(i) HTAWS that interface with previously approved navigation systems:

(A) Class (A) equipment may use approved Area Navigation (RNAV), which should include GPS which complies with **(D)** below.

(B) Class (B) equipment is required to interface with an approved GPS for horizontal and vertical position, which complies with **(D)** below.

(C) Previously approved RNAV and GPS systems that are used for navigation are considered suitable for HTAWS horizontal and vertical position inputs, if they comply with **(D)** below.

(D) GPS equipment must meet the requirements of TSO-C129a and provide 95% horizontal and vertical position accuracy figure of merit (FOM) estimates, in accordance with ARINC-743A.

(E) If a Wide Area Augmentation System (WAAS) is used as a position source, it should meet TSO C-145 and comply with the FOM requirements of **(D)** above.

(F) HTAWS functions that require a navigation source for operations should be automatically disabled when the source has degraded to a point where its accuracy can no longer support the HTAWS functions. An aural and visual annunciation of this loss of function is required except for catastrophic failure where a visual annunciation will be acceptable.

(ii) HTAWS equipment with internal GPS position source: Class (A) and Class (B) equipment that uses a GPS internal to the HTAWS for horizontal and vertical position information, must use a GPS that complies with **(i)(D)** above.

(iii) The HTAWS should be capable of detecting a positional error that exceeds 0.25 NM, which is considered unsuitable for the HTAWS, and the functions that require GPS for operations should be automatically disabled and an aural and visual annunciation provided. An exception to this requirement will be made for a catastrophic failure where only a visual annunciation will be accepted. The applicant should be able to demonstrate that the HTAWS, as installed on the helicopter, provides the required position information accuracy (latitude/longitude and altitude) for the HTAWS functions.

(2) Vertical Position Aiding. The following sources are considered suitable for use in aiding vertical position. They may be used in combination, if the appropriate accuracy is demonstrated. The applicant should be able to demonstrate that the HTAWS, as installed on the aircraft, provides the appropriate vertical information for the HTAWS functions. Where operations are reliant on the use of QFE, an adequate means of determining the altitude should be provided. Geometric altitude should be enabled if the system has the facility.

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

(ii) Radio Altimeter. Vertical position information provided by a radio altimeter that meets the accuracy specified in TSO-C67 or later version, is considered acceptable as a source of vertical position information. Class (B) equipment does not require a radio altitude input.

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

(iv) GPS. Vertical position information provided by GPS may be used in combination with other sources of vertical position. If GPS is used as the only means for the determination of vertical position, then it must meet the requirements of TSO-C145, or later versions and paragraph **(1)(i)(D)** above.

(v) IRS. Vertical position information provided by an Inertial Reference System (IRS) may be used in combination with other sources of vertical position. If an IRS is used as the only means for the determination of vertical position, then it must meet the requirements of TSO-C115b, or later versions and **(1)(i)(D)** above.

i. Terrain Database. The terrain database for HTAWS shall be validated via the TSO-C151b authorization process, or similar process. If the TSO or equivalent process is not used to validate the database, the installer should demonstrate that the integrity is acceptable for the installation. There are three additional areas of concern that should be addressed during the installation process:

(1) Updates. The installed system should be capable of accepting updated terrain database and obstacle database (if applicable). The HTAWS manufacturers must have a procedure in place whereby the manufacturer can inform the aircraft owner/operator about database updates. The procedure should contain sufficient information to enable the owner/operator to make a logical safety decision as to whether it is appropriate to purchase and install the update. A means should be provided for identifying the local terrain and obstacle resolution for inclusion in the Pilot's Guide and Flight Manual (or Supplement).

(2) Valid Regional Data. The Pilot's Guide and Flight Manual (or Supplement) should identify the procedures for determining the status of the terrain and obstacle database. Operators should use this information to determine if updates include significant changes to the terrain and obstacle databases for the area of intended operation.

(3) Accuracy. For Low Altitude Mode operation the database should provide at least 6 arc-second data resolution with at least 25-foot vertical accuracy. For operations

in Regions where 6 arc-second or higher resolution data is not available, the Pilot's Guide and Flight Manual (or Supplement) should provide instructions for use of Low Altitude Mode (and other inhibit functions) when operating at low altitudes and high density urban environments.

j. Display Presentation. For Class (A) HTAWS installed without an operational requirement, the terrain and obstacle display is optional; however, the flight crew's ability to identify potential vertical and horizontal flight path conflicts and correct these conflicts before an alert occurs is greatly enhanced by displaying this information. Additionally, a visual display of the hazard will help support the appropriate recovery when an alert occurs. Therefore, it is recommended with any HTAWS installation a means of displaying Terrain information should be included when ever practical.

(1) Terrain and Obstacle Display.

(i) When a display is installed, the HTAWS equipment must be capable of providing terrain/obstacle alerting data to a cockpit display. The display hardware may be stand alone or interfaced with existing equipment, such as a weather radar (WXR), navigation displays, or other compatible display systems. The actual display presentation format will depend on the onboard display hardware, the options made available by the HTAWS manufacturer, and the features desired by the customer/user. Regardless of what format is used, the display presentation should enhance the flight crew's awareness of terrain and obstacle hazards.

(ii) The terrain and obstacle display system is an output from the HTAWS; therefore, the possibility of misleading information on the display due to undetected or latent failures should be commensurate with the failure condition category.

(iii) During the development of the HTAWS display, the applicant should use a representative sample of pilots to participate in the design and evaluation process for the proposed presentation format if a novel presentation is considered.

(iv) The applicant may consider selecting a display where multiple functions are presented. In these cases, a means to select or de-select the display of terrain and obstacle information should be provided. However, care should be exercised in selecting such a multifunction implementation, to ensure that the display sharing is appropriate for the specific functions. The use of the HTAWS display should not unacceptably detract from the usability of existing functions. Since the HTAWS display is not to be used for navigation, the use of the display should not impair the ability of the pilot to perform required navigation functions. An example of such an impairment would be an installation that forces the pilot to choose between the HTAWS display and the needed navigation information in situations where both could be effectively used simultaneously and continuously (e.g., instrument approach in the vicinity of hazardous terrain and obstacles). If the timesharing of the display between HTAWS and other functions is deemed acceptable, the design should facilitate simple

switching between the functions, with minimal time delays, so both functions are sufficiently accessible in realistic flight scenarios.

(v) The terrain and obstacle display should be installed in a location that provides monitoring by the pilot(s) for identification of potential flight path conflicts. In general, the terrain and obstacle display should be in a location similar to other multifunction displays, such as electronic maps and weather radar.

(2) Terrain and Obstacle Display Presentation. HTAWS equipment should be designed to interface with a color terrain and obstacle display. If there are multiple terrain and obstacle views available, at least one terrain display and obstacle should be capable of providing all of the following terrain-related information:

(i) The terrain and obstacle should be depicted relative to the aircraft's position such the pilot may estimate the relative bearing to the terrain and obstacle of interest.

(ii) The terrain and obstacle depicted should be oriented to either the heading or track of the aircraft. In addition, a north-up orientation may be added as a selectable format.

(iii) Variations in terrain and obstacle elevation depicted relative to the aircraft's elevation (above and below) should be visually distinct. Terrain or an obstacle that is more than 1,500 feet below the aircraft's elevation need not be depicted.

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

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

(vi) The terrain and obstacle display should be viewable in direct sunlight.

(vii) An inhibited, failed, or inoperative HTAWS should be indicated to the flight crew in a manner consistent with the flight deck design philosophy.

(viii) The terrain and obstacle display presentation should complement and be compatible with the terrain alerting function of the HTAWS.

(ix) Terrain and obstacle mapping should allow the flight crew to determine relative terrain elevation.

(x) The terrain and obstacle display should be designed so the flight crew can readily determine if terrain or obstacle is a threat to the aircraft.

(xi) The colors and textures used for threat terrain or obstacle should be intuitive and indicate the immediacy of the threat.

(xii) If the terrain or obstacle data is presented on a shared display, the terrain and obstacle mode and terrain and obstacle information should be easily distinguishable from weather and other features.

(xiii) For color displays, the selected colors should complement the discrete visual and aural alerts that are presented to the flight crew. Accordingly, any colors that are used for the threat terrain and obstacle display should match the colors used for discrete visual alerts.

(xiv) If additional terrain and obstacle views are provided, they should not present information that is inconsistent or incompatible with the features described above. Each view should be consistent with the other as far as color, scale, and textural information. When transitioning between views, the range scale should remain the same for each view. Each view will be carefully evaluated to ensure that it does not interfere with or reduce the effectiveness of the HTAWS. Since such displays may include functions that go beyond the scope of this guidance, they should be evaluated based on the relevant regulations, guidance material, or industry standards, as appropriate.

(3) Pop-Up Mode-Switching Functionality.

(i) An automatic pop-up feature should be incorporated. If the display does not provide a pop-up feature, a flight manual limitation should require the Terrain and Obstacle Display be selected when engaged in Low Altitude Mode operation.

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

(A) The pop-up functionality should automatically display HTAWS-related information when an HTAWS caution alert occurs.

(B) The terrain and obstacle display mode should be annunciated on the display. If this is not feasible then a mode annunciation light should be installed near the terrain and obstacle display.

(C) The pop-up functionality should be implemented consistently for weather, predictive wind shear, and traffic alerts, including any overlay design philosophies. The pop-up must not remove or impair the pilot's use of essential flight or navigational information.

(D) The display should be designed so that it is very evident that an automatic pop-up has occurred.

(E) Manually switching back to the original mode of operation should require minimal effort.

(F) Automatic switching back to the original mode of operation after the caution or warning ceases should not be allowed unless it is part of the aircraft design philosophy.

(iii) Pop-Up Inhibit Feature. For dual displays, pop-up functionality may be inhibited if the terrain and obstacle map is on at least one display when a terrain alert occurs. However, if the terrain and obstacle map is not on a display when a terrain alert occurs, the terrain and obstacle map, with the alerts, should be automatically displayed.

(4) Auto-Range Switching Mode.

(i) An auto-ranging function during alerts should be provided. If provided, an auto-ranging display should be designed so that range is evident to the flight crew. The range selected for auto-ranging should provide a usable depiction of the threat on the display. Switching back to manually selected range should require minimal effort. If auto range is not provided, an RFM or RFMS limitation should require the selection of a range of 3 miles or less when low altitude mode is selected.

(ii) For displays that do not support a range of 3 miles or less, an evaluation of adequacy for operation in Low Altitude Mode should be performed.

k. Alerts.

(1) In addition to meeting the color requirements of § 29.1322, as applicable, the HTAWS alerts should be clear, concise, and unambiguous.

(2) The certification plan should include tests and analyses to assure that the visual and aural alerts are consistent with the alerting philosophy of the aircraft flight deck in which the HTAWS equipment is installed. This is particularly important with retrofit installations, which may use previously-installed alerting annunciations. The plan should consider that the visual alerts are:

- Located in the pilots field of view,
- Consistent with their associated voice, or aural call out, and
- Consistent with the colors specified in § 29.1322 and TSO C-113, both in the discrete and textual display formats.

l. Alert Prioritization.

(1) Installations of HTAWS on aircraft also equipped with Traffic Alert and Collision Avoidance System (TACAS) should include an alert prioritization scheme such that:

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

(ii) Alerts for situations requiring immediate action by the flight crew have priority in situations where conditions for multiple alerts may occur.

NOTE: In older aircraft, the system architecture may preclude the prioritization of alerts for multiple alerting systems. If such is the case, a prioritization scheme is not required. However, if simultaneous alerts can be given, then the aural words should be understandable and the associated visual alerts should not be confusing to the flight crew.

(2) Implementing this prioritization scheme within the HTAWS equipment is acceptable. Figure AC 29.MG 18-1, below, displays an example of the recommended alert prioritization.

(3) Installation of HTAWS on helicopters with central or integrated Master Aural Warning system should show compatibility to a master aural warning scheme that is consistent with overall cockpit design.

Recommended Alert Prioritization between the HTAWS and TCAS TA

Priority		Description
Highest **Class (A)**		Pull-Up Warning *(Excessive Rates of Descent)*
Class (A)		Terrain Terrain *(Excessive Closure Rates)*
Class (A)		Terrain Closure Pull-Up Warning *(Excessive Closure Rates)*
Class (A)/(B)		Terrain Awareness Warning *(FLTA)*
Class (A)		Warning Obstacle *(Look ahead obstacle warning)*
Class (A)		Minimums *(Voice Callouts)*
Class (A)/B		Terrain Awareness Caution *(FLTA)*
Class (A)/(B)		Caution Obstacle (look ahead obstacle caution)
Class (A)		Too Low Terrain *(Flight Into Terrain When Not in Landing Configuration)*
Class (A)		Altitude Callouts *(Voice callouts)*
Class (A)		Too Low Gear *(Flight Into Terrain When Not in Landing Configuration)*
Class (A)		Sink Rate *(Excessive Rates of Descent)*
Class (A)/(B)		Don't Sink *(Excessive Altitude Loss After Take-off)*
Class (A)		Glide slope *(Excessive Downward Deviation From an ILS Glide slope)*
Class (A)/B		TCAS TA *("Traffic Traffic") (*)*
Class (A)		Bank Angle *(Voice Callouts)*
Class (A)		Tail Strike (*Voice Callouts*)
Class (A)/(B)		Terrain INOP Status (*Be Alert Terrain INOP*)
Lowest		TCAS TA *("Traffic Traffic") (*)*

(*) TCAS TA Priority can be either priority 15 or 19.
(Note: The alert described above only accounts for HTAWS/TCAS aural priorities. Other aircraft system aural alerts may be present and the resulting prioritization would then need to be established on an installation basis.)

FIGURE AC 29.MG 18-1

m. System Inhibit.

(1) A means for the flight crew to inhibit the following HTAWS functions should be provided:

FLTA and Basic GPWS audio for a period of time not to exceed 5 minutes or FLTA cautions and warnings. (momentary switch with 5-minute reset)
--OR--
FLTA Cautions and Warnings

Basic GPWS – Excessive downward deviation from the ILS glide slope

Basic GPWS for extreme low-level operation and FLTA. Note: This option should have specific coverage in the RFM/RFMS for its use and operational constraints.

(2) Appropriate annunciation of the inhibited functions should be provided to the flight crew. Flight crew procedures for disabling various HTAWS functions should be identified in the Flight Manual (or Supplement). For Class (A) equipment, inhibiting the FLTA functionality, if provided, should not affect the Basic GPWS functions.

n. Flight Data Recorder. For those applications that require crash-survivable flight data recording in accordance with the requirements of § 29.1459(e) (flight recorders), consideration should be given to provide a means to record the FLTA alerts. (It is not necessary to distinguish between Basic GPWS and the new FLTA alerts.) If this provision is implemented, a means should also be provided to record an FLTA inhibit.

o. Ground Test Considerations.

(1) A ground test should be conducted for each HTAWS installation. The level of testing required will be determined by the scope of the installation (First of a Model vs. Follow-on). Some items to consider for ground test should include:

Location of HTAWS controls, displays, and annunciators;

Evaluation of identified failure modes;

Evaluation of all HTAWS interfaces; and,

Electromagnetic interference (EMI)/electromagnetic compatibility (EMC) testing, and VHF harmonic tests for HTAWS with internal GPS receivers.

(2) Considerations should be made (to the maximum extent possible) for evaluating display characteristics and interface if it can be shown that all of the performance aspects of the display that are available during flight can be evaluated on the ground.

p. Flight Test Considerations.

(1) The level of flight test required to validate a particular HTAWS installation will be based on the aircraft system architecture, and credit given for previously certified installations, simulation, and ground testing. The actual requirement for a flight test needs to be evaluated for each installation. First time installations and new sensor inputs will require flight test. Follow-on installations that introduce changes in flight deck configurations may require flight test if they cannot be evaluated as specified in paragraph o of this document. The evaluation of new sensor models or aircraft models may require flight test, unless it can be shown through a sensitivity analysis that the new sensor's dynamic characteristics and the model aircraft during flight are compatible with the current sensor parameters, and will not effect the performance of the HTAWS. The following examples are intended to assist in determining the flight test guidelines for some potential or likely HTAWS configurations. Figure AC 29.MG 18-2, (which follows the five examples), provides a summary of these examples.

(i) Example 1. This is the first time the vendor's equipment has been installed in any aircraft for the purpose of receiving a first time FAA/AUTHORITY approval. If such is the case, then a complete and thorough Ground and Flight Test program should be conducted to verify the adequacy of the installation. If the HTAWS has been approved on another helicopter model, the scope of the testing should be reduced to assure functionality of each mode, and proper interface with other aircraft systems and displays.

(ii) Example 2. This involves a follow-on installation of a previously approved HTAWS in which a required sensor input has not been previously approved for the specific vendor's equipment. For example, if the sensor that provides barometric altitude rate (or equivalent) to the HTAWS equipment has not been previously approved, the flight test evaluation should focus on the HTAWS functions affected by barometric altitude rate such as excessive rates of descent.

(iii) Example 3. This involves a follow-on installation of a previously approved HTAWS in which the Terrain and Obstacle Display has not been previously approved. In this case, the focus of the flight test evaluation should be on display related issues and tests specified in paragraph t(4) (Terrain and Obstacle Display Flight Test Considerations) of this AC.

(iv) Example 4. This involves a follow-on installation of a previously approved HTAWS in which the horizontal and vertical position source sensor input has not been previously approved for the specific vendor's equipment. In this case, the focus of the flight test evaluation should be on the adequacy of the horizontal position source and the display of the terrain and obstacle as determined by that horizontal position source. In addition, since the navigation system provides track and ground speed information to HTAWS, which affect the alerting logic, an FLTA functional flight test evaluation test is warranted. Some basic GPWS installations use the horizontal

position information to desensitize some of the basic GPWS modes. Verification of the function and proper interface installation may require additional flight-testing for the basic GPWS.

(v) Example 5. This involves a follow-on installation of a previously approved HTAWS in which the radio altitude to the HTAWS equipment has not been previously approved. In this case, the focus of the flight test evaluation should be on the HTAWS functions affected by radio altitude such as one of the Basic GPWS. Only one mode test is required to assure that the radio altimeter input is properly installed to the HTAWS. This example does not apply to Class (B) HTAWS.

(vi) Example 6. This involves an initial installation of a vendor's HTAWS in a model aircraft that was previously approved with Basic GPWS equipment from the same vendor. Same basic GPWS algorithms, and the same sensors that are used for the GPWS installation are used for the HTAWS installation. If such is the case, then Basic GPWS testing is not required to be accomplished for the HTAWS installation. However, there are exceptions and the following situation is an example:

Exception: A basic GPWS is installed in an aircraft; subsequently, the HTAWS is to be installed. The sensors used for the basic GPWS and those used for the HTAWS are the same, except that some of the algorithms were changed and some features were added. Ultimately, an evaluation should be made to check the differences between the basic GPWS algorithms that were certified and the basic GPWS algorithms used for the HTAWS to determine if any flight-testing is necessary.

Flight Test Matrix

WS

HTAWS TEST Examples	FLTA	Basic GPWS*	Terrain Display	Horizontal & Vertical Position Source
Example 1	X	X	X	X
Example 2		X		
Example 3			X	
Example 4	X	If desensitized	X	X
Example 5		X		
Example 6	X		X	X

** Class (A) equipment only*

FIGURE AC 29.MG 18-2

(2) FLTA Flight Test Considerations.

(i) Flight-testing to verify the proper operation of the FLTA function can be conducted in an area where the terrain or obstacle elevation for the test runs is known to be within approximately 25 feet.

(ii) Test runs are recommended to be level flight at approximately the peak elevation of the Terrain/Obstacle. After caution and warning messages, the flight path should be adjusted to pass 50 to 100 feet above the terrain/obstacle of interest. The test runs should verify that:

(A)All alerts (caution and warnings) are given at an appropriate point in the run.

(B) All pop-up, auto-range, or other display features are working correctly.

(C) The display depicts the terrain or obstacle accurately.

(D) Low Altitude (if installed) alerts (cautions and warnings) are given at an appropriate point in the test run.

(E) Inhibit functions operate properly.

(3) Basic GPWS Flight Test Considerations. Flight-testing to verify the proper operation of Basic GPWS functions can be conducted in any area where the terrain elevation is known to the flight crew. The following information is intended to provide guidance for conducting flight tests to exercise and verify the proper operation of each GPWS function. The need to conduct flight-testing for follow-on HTAWS installations will depend upon the nature of the new or modified sensors and their impact on that particular GPWS function.

(i) Excessive Rates of Descent (Optional). This test should be conducted over level terrain or water. For Class (A) equipment, exercising this test verifies the proper installation of barometric altitude (and the corresponding computation of barometric altitude rate) and radio altitude. Only one test run is required to determine proper installation.

(ii) Excessive Closure Rate to Terrain. This test should be conducted in an area of known rising terrain. It is recommended that one level test run at an altitude 200 feet above the terrain peak elevation be conducted. For Class (A) equipment only, this test will verify the proper installation of the radio altimeter.

(iii) Excessive Altitude Loss after Takeoff. This test is conducted after a normal takeoff profile has been established but before reaching pattern altitude. For

Class (A) equipment, exercising this test verifies the proper installation of barometric altitude, barometric altitude rate, and radio altitude.

(iv) Flight into Terrain when Not in Landing Configuration. This test should be conducted while on a visual approach to a runway or over level terrain or water. For Class (A) equipment only, exercising this test verifies the proper installation airspeed and radio altitude as well as the gear sensor inputs to HTAWS.

(v) Excessive Downward Deviation from an ILS Glide slope. This test should be conducted during an ILS approach. For Class (A) equipment only, this test will verify the proper installation of the ILS Glide slope input to HTAWS. For aircraft equipped with dual ILS system, both systems should be demonstrated.

(4) Terrain and Obstacle Display Flight Test Considerations.

(i) Flight-testing to verify the proper operation of the Terrain and Obstacle Display should be conducted while verifying all the other required HTAWS functions.

(ii) Emphasis should be placed on verifying compliance with the provisions specified in paragraph **j(1)** (Terrain and Obstacle Display) of this document, during normal aircraft maneuvering during all phases of flight. Pop-up and auto-ranging features should be evaluated, if applicable.

(iii) The applicant should perform sustained standard rate turns to evaluate:

- Symbol stability
- Flicker
- Jitter
- Display update rate
- Color cohesiveness
- Readability
- The use of color to depict relative elevation data
- Caution and warning alert area depictions
- Map masking
- Overall suitability of the display

(5) Added Features Flight Test Considerations**.** Flight-testing should be required to verify the proper operation of additional implemented features (i.e. functions not defined by TSO C151b, or paragraph u) such as:

Autorotation detection,

Tail Strike,

Bank angle,

Altitude call outs “Approaching Minimums,” or

Other features not listed here.

(6) Corrected Pressure Altitude Variations in Cold Weather. The HTAWS may be designed to account for the effects of cold weather on barometric altitude, while determining vertical position. Flight-testing may be required, unless a suitable verification procedure can be conducted. This will depend on the design of the cold weather compensation. This test is not required for systems that do not use corrected pressure altitude for cold weather compensation.

q. Rotorcraft Flight Manual (RFM)/Rotorcraft Flight Manual Supplement (RFMS).

The applicant should make an evaluation to determine if there are any limitations of the system and, if so, how they will affect aircraft operations. Any limitations affecting operations should be included in the RFM/RFMS. As a minimum, the applicant should provide instructions in the Limitations Section of the RFM/RFMS that include the following as appropriate (i.e., for systems approved on a no operational credit basis):

(1) Limitations. The following instructions should be included in the Limitations section of all RFM/RFMS:

(i) Navigation must not be predicated upon the use of the HTAWS information.

NOTE: The Terrain and Obstacle Display is intended to serve as a terrain and obstacle awareness tool only. The Display and database may not provide the accuracy or fidelity on which to base routine navigation decisions and plan routes to avoid terrain or obstacles.

(ii) The status of the inclusion of Power Lines in the Obstacle Database shall be stated.

(iii) Low Altitude Mode shall not be selected when operating under IMC conditions except as required when performing offshore platform IMC Approach Procedures.

(iv) The operator shall select a range below 3 miles or an alternate range that has been demonstrated by the applicant to be appropriate when low altitude mode is activated on displays that do not auto-range.

(2) Operational Considerations for Normal/Abnormal Procedures. In addition to the GPWS operational procedures, consider the following:

(i) Terrain or Obstacle Awareness Caution**.** When a terrain or obstacle awareness CAUTION occurs, verify the aircraft flight path and correct it, if required.

(ii) Terrain or Obstacle Awareness Warning**.** When a terrain or obstacle awareness WARNING occurs, immediately initiate a maneuver that will provide maximum terrain or obstacle clearance, until all alerts cease.

(iii) A means should be provided for identifying the local terrain and obstacle resolution for inclusion in the Flight Manual (or Supplement).

(iv) Audio Inhibit. For those installations that include the ability to inhibit all or some of the HTAWS audio alerts, the Flight Manual (or Supplement) should include:

- When the audio inhibit function should be used.
- What alerts are inhibited.
- How long the alerts are inhibited.
- How to re-establish the alerts.

For Example: “For operations in day VFR conditions where terrain clearance may be assured visually and HTAWS audio alerts will hamper aircrew performance, the AUDIO INHIBIT button may be pushed to inhibit all HTAWS audio alerts. The audio alerts will resume five minutes after inhibit is selected or when the AUDIO INHIBIT button is pressed again.”

(v) Altitude Reference. The Flight Manual (or Supplement) should explain how different altitude sources are blended to create the altitude used by the HTAWS. If the blended altitude is displayed to the pilot, a caution should state that ATC assigned/posted altitudes will be flown according to standard barometric altimeters with a correct altimeter setting. Blended altitudes may not provide adequate traffic separation. If the use of QFE altimeter settings adversely affects the performance of

the HTAWS, procedures for QFE operations will be presented in the Flight Manual (or Supplement).

(vi) Environmental Requirements**.** For operations in cold weather, either the system should be able to account for variations in cold weather at temperatures at or below 0° Celsius, or additional flight crew procedures should be considered to address pressure altitude limits for vertical position determination. Limitations may be needed to address insufficient determination of the aircraft's vertical position in cold weather temperatures.

r. Instructions for Continued Airworthiness. Instructions for Continued Airworthiness are required by § 29.1529 as appropriate and in accordance with FAR/JAR 29 Appendix A. In addition to Appendix A requirements, the applicant should identify the following items as a minimum:

(1) Indicate when the terrain and obstacle database need to be updated and how to implement this.

(2) Maintain IAW maintenance instructions.

s. Additional Considerations for Helicopter to TSO C-151b. Suggested consideration to TSO C-151b is provided below for helicopters. Items that are commentary only are italicized.

Class A

Additional Considerations to DO-161

Mode 1

An Excessive Descent Rate warning function is not required but may be included optionally.

Mode 2

A Helicopter Class A TAWS should provide an Excessive Closure Rate to Terrain warning within a minimum of 8 seconds of impact with terrain. The system should provide a reduced nuisance free warning when in a landing flight profile. Provision should be made to prevent nuisance warnings during day VFR Low Altitude flying.

Mode 3

A Helicopter Class A TAWS should provide a warning of Excessive Altitude Loss during Takeoff. A warning shall be generated if the aircraft losses more than 40% of its terrain clearance during takeoff. Takeoff is defined as at least the first 60 seconds of flights when greater than 50 knots and above 100 feet AGL.

Mode 4

A Helicopter Class A TAWS should provide a warning of Insufficient Terrain Clearance when not in a landing configuration (Gear Up) by 150 feet AGL for retractable gear aircraft. For fixed gear aircraft, a warning of Insufficient Terrain Clearance when not at landing speeds should be provided by 100 feet AGL. During an autorotation, improper landing gear configuration warnings should be provided by 400 feet AGL.

Mode 5 No change is necessary for Mode 5.

Helicopter Additions/Replacements to TSO C-151b

Required Terrain Clearance (RTC) By Phase of Flight

Alternate Figure AC 29.MG 18-2.1 is shown below.

TAWS REQUIRED TERRAIN CLEARANCE (RTC) BY PHASE OF FLIGHT

Phase of Flight	TERPS (ROC)	TAWS (RTC) Level Flight	TAWS (RTC) Descending
En route	1000 Feet	150 Feet	100 Feet
Terminal (Intermediate Segment)	500 Feet	150 Feet	100 Feet
Approach	250 Feet	150 Feet	100 Feet
Departure (See Note 1)	48 Feet/NM	100 Feet	100 Feet

Note 1: During the Departure Phase of Flight, the FLTA function of Class A and B equipment should alert if the aircraft is projected to be within 100 feet vertically of terrain. However Class A and Class B equipment should not alert if the aircraft is projected to be more than 150 feet above the terrain.

Alternate FIGURE AC 29. MG 18-2.1

Premature Descent Alert (PDA)

Since helicopters can land anywhere, the PDA is inappropriate.

Voice Callouts

Since 500 feet AGL is a normal helicopter flight altitude, this callout is inappropriate.

Altitude Accuracy A new requirement is proposed.

A means should be provided to compute actual MSL altitude and a Vertical Figure of Merit (VFOM). FLTA warning altitudes should compensate for estimated altitude errors.

Aural and Visual Alerts An addition to Table 4.1 of TSO C-151b is proposed.

Add the message **"Warning Terrain"** to Warning Aural Alert messages for Reduced Required Terrain Clearance and Imminent Impact with Terrain.

Low Altitude Mode A new helicopter requirement is proposed.

A means should be provided to manually select a reduced sensitivity state for Low Altitude and High Density Metropolitan operation.

Class B

Helicopter Additions/Replacements to DO-161A

Mode 1

Mode 1 is not a significant component of Helicopter CFIT accident history. Because of the complexity of Autorotation detection, Mode 1 should not be required for Class B helicopter equipment.

Mode 3

Adequate coverage for inadvertent descent after takeoff should be provided by the FLTA function, or other Mode 3 algorithm that prevents CFIT during takeoff. Takeoff is defined as at least the first 60 seconds of flights when greater than 50 knots and above 100 feet AGL.

Helicopter Additions/Replacements to TSO C-151b

Voice Callouts

Since 500 feet AGL is a normal helicopter flight altitude, this callout is inappropriate.

Test Conditions

Exclude TSO C-151b paragraphs 1.1 through 1.6 as not applicable.

TSO C-151b paragraph 1.7 applies as written.

TSO C-151b paragraphs 2.0 through 2.2 apply using Table G for speed cases of 100 through 160 knots.

TSO C-151b paragraphs 3.0 and 3.1 are excluded as not applicable.

TSO C-151b paragraphs 4.0, 4.2, and 4.3 apply as written. Case 4.1 is excluded as not applicable.

TSO C-151b paragraphs 5.0 and 5.1 are applicable as written.

TSO C-151b paragraphs 6.0 through 6.3 are to be determined.

TSO C-151b paragraphs 7.0, 8.0, and 9.0 are excluded as described above in sections 2.1 and 2.2.