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Airworthiness Approval Global Positioning System
For Use as a VFR and IFR Supplemental Navigation System

21-3.1 Purpose
This advisory circular (AC) establishes an acceptable means of obtaining ECAA approval of Global Positioning System (GPS) equipment for use as a supplemental navigation system during VFR and IFR operations.

21-3.3 Related Egyptian civil aviation regulations
Egyptian Civil Aviation Regulations parts 21, 43, 65, 91, and 121.

21-3.5 Related reading materials
(a) International Civil Aviation Organization Annexes 6 Operation of Aircraft, 8 Airworthiness of Aircraft and 10 Communications.

(b) United States Federal Aviation Administration (FAA)/Technical Standard Order (TSO) C129, Airborne Supplemental Navigation Equipment Using the Global Positioning System (GPS). Copies may be obtained from the Department of Transportation, Aircraft Certification Service, Aircraft Engineering Division, AIR-130, 800 Independence Avenue, SW, Washington, DC 20591.

(c) RTCA, Inc. Document No. DO-160C, Environmental Conditions and Test Procedures for Airborne Equipment; Document No. DO-178B, Software Considerations in Airborne Systems and Equipment Certification; Document No. DO-200, Preparation, Verification and Distribution of User Selectable Navigation Data Bases; Document No. DO-201, User Recommendations for Aeronautical Information Services; and Document No. DO-208, Minimum Operational Performance Standards for Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS). Copies may be purchased from RTCA, Inc., 1140 Connecticut Avenue, NW, Suite 1020, Washington, DC 20036.

(d) Department of Defense Interface Control Document (ICD) ICD-GPS-200B, Navstar GPS Space Segment/Navigation User Interface. Copies of the civil version of this document may be requested from the GPS Joint Program Office, SSD/CZ, Los Angeles AFB, CA 90006.

(e) Defense Mapping Agency (DMA) Technical Report DMA TR 8350.2, Department of Defense World Geodetic System 1984, Its Definition and Relationships With Local Geodetic Systems. Copies of this document may be requested from the Defense Mapping Agency, Systems Center (SG), 8613 Lee Highway, Fairfax, VA 22031-2138.

21-3.7 GPS navigation background
(a) System description**.** GPS is a satellite-based radio navigation system that uses precise range measurements from GPS satellites to determine a precise position anywhere in the world. The GPS constellation consists of 24 satellites in various orbital planes approximately 11,000 nautical miles (NM) above the earth. The satellites broadcast a timing signal and data message that the airborne equipment processes to obtain satellite position and status data, and to measure how long each satellite's radio signal takes to reach the receiver. By knowing the precise location of each satellite and precisely matching timing with the atomic clocks on the satellites, the receiver can accurately measure the time the signal takes to arrive at the receiver and thus determine the satellite's precise position. A minimum of three satellites must be in view to determine a two-dimensional position. Four satellites are required to establish an accurate three-dimensional position. GPS equipment determines its position by precise measurement of the distance from selected satellites in the system and the satellite's known location. The accuracy of GPS position data can be affected by various factors. Many of these accuracy errors can be reduced or eliminated with mathematics and sophisticated modeling, while other sources of errors cannot be corrected. The following are examples of those errors that cannot be corrected:

(1) Atmospheric propagation delays can cause relatively small measurement errors, typically less than 100 feet. Ionosphere propagation delays can be partially corrected by sophisticated error-correction capabilities.

(2) Slight inaccuracies in the atomic clocks on the satellites can cause a small position error of approximately 2 feet.

(3) Receiver processing (such as mathematical rounding and electrical interference) may cause errors that are usually either very small (which may add a few feet of uncertainty into each measurement) or very large (which are easy to detect). Receiver errors are typically on the order of 4 feet.

(4) Conditions that cause signal reflections before the satellite's transmitted signal gets to the receiver can cause small errors in position determination or momentary loss of the GPS signal. While advanced signal processing techniques and sophisticated antenna design are used to minimize this problem, some uncertainty can still be added to a GPS measurement.

(5) A satellite's exact measured orbital parameters (ephemeris data) can contain a small error of approximately 4 feet.

(b) System operation**.**

(1) The United States Department of Defense (DOD) is responsible for operating the GPS satellite constellation and constantly monitors the GPS satellites to ensure proper operation. Every satellite's ephemeris data are sent to each satellite for broadcast as part of the data message sent in the GPS signal. The GPS is a system of Cartesian earth-centered, earth-fixed coordinates as specified in the DOD World Geodetic System 1984 (WGS-84). Navigation values, such as ground speed and distance and bearing to a waypoint, are computed from the aircraft's latitude/longitude and the location of the waypoint. Course guidance is usually provided as a linear deviation from the desired track of a great circle course between defined waypoints.

(2) GPS navigation capability from the 24-satellite constellation is available 24 hours a day anywhere in the world. GPS status is broadcast as part of the data message transmitted by the satellites. Additionally, system status is planned to be available through Notices to Airmen (NOTAM). Status information is also available by means of a telephone data service from the United States Coast Guard. The GPS status recording is available 24 hours a day by calling (202) 313-5906. Availability of suitable navigation capability from the satellite constellation is expected to approach 100 percent.

(3) GPS signal integrity monitoring will be provided by the GPS navigation receiver using receiver autonomous integrity monitoring (RAIM). For GPS sensors that provide position data only to an integrated navigation system (e.g., FMS, multi-sensor navigation system), a level of GPS integrity equivalent to that of RAIM may be provided by the integrated navigation system.

(c) Selective availability (SA). SA is essentially a method by which (DOD) can artificially create a significant clock and ephemeris error in the satellites. This feature is designed to deny an enemy nation or terrorist organization the use of precise GPS positioning data. SA is the largest source of error in the GPS system. When SA is active, the DOD guarantees horizontal position accuracy will not be degraded beyond 100 meters 95 percent of the time, and beyond 300 meters 99.99 percent of the time.

(d) Receiver autonomous integrity monitoring (RAIM). A technique whereby a civil GPS receiver/processor determines the integrity of the GPS navigation signals using only GPS signals or GPS signals augmented with altitude. This determination is achieved by a consistency check among a series of satellites being tracked. At least one satellite in addition to those required for navigation must be in view for the receiver to perform the RAIM function.

(e) System availability**.** The percentage of time (specified as 98 percent) that at least 21 of the 24 satellites must be operational and providing a usable navigation signal.

(f) General operational limitations.

(1) Enroute domestic, terminal, and non-precision approach (except localizer, LDA and SDF) use as a supplemental navigation system. A GPS system that meets the requirements of class A1 equipment as specified in TSO-C129 may be approved for enroute, terminal, and non-precision instrument approach (except localizer, LDA, and SDF) supplemental navigation. A GPS system that meets the requirements of Class A2 equipment as specified in TSO-C129 may be approved for enroute and terminal supplemental navigation. All GPS accuracy

and integrity requirements must be met without the need for operator input of necessary data.

(2) Enroute oceanic and remote operation. A GPS system that meets the requirements of Class A() equipment as specified in TSO-C129 may be approved as one of the means, but not the only means, for oceanic and remote navigation.

(3) IFR navigation equipment. GPS equipment for IFR navigation is for use as a supplemental navigation system. The installation of GPS equipment does not affect the requirement for a primary means of navigation appropriate to the route intended to be flown. Within most land areas and surrounding coastal waters, this requirement can be met with an operational, independent VOR receiver. Additional navigation equipment redundancy may be required for operation in oceanic and remote airspace.

(4) Operating limitations. The design of particular GPS equipment will require operational areas be limited to those areas in which the equipment has been demonstrated to meet the performance specifications of this advisory circular because of system characteristics and other factors affecting system operation. Operating limitations that may affect the approved operating area for particular GPS equipment (that is, extreme North and South latitudes, data base coverage, etc.) must be specified in the operating limitations section of the Airplane/Rotorcraft Flight Manual Supplement (AFMS/RFMS). ECAA approval of GPS navigation equipment does not constitute approval to conduct GPS based navigation in airspace controlled by foreign airworthiness authorities. Systems that do not provide for coordinate reference system conversions of the displayed navigation information should not be used in airspace that is not referenced to the WGS-84 or NAD-83 geodetic datums. Operating limitations relating to geodetic datums for particular GPS navigation equipment should be included in the limitations section of the AFMS/RFMS.

(g) Equipment classes. Equipment installed in accordance with the guidance provided by this AC for IFR operations shall meet the requirements for Class A() equipment as defined in TSO-C129.

(h) Future Air Navigation System (FANS) concept. Information in this AC is not intended to restrict the development, certification, or operational approval of current or future GPS equipment installations designed to comply with Required Navigation Performance (RNP) or other FANS design requirements.

(i) Portable units. All portable electronic systems and portable GPS units must be handled in accordance with the provisions of Part 91.21 and EAC 21-2. The operator of the aircraft must determine that each portable electronic device will not cause interference with the navigation and communications systems of the aircraft on which it is to be used. Portable GPS units which are attached by Velcro tape or hard yoke mount that require an antenna (internally or externally mounted) are considered to be portable electronic devices and are subject to the provisions of Part 91.21. All portable GPS equipment attached to the aircraft by a mounting device must be installed in an approved manner and in accordance with Part 43. Any questions concerning installation should be referred to Flight Safety Standards Sector (ECAA). A critical aspect of any GPS installation is the installation of the antenna. Shadowing by the aircraft structure can adversely affect the operation of the GPS equipment. ECAA approval of avionics components, including antennas, requires an evaluation of the applicable aircraft certification regulations prior to approval of an installation. The regulations require that the components perform their intended functions and be free of hazards in and of themselves and to other systems as installed. Pilots and engineers should be aware that a GPS signal is weak, typically below the value of the background noise. Electrical noise or static in the vicinity of the antenna can adversely affect the performance of the system. It is required that system installations be flight tested in conjunction with other navigation equipment. Unless a portable GPS receiver is TSO C-129 approved, it can not be used as a basis for approval of IFR operations.

21-3.9 Definitions.

Any terms used in this advisory circular that have a meaning specific to the context of this AC are contained in appendix 1: Glossary.

21-3.11 System accuracy

(a) 2D accuracy requirements (95 percent probability).

(1) The total position fixing error of the airborne GPS equipment shall be equal to or less than the following:

KEY: A = Oceanic/Remote (NM)
B = Enroute Domestic (NM)
C = Terminal (NM)
D = Nonprecision Approach (NM)
E = Position fixing error
F = CDI Centering

Error Type	A	B	C	D *
E **	0.124	0.124	0.124	0.056
F ***	0.21	0.2	0.2	0.01

* Nonprecision approach criteria only applies to Class A equipment.

** Equipment error assumes an average HDOP of 1.5, GPS equipment waypoint input resolution of 0.01 minute, and coordinate output resolution of 0.01 minute for approach and 0.1 minute otherwise.

*** The maximum difference between the displayed crosstrack deviation and the computed crosstrack deviation.

(2) The reference datum shall use latitude/longitude values corresponding to the WGS-84 ellipsoid (Defense Mapping Agency (DMA) Technical Report DMA TR 8350.2, Department of Defense World Geodetic System 1984, Its Definition and Relationships With Local Geodetic Systems).

(b) Flight technical error (FTE)**.** Since FTE factors are normally beyond the control of equipment manufacturers or installers, these error sources are not included in the accuracy specifications of paragraph 21-3.11(a)(1). It has been determined that when properly installed in an aircraft, Class A equipment meeting the operational and display characteristics contained in this AC and TSO-C129 provides for acceptable values of FTE. FTE should not exceed 1.0NM for enroute, 1.0NM for approach transition, or 0.25NM for approach operating modes on a 95 percent basis.

21-3.13 Airworthiness criteria for GPS installations used as a supplemental navigation system limited to Visual Flight Rules (VFR) only

(a) Application process:

Operators wishing to obtain approval of class A GPS equipment limited to VFR use only may do so via the Type Certificate (TC), Supplemental Type Certificate (STC), or, for equipment previously approved via the TC or STC process, data approved by the ECAA. The approval for return to service must be signed by one of the entities noted in ECAR Parts 43 and 65; that is, repair station, manufacturer, licensed or authorized engineer.

(1) The initial (first time airworthiness approval) certification of a GPS navigation system must be accomplished via the TC or STC approval process. The ECAA will review and, if acceptable, approve foreign STCs.

(2) Subsequent (follow on) installations of the same GPS navigation system (hardware and software) in other aircraft are approved using a less extensive evaluation process since the basic engineering design of the GPS equipment has already been evaluated and approved by the ECAA. Approval of follow on installations may be accomplished via the TC, STC, or the ECAA evaluation process. The extent of required evaluations depends upon the degree of integration of the GPS system with other aircraft systems, the similarity between the initial and follow on aircraft models, and other changes that may have been incorporated in the GPS navigation system.

(b) Airworthiness considerations:
GPS equipment approved for VFR use only does not require TSO-C129 authorization, however, it must at least meet the enroute/terminal system accuracy criteria (0.124NM, 95 percent probability) and in the system accuracy as defined above. Airworthiness considerations should include the following:

(1) Electromagnetic compatibility. The GPS equipment installation does not interfere with the normal operation of other equipment installed in the aircraft.

(2) Environmental conditions. The GPS equipment is appropriate to the aircraft environment in which it is installed.

(3) Equipment mounting. The installation of the GPS equipment, including antenna, must be sufficient to meet all structural mounting, dynamic, and emergency landing loads appropriate to the aircraft. It is acceptable to use the methods in the U.S. FAA AC 43.13-2A, "Acceptable Methods, Techniques, and Practices - Aircraft Alterations."

(4) Navigation source annunciator. A navigation source annunciator is provided on or near each affected display if the GPS installation supplies any information to displays such as a Horizontal Situation Indicator (HSI), Course Deviation indicator (CDI), distance display, electronic map, etc., which can also display information from other systems normally used for aircraft navigation.

(5) Computer software. RTCA/DO-178B, provides an acceptable means for showing that software complies with applicable airworthiness requirements. The applicant should substantiate software levels in the safety assessment. As an alternative to substantiating software level(s) in a safety assessment, the applicant may develop all software that contains or affects navigation and integrity functions to at least the Level D criteria, as defined in RTCA/DO-178B.

(6) Failure protection. Any probable failure of the airborne GPS navigation system must not degrade the normal operation of other required equipment or create a flight hazard. Likewise, normal operation of the GPS equipment must not adversely affect the performance of other aircraft equipment. The interfaces with other aircraft equipment must be designed such that normal or abnormal GPS equipment operation does not adversely affect the operation of other equipment. Operation of other equipment shall not adversely affect the GPS equipment operation.

(7) System controls, displays and annunciators. All displays, controls, and annunciators must be easily readable under all normal cockpit conditions and expected ambient light conditions (total darkness to bright, reflected sunlight). Night lighting provisions must be consistent with other cockpit lighting. All displays and controls should be arranged to facilitate equipment usage. Controls that are normally adjusted in flight shall be accessible and properly labeled as to their function. System controls and displays should be designed to maximize operational suitability and minimize pilot workload. System controls should be arranged to provide adequate protection against inadvertent system turnoff. Reliance on pilot memory for operational procedures shall be minimized.

(8) Navigation/integrity annunciation. The GPS equipment should indicate, independent of any operator action:

(i) The following conditions by means of a navigation warning flag on the navigation display:

(A) The absence of power necessary for the navigation function.

(B) Probable equipment malfunctions or failures affecting the navigation function.

(C) Loss of navigation function.

(ii) If an integrity monitoring function (such as RAIM) is provided, an appropriately located annunciator shall be provided to indicate loss of the integrity monitoring function.

Note 1: For equipment not incorporating an external navigation display (CDI, HSI, etc.) complete blanking of the Control Display Unit (CDU) display is acceptable.

Note 2: Presentation of a failure/status annunciation (flag or integrity annunciation) does not require removal of navigation information from the navigation display.

(9) Autopilot/flight director coupling. The GPS navigation system may be coupled to an autopilot and/or flight director system, if a deviation or steering output that is compatible with the autopilot/flight director system is provided and no unusual interface is required.

(10) VFR limitation placard. A placard stating "GPS limited to VFR use only" must be installed in clear view of, and readable by, the pilot.

(11) Manufacturer's instructions. The GPS equipment, including antenna, must be installed in accordance with the instructions and limitations provided by the manufacturer of the equipment.

(c) VFR airworthiness approval:

There are two types of VFR airworthiness approval, which differ significantly as to test requirements and data analysis.

(1) First time VFR airworthiness approval criteria (for a particular type of GPS equipment) to be used on Egyptian registered aircraft. This type of approval refers to the very first time an applicant presents a particular (hardware and software configuration) model GPS navigation system for ECAA airworthiness installation approval and certification for VFR navigation use. The first approval of a particular GPS navigation system must be accomplished through the TC or STC process. Each new model of GPS equipment or significant changes (hardware or software) to existing equipment shall undergo the same approval process as the original equipment unless it can be shown by analysis and tests acceptable to the ECAA that the new model will function as well or better than the approved equipment. The first time approval is conducted in four phases:

(i) Foreign TC or STC evaluation. This phase consists of an ECAA review of the data contained in the TC or STC issued and approved a foreign Civil Aviation Authority. A review of the letter of authorization issued by the owner of the TC or STC authorizing the installer or operator to use the TC or STC.

(ii) Aircraft installation data evaluation. The following assessments are made:

(A) Review of the equipment installation in the aircraft.

(B) Verification that the GPS equipment is appropriate to the aircraft environment in which it is installed.

(C) Verification that the installation of the GPS equipment, including antenna, is sufficient to meet all structural mounting, dynamic, and emergency landing loads appropriate to the aircraft.

(D) Verification that a placard stating "GPS limited to VFR use only" is installed in clear view of and readable by the pilot.

(E) Verification that the GPS equipment installation does not interfere with the normal operation of other equipment installed in the aircraft.

(iii) Ground test evaluation. Static ground tests are conducted to verify the installed GPS equipment configuration (including the antenna) provides position data meeting the enroute/terminal accuracy criteria specified in this AC.

(iv) Flight test evaluations. Flight tests are conducted to verify proper operation and accuracy of the GPS equipment as installed in the aircraft. Flight tests should include at least the following:

Note: Required flight evaluations for the first-time airworthiness approval of a particular GPS system are accomplished by the operator with an ECAA representative observing the tests.

(A) Evaluation of installed GPS navigation system to verify that it is functioning properly, safely, and operates in accordance with the manufacturer's specifications.

(B) Evaluation of steering response while the autopilot and/or flight director is coupled to the GPS equipment during a variety of different track and mode changes. All available display sensitivities should be evaluated.

(C) Evaluation to verify the GPS installation does not adversely affect other on-board equipment (this test may be partially accomplished as a ground test).

(D) Validate GPS navigation system accuracy by at least 5 low altitude overflights of one or more surveyed locations (ensure survey point coordinates are relative to WGS-84 or NAD-83). An acceptable method of conducting this accuracy demonstration is to accomplish low altitude (less then 100 feet AGL) overflight of a runway threshold and record the GPS position as the aircraft crosses the threshold. The system accuracy is the distance between the coordinate position determined by the GPS and the coordinate position of the surveyed location (runway threshold). Runway threshold coordinates may be obtained from the airport operator.

(E) Evaluation of the accessibility of all controls pertaining to the GPS installation.

(F) Evaluation of the visibility of the controls, displays, and annunciators relating to the GPS installation during day and night lighting conditions. No distracting cockpit glare or reflections may be introduced and all controls must be illuminated for identification and ease of use. Night lighting shall be consistent with other cockpit lighting.

(2) Follow on VFR airworthiness installation approvals. This type of approval refers to installation approvals in any model or type of aircraft after a first time airworthiness approval of the particular GPS equipment has been issued to an Egyptian registered aircraft. Follow on approvals may use the first time airworthiness approval as a basis for installation approval. The applicant or installing agency requesting a follow on GPS equipment installation limited to VFR use should:

(i) Unless otherwise provided, contact either the manufacturer or organization responsible for obtaining the first time airworthiness approval of the GPS equipment in order to:

(A) Obtain a sample airplane or rotorcraft flight manual supplement (or supplemental flight manual), if required for the aircraft.

(B) Obtain verification of the equipment approval status, including antenna, software, autopilot/flight director interface, system integration requirements, etc.

(C) Verify that the maximum operating speed for which the GPS equipment is qualified is compatible with the maximum expected ground speed of the aircraft.

(ii) Conduct a data evaluation as outlined in this AC.

(iii) Conduct a functional flight evaluation.

(iv) Obtain approval for the use of the TC or STC.

21-3.15 Airworthiness criteria for GPS installations used as a supplemental navigation system under instrument flight rules (IFR)

(a) Application process:

Operators wishing to obtain approval of class A() GPS equipment for IFR operations must do so via the TC STC process. For equipment produced under TSO-C129 authorization that has previously obtained initial ECAA installation approval may also be obtained via data approved by the. The approval for return to service must be signed by one of the entities noted in ECAR Parts 43 and 65, that is, repair station, manufacturer, licensed or authorized engineer.

(1) The initial (first time airworthiness approval) certification of a GPS navigation or sensor system requires extensive engineering and flight test evaluations and must be accomplished via the TC or STC approval process. The ECAA will review and, if acceptable, approve the foreign TC or STC.

(2) Subsequent (follow on) installations of the same GPS navigation system (hardware and software) in other aircraft are approved using a less extensive evaluation process since the basic engineering design of the GPS equipment has already been evaluated. Approval of follow on installations may be accomplished via the TC, STC, or ECAA evaluation process. The extent of required evaluations depends upon the degree of integration of the GPS system with other aircraft systems, the similarity between the initial and follow on aircraft models, and other changes that may have been incorporated in the GPS

navigation system. Major changes to software accomplishing navigation, integrity, or availability functions or significant changes to operating limitations can only be approved using the TC or STC process.

(b) Airworthiness considerations:
GPS navigation equipment approved as a supplemental navigation system for oceanic and remote enroute, domestic enroute, terminal, and nonprecision instrument approach (except localizer, LDA, and SDF) operations does not require TSO-C129 authorization, however, it must meet the minimum navigation performance and operation standards of Class A1 or A2 equipment, as applicable, specified in TSO-C129 and this AC. Airworthiness considerations should include the following:

(1) System integrity and software development. Loss of navigation information is considered to be a major failure condition for the aircraft. Providing/presenting hazardously misleading information to the crew is also considered to be a major failure condition for the aircraft. GPS navigation data is considered to be hazardously misleading when non-annunciated position errors exist that are greater than those specified by the GPS position integrity performance requirements in Table 21 of RTCA/DO-208. The applicant should conduct a safety assessment of the GPS equipment installation to verify that design errors and failure modes that produce major failure conditions are improbable.

(i) TSO-C129 or equivalent foreign CAA certification, as applicable, provide an acceptable means for showing that the hardware complies with pertinent airworthiness requirements.

(ii) The RTCA/DO-178B document provides an acceptable means for showing that software complies with pertinent airworthiness requirements. The applicant should substantiate software levels in the safety assessment. As an alternative to substantiating software level(s) in a safety assessment, the applicant may develop all software that contains or affects navigation and integrity functions to at least the Level C criteria, as defined in RTCA/DO-178B.

(iii) The ECAA may grant a deviation to TSO-C129 to permit the applicant to use the procedures of RTCA/DO-178B instead of RTCA/DO-178A.

(iv) If software was developed using RTCA/DO-178A procedures (as is specified in TSO-C129), the applicant may need to further evaluate some features of the software. RTCA/DO-178A does not address some applications of digital technology commonly found in GPS navigation systems (for example, use of user modifiable software, option selectable software, software development and verification tools, previously developed software in modular architectures, and field loadable software capabilities). In these cases RTCA/DO-178A does not provide adequate procedures and the applicant must include in the software aspects of certification plan the means for showing that these features comply with pertinent airworthiness requirements. One acceptable means for demonstrating such features comply with the pertinent airworthiness requirements is to comply with pertinent portions of the criteria contained in RTCA/DO-178B, which would supplement the basic criteria contained in RTCA/DO-178A.

(v) The ECAA strongly recommends that the applicant use the procedures described in RTCA/DO-178B (or later revision) to show that the software aspects of a system comply with pertinent airworthiness requirements. For software developed prior to the availability of RTCA/DO-178B, Section 12.1.4 of RTCA/DO-178B provides a method for upgrading a baseline for software development so that changes can be made in accordance with the criteria contained in RTCA/DO-178B.

(vi) If Application Specific Integrated Circuits (ASICs) are used, they must be developed using a structured process similar to that used for software developed under RTCA/DO-178B. If deterministic tests exhaustively consider all possible input values and verify that the ASIC completely meets all pertinent requirements, then a structured development process is not required. Either methodology should be approved in advance.

(2) Display format/operating procedure changes. Changes to navigational display formats and navigation/function operating procedures (implemented through hardware or software) may constitute major changes requiring additional evaluation.

(3) Location of the GPS display. Each display element (that is, the Course Deviation Indicator (CDI), Horizontal Situation Indicator (HSI), map display, etc.), used as a primary flight instrument in the guidance and control of the aircraft, for maneuver anticipation, or for failure/status/integrity annunciation, shall be located where it is visible to the pilot (in the pilot's primary field of view) with the least practicable deviation from the pilot's normal position and line of vision when looking forward along the flight path.

Note 1: CDI displays contained in the CDU will most likely not be acceptable for IFR operations.

Note 2: Flight Technical Error (FTE) can be reduced when numeric display information is integrated with the non-numeric display or is located within the pilot's primary field of view. Both digital crosstrack and track angle error have been shown to reduce FTE. This information should be displayed together (either within the CDU or remotely displayed near the non-numeric display) for better tracking performance. The use of non-numeric crosstrack data integrated with nonnumeric track angle error data into one display may provide the optimum of situation and control information for the best overall tracking performance.

(4) Failure protection. Any probable failure of the airborne GPS navigation system shall not degrade the normal operation of other required equipment or create a flight hazard. Likewise, normal operation of the GPS equipment installation shall not adversely affect the performance of other aircraft equipment. The interfaces with other aircraft equipment must be designed such that normal or abnormal GPS equipment operation shall not adversely affect the operation of other equipment nor shall normal or abnormal operation of other equipment adversely affect the GPS equipment operation.

(5) Environmental conditions. The aircraft environment in which the GPS system is installed shall be found to be compatible with the environmental categories (or criteria) in RTCA/DO-160C to which the equipment was tested.

(6) Electromagnetic compatibility. The GPS navigation system should not be the source of objectionable electromagnetic interference, nor be adversely affected by electromagnetic interference from other equipment in the aircraft.

(i) The GPS equipment should be shown to meet the 2D accuracy requirements of this AC when subjected to a radiated signal with continuous wave (cw) modulation at a frequency of 1.57542 GHz and an electric field strength of 20 mv/meter measured at the exterior case of the GPS receiver. The radiated susceptibility test procedures of RTCA/DO-160C, Section 20, should be followed when conducting this test. The test should be conducted with simulated satellite inputs and should not result in the loss of track of any satellite used for navigation. The duration of the test must be sufficient to determine if tracking has been lost (20 seconds should normally be long enough, depending on the coasting features used by the GPS equipment). This test will usually be conducted by the GPS equipment manufacturer, but if not, the applicant is responsible for conducting the test.

(ii) Intermodulation effects are possible between multiple channel SATCOM installations and GPS. GPS equipment should not be installed in aircraft with multiple SATCOM channels unless the SATCOM equipment is modified to prevent simultaneous use of interfering frequencies. Current multichannel SATCOM equipment has not been modified in this manner and should not be installed with GPS equipment. In addition, certain GPS manufacturers have been granted a deviation to the requirements of TSO-C129 and will include a limitation in their installation instructions that states that the GPS equipment can not be installed in aircraft with SATCOM equipment. If such GPS equipment is installed in an aircraft the TC, STC, or ECAA approval should appropriately limit the future installation of SATCOM equipment in the aircraft.

(iii) Harmonic interference from VHF transmissions on 121.150, 121.175, 121.200, 131.250, 131.275, and 131.300 MHz may adversely affect reception of the GPS signal if less than 100 dB isolation is provided. Low pass or notch filters installed at the output of the VHF transmitter to attenuate the undesired VHF signal should have an insertion loss of 2 dB or less to preclude the need for re-evaluation of installed VHF transceiver performance.

(7) Anti-ice protection. If the aircraft in which the GPS equipment is installed is approved for flight into known icing conditions, the antenna must be found not to be susceptible to ice buildup (that is, is installed in a nonicing location on the aircraft, or is of a sufficiently low profile that ice does not accumulate on the antenna). Alternatively, the GPS equipment can be shown to operate satisfactorily when the antenna is subject to icing provided there are no harmful effects, such as possible ingestion of accumulated ice or degradation in aerodynamic performance. (The effects of ice accumulation on the antenna, if any, can be found in the manufacturer's installation instructions.)

(8) System controls, displays and annunciator. All displays, controls, and annunciators must be readable under all normal cockpit conditions and expected ambient light conditions (total darkness to bright reflected sunlight). Night lighting provisions must be compatible with other cockpit lighting. All displays and controls must be arranged to facilitate equipment usage. Controls that are normally adjusted in flight shall be accessible and properly labeled as to their function. System controls and displays shall be designed to maximize operational suitability and minimize pilot workload. System controls shall be arranged to provide adequate protection against inadvertent system turnoff. Reliance on pilot memory for operational procedures shall be minimized.

(9) Navigation database. The GPS equipment shall incorporate an appropriately updateable navigation data base (in the WGS-84 or NAD-83 coordinate datum) containing at least the following location information in terms of latitude and longitude with a resolution of 0.01 minute or better for the area(s) in which IFR operations are to be conducted: all airports, VORs (and VORTACs), NDBs, and all named waypoints and intersections shown on en route and terminal area charts, Standard Instrument Departures (SIDs) and Standard Terminal Arrival Routes (STARs). For Class A() equipment, the navigation data base must also include all waypoints and intersections included in published no precision instrument approach (except localizer, LDA, and SDF) procedures. Instrument approaches must be conducted using a current database. User entry or modification of navigation data base data shall not be possible. (This does not preclude the storage of "user defined data" within the equipment.) Additional data base coding, storage, and approach waypoint presentation requirements as specified in TSO-C129 must be provided. Navigation data bases shall meet the standards specified in sections 3, 4, and 5 of RTCA/DO-200, "Preparation, Verification and Distribution of User Selectable Navigation Data Bases" and sections 2 through 7 of RTCA/DO-201, "User Recommendations for Aeronautical Information Services."

(10) Pressure/barometric altitude inputs. An appropriate input of pressure and/or barometric altitude must be provided to the GPS equipment.

(11) Manufacturer's instructions. The GPS equipment, including antenna, shall be installed in accordance with the instructions and limitations provided by the manufacturer of the equipment.

(c) IFR airworthiness approval:

There are two types of IFR airworthiness approval which differ significantly as to test requirements and data analysis.

(1) First time IFR airworthiness approval (for a particular type of GPS equipment). This type of approval refers to the very first time an applicant presents a particular (hardware and software configuration) model GPS navigation system for ECAA airworthiness installation approval and certification for IFR navigation use. The first approval of a particular GPS navigation system must be accomplished through the TC or STC process. Each new model of GPS equipment or significant changes (hardware or software) to existing equipment

shall undergo the same approval process as the original equipment. A first time approval is conducted in four phases:

(i) Foreign TC or STC evaluation. This phase consists of an ECAA review of the data contained in the TC or STC issued and approved a foreign Civil Aviation Authority. A review of the letter of authorization issued by the owner of the TC or STC authorizing the installer or operator to use the TC or STC. This phase consists of ensuring the TC or STC has considered and approved the following:

(A) Analysis of the manufacturer's procedures for development of software and review of supporting documentation.

(B) Verification of compliance with the appropriate environmental qualification standards and tests specified in RTCA/DO-160C.

(C) Verification of compliance with the minimum performance and operation standards applicable to Class A() equipment specified in TSO-C129.

(D) Analysis of failure modes and annunciations.

(E) Review of reliability data to establish that all probable failures are detected and that failure rates meet acceptable criteria.

(F) Evaluation of the ease of use of the controls and of the viewing ease (for example brightness, contrast, intensity, dimming, etc.) of the displays and annunciations from a human factors point of view.

(G) Review of installation and maintenance manuals. Special attention should be given to the manufacturer's instructions for locating the GPS antenna on the aircraft.

(H) Evaluation of the operator's manual (pilot's guide).

(ii) Aircraft installation data evaluation. Normally the manufacturer of the GPS equipment will provide an aircraft as a test bed for the first time installation approval. This approval will serve as a basis for subsequent installation approvals regardless of aircraft type or model. The following assessments are to be made:

(A) Review of installation drawings, wiring diagrams, and descriptive wiring routing.

(B) Evaluation of the cockpit layout of the installed equipment with emphasis on equipment controls, applicable circuit breakers (labels and accessibility), switching arrangement, and related indicators, displays, annunciator, etc.

(C) Analysis of a data flow diagram in order to review which equipment provides what data to which other equipment.

(D) Review of a structural analysis of the equipment installation, including antenna, in order to ascertain whether structural mounting, dynamic, and crash load requirements are satisfied.

(E) Review of an electrical load analysis in order to verify that the total electrical load requirements are within the capabilities of the aircraft's electrical generating system. Determine that the supplied electrical power is consistent with applicable equipment reliability requirements.

(F) Verification that the aircraft environment in which the GPS equipment is installed is appropriate to the environmental categories (or criteria) in RTCA/DO-160C to which the equipment has been tested.

(G) Evaluation of the antenna installation. It is important that the antenna be one that is approved for the particular type of GPS equipment installed. A critical aspect of any GPS installation is the installation of the antenna. Adequate isolation must be provided between the GPS antenna and any other transmitting antenna(s) installed on the aircraft. Shadowing by aircraft structure can adversely affect the operation of the GPS equipment. Typically, a GPS antenna is located forward of the wings on the top of the fuselage to minimize effects of the wings, tail, etc. during aircraft maneuvering. For installations on helicopters, the effects of the rotor blades on antenna performance must be considered.

Note: The GPS signal is typically below the value of the background noise. Electrical noise in the vicinity of the antenna can adversely affect the performance of the system. Antenna installation in close

proximity to traffic alert and collision avoidance system (TCAS), satellite communication (SATCOM), and other transmitting antennas (particularly "L" band) should be carefully evaluated for potential mutual interference.

(iii) Ground test evaluations. Static ground tests are conducted to verify the installed GPS equipment configuration (including the antenna) provides position data meeting the accuracy criteria specified in this AC. These tests shall cover a continuous period of 24 hours with a maximum sample interval of five minutes.

Note: The 24-hour ground accuracy test may be performed on the aircraft or by use of a representative mockup configuration. If a mockup test fixture is used, the entire installed GPS equipment configuration, including antenna, must consist of the hardware to be used in the installation and be representative of the installed system configuration.

(iv) Flight test evaluations. Flight tests are conducted to verify proper operation and accuracy of the GPS system in the aircraft. Flight tests should include at least the following:

Note: Required flight evaluations for the first-time airworthiness approval of a particular GPS system are accomplished by the operator with an ECAA representative observing the tests.

(A) Evaluation of the overall operation of the GPS equipment to include at least the following: the ability to readily create and modify a flight plan, perform "DIRECT TO" functions, hold at a designated waypoint, intercept and track to or from a waypoint on a selected course, turn anticipation, waypoint sequencing, and the general presentation of navigational data (depiction of the "TO" waypoint, distance to waypoint, estimated time of arrival, estimated time en route, ground speed, etc.).

(B) Review of various failure modes and associated annunciations, such as loss of electrical power, loss of signal reception, GPS equipment failure, autopilot/flight director response to GPS flags, etc.

(C) Evaluation of steering response while autopilot and/or flight director is coupled to the GPS equipment during a variety of different track and mode changes. This evaluation shall include, as applicable, transition from enroute to approach transition to approach modes and vice-versa. Additionally, all available display sensitivities shall be evaluated.

(D) Evaluation of displayed GPS navigation parameters on interfaced cockpit instruments such as HSI, CDI, distance display, Electronic Flight Instruments System (EFIS), moving maps, fuel management systems, etc.

(E) Assessment of all switching and transfer functions, including electrical bus switching, pertaining to the GPS installation.

(F) Evaluation to determine satisfactory Electromagnetic Compatibility (EMC) between the GPS installation and other onboard equipment (this test may be partially accomplished as a ground test).

Note 1: Particular attention should be given to other "L" band equipment, such as TCAS or SATCOM equipment, VHF transmissions on the frequencies (see NOTE 2 below), high frequency (HF) communications systems, and other transmitting equipment (ACARS, AFIS, Flightfone, etc.).

Note 2: Installation instructions for each GPS receiver installation shall include the requirement for verification of adequate isolation from the interference of VHF communication transceivers. These tests shall be conducted on the completed GPS installation by tuning each VHF transmitter to the frequencies listed below and transmitting for a period of 20 seconds while observing the signal status of each satellite being received. Degradation of individually received satellite signals below a point where navigation is no longer possible is not acceptable and will require that additional isolation measures (low pass or notch filters installed at the output of the VHF transmitter, additional spacing between the VHF transmitter and the GPS antenna, replacement of the

VHF transmitter with a unit having no excessive harmonic emissions, etc.) be included in the aircraft installation. Re-evaluation of installed VHF transceiver performance is not necessary if the filter insertion loss is 2 dB or less. The following VHF frequencies shall be evaluated:

121.150 MHz	131.250 MHz
121.175 MHz	131.275 MHz
121.200 MHz	131.300 MHz

(G) Evaluation of the accessibility of all controls pertaining to the GPS installation.

(H) Evaluation of the visibility of the controls, displays, and annunciators relating to the GPS installation during day and night lighting conditions. No distracting cockpit glare or reflections may be introduced and all controls must be illuminated for identification and ease of use. Night lighting shall be consistent with other cockpit lighting.

(I) Analysis of crew workload when operating the GPS equipment in association with other piloting requirements.

(J) Validate GPS accuracy in each operating mode by at least 5 low altitude overflights of one or more surveyed locations (ensure survey point coordinates are relative to WGS-84 or NAD-83). An acceptable method of conducting this accuracy demonstration is to accomplish low altitude (less than 100 feet AGL) overflight of a runway threshold and record the GPS position as the aircraft crosses the threshold. The system accuracy is the distance between the coordinate position determined by the GPS and the coordinate position of the surveyed location (runway threshold). Runway threshold coordinates may be obtained from the airport operator.

(K) Verify continuity of navigation data during normal aircraft maneuvering, including holding patterns and turns at up to at least 30 degrees of bank for one minute.

(L) Verify that Flight Technical Error (FTE) can be maintained at less than 1.0NM for enroute, 1.0NM for approach transition, and 0.25NM for approach operating modes both with and without autopilot and/or flight director use, as applicable.

(M) For equipment approved for approach, conduct a sufficient number of approaches and transitions from enroute to terminal to approach operations using the navigation data base to verify proper operation of the GPS navigation system in the approach environment. This evaluation should include at least: turn anticipation, waypoint sequencing, display sensitivity changes, annunciations, procedure turns at the Final Approach Fix (FAF), holding patterns at the missed approach holding fix, transitions from TO-FROM operation to TO-TO operation, heading legs after the Initial Approach Fix (IAF) to intercept the final approach course both before and after the FAF, and DIRECT TO operation before and after the IAF.

(2) Follow on IFR airworthiness installation approvals. This type of approval refers to installation approvals after a first time airworthiness approval of the particular GPS equipment has been issued. Follow on approvals may use the first time airworthiness approval with the written permission of the holder of the TC or STC, as a basis for installation approval.

(i) Unless otherwise provided, contact either the manufacturer or organization responsible for obtaining the first time airworthiness approval of the GPS equipment in order to:

(A) Obtain a sample airplane or rotorcraft flight manual supplement (or supplemental flight manual, if appropriate).

(B) Obtain verification of the equipment approval status, including antenna, software, autopilot/flight director interface, system integration requirements, etc.

(C) Discuss any problem areas and seek assistance in their solution.

(D) Verify that the design maximum operating speed for the GPS equipment is compatible with the maximum expected ground speed of the aircraft.

(E) Obtain written authorization to use the TC or STC.

(ii) If the aircraft is approved for flight in known icing conditions, verify the suitability of the antenna installation in accordance with the guidance specified in this AC.

(iii) Conduct a data evaluation similar to that outlined in this AC.

(iv) Conduct a functional flight evaluation covering the following items:

(A) Overall operation of the installed GPS equipment, including interface with other equipment in the aircraft.

(B) The effect(s) of GPS equipment failure (open circuit breaker), including autopilot/flight director response, if applicable.

(C) If interfaced with an autopilot and/or flight director, steering response while the autopilot and/or flight director is coupled to the GPS equipment.

(D) Displayed GPS navigation parameters on all interfaced cockpit instruments.

(E) The effect(s), if any, of switching and transfer functions, including electrical bus switching, pertaining to the GPS installation.

(F) Evaluation to determine satisfactory EMC between the GPS installation and other equipment as specified in this AC.

Note: Verification of adequate isolation from harmonic interference of VHF communication transceivers is required for installation of GPS navigation equipment in each individual aircraft. This test should be repeated if a VHF transceiver is replaced or added, or if a new or replacement VHF communications antenna is installed.

(G) Accessibility and visibility (day and night conditions) of all controls pertaining to the GPS installation.

(H) Validate GPS accuracy in each operating mode as specified in this AC.

(I) Verify continuity of navigation data during 360 degree left and right turns at 30 degrees of bank.

(J) Monitor displayed crosstrack error during enroute, and, if applicable, approach transition and approach operations to verify FTE is less than 1.0 nmi (enroute and approach transition) and 0.25 nmi (approach), both with and without use of the autopilot and flight director (if installed).

(K) For equipment approved for approach, conduct at least three published instrument approaches (retrieved from the data base) to verify proper operation of the equipment in the approach environment.

Note: Required flight evaluations will be conducted by the operator and observed by the ECAA.

21-3.17 Operational considerations

(a) Flight manual supplement:

An appropriate airplane or rotorcraft flight manual supplement (or, for aircraft without an ECAA approved flight manual, a supplemental flight manual) containing the limitations and operating procedures applicable to the equipment installed should be provided for each installation of GPS navigation equipment for IFR approval. A flight manual supplement or supplemental flight manual may be necessary for installations limited to VFR use only, depending upon the complexity of the installation and need to identify necessary limitations and operating procedures.

(b) Other navigation equipment required:

GPS equipment for IFR navigation is for use as a supplemental navigation system. The installation of GPS equipment does not affect the requirement for a primary means of navigation appropriate to the route intended to be flown. Within most land areas and surrounding coastal waters, this requirement can be met with an operational, independent VOR receiver. Additional navigation equipment redundancy may be required for operation in oceanic and remote airspace.

(c) Alternate airport requirements:

The pilot-in-command should only select an Airport as a destination alternate Airport if an instrument approach procedure that does not rely on GNSS / GPS is available either at that Airport or at the destination Airport .

Notice :

- The limitation applies only to destination alternate Airports for flights when a destination alternate Airport is required. A take-off or en route alternate Airport with instrument approach procedures relying on GNSS / GPS may be planned without restrictions. A destination Airport with all instrument approach procedures relying solely on GNSS / GPS may be used without a destination alternate Airport if the conditions for a flight without a destination

- The term 'available' means that the procedure can be used in the planning stage and complies with planning minima requirements.

(d) alternate aerodrome are met

(e) Operational area:

Operators and their crews must consult the approved flight manual supplement for their aircraft to determine approved operational areas that may apply to particular systems. Crews must be aware that operational areas for different systems may be different, and the appropriate operating area(s) for a particular system can only be determined by reference to the approved flight manual supplement or other ECAA approved documents.

21-3.19 Procedure for obtaining ECAA approval.

The applicant requesting VFR or IFR GPS equipment installation approval should:

(a) Prepare and present ECAA Form 1120-104 with all required data to the ECAA.
Note: The applicant should contact either the manufacturer or organization responsible for obtaining the first time airworthiness approval of the GPS equipment in order to obtain approval for use, all required data and a sample airplane or rotorcraft flight manual supplement (or supplemental flight manual), if required for the aircraft.

(b) Schedule a meeting with ECAA to review all required data and obtain ECAA verification of the equipment approval status, including antenna, software, etc.
If satisfactory, the ECAA will approve and monitor the installation.
Note: It is the responsibility of the person(s) performing the alteration to ensure that the equipment and its installation satisfies all interference immunity requirements and that mutual compatibility with other equipment and systems is maintained. The applicant must show evidence that such tests and/or analyses were satisfactorily conducted to ensure interference immunity and mutual compatibility.

(c) The applicant will conduct a functional ground and flight evaluation with ECAA participation.

(d) Provide the ECAA with the final data and installation package that includes all test results.

APPENDIX 1

21-3.abb.21 Glossary

(a) Availability. The availability of the GPS system is the percentage of time that the services of the GPS system are usable. Availability is an indication of the ability of the system to provide usable service within the specified coverage area. Signal availability is the percentage of time that navigational signals transmitted from the satellites are available for use.

(b) Barometric altitude. Altitude in the earth's atmosphere above mean standard sea level pressure datum, measured by a pressure (barometric) altimeter and corrected for local barometric pressure setting.

(c) Differential GPS. A technique used to improve GPS system accuracy by determining positioning error from the GPS satellites at a known fixed location and subsequently transmitting the determined error, or corrective factors, to GPS users operating in the same area.

(d) Distance Root Mean Square (DRMS). The root-mean-square value of the distances between the measured and true location in a collection of measurements. The two dimensional circular error distribution, where 95 percent of the position solutions must lie within the defined radius of the circle, is represented by two times the DRMS (2 DRMS).

(e) Enroute operations. The phase of navigation covering operations between departure and arrival terminal phases. The enroute phase of navigation has two subcategories: enroute domestic and enroute oceanic/remote.

(f) Enroute domestic. The phase of flight between departure and arrival terminal phases, with departure and arrival points within Cairo FIR.

(g) Enroute oceanic and remote. The phase of flight between the departure and arrival terminal phases, with an extended flight path over an ocean.

(h) Flight Technical Error (FTE). Navigation error introduced by the pilot's (or autopilot's) capability to utilize displayed guidance information to track the desired flight path.

(i) Geometric altitude. Altitude above the surface of the WGS-84 ellipsoid.

(j) Geometric Dilution of Precision (GDOP). A measure of the satellite geometric effects that degrade a user's position determination.

(k) GPS equipment classes A(), B(), and C(). GPS equipment is categorized into the following classes (ref. TSO-C129):

(1) Class A (). Equipment incorporating both the GPS sensor and navigation capability. This equipment incorporates receiver autonomous integrity monitoring (RAIM). Class A1 equipment includes enroute, terminal, and no precision approach navigation capability. Class A2 equipment includes enroute and terminal navigation capability only.

(2) Class B (). Equipment consisting of a GPS sensor that provides data to an integrated navigation system (that is, flight management system, multi-sensor navigation system, etc.). Class B1 equipment includes RAIM and provides enroute, terminal, and no precision approach capability. Class B2 equipment includes RAIM and provides enroute and terminal capability only. Class B3 equipment requires the integrated navigation system to provide a level of GPS integrity equivalent to RAIM and provides enroute, terminal, and no precision approach capability. Class B4 equipment requires the integrated navigation system to provide a level of GPS integrity equivalent to RAIM and provides enroute and terminal capability only.

(3) Class C (). Equipment consisting of a GPS sensor that provides data to an integrated navigation system (that is, flight management system, multi-sensor navigation system, etc.), which provides enhanced guidance to an autopilot or flight director in order to reduce flight technical error. Installation of Class C() equipment is limited to aircraft approved under 14 CFR part 121 or equivalent criteria. Class C1 equipment includes RAIM and provides enroute, terminal, and no precision approach capability. Class C2 equipment includes RAIM and provides enroute and terminal capability only. Class C3 equipment needs the integrated navigation system to provide a level of GPS integrity equivalent to RAIM and provides enroute, terminal, and no precision approach capability.

Class C4 equipment requires the integrated navigation system to provide a level of GPS integrity equivalent to RAIM and provides enroute and terminal capability only.

(l) Horizontal Dilution of Precision (HDOP). A measure of the satellite geometric effects which degrade a user's horizontal position determination.

(m) Integrity. The probability that the system will provide accurate navigation as specified or timely warnings to users when GPS data should not be used for navigation.

(n) Mask angle. A fixed elevation angle referenced to the user's horizon below which GPS satellites are ignored by the receiver software.

(o) Nonprecision approach operations. Those flight phases conducted on charted Instrument Approach Procedures (IAPs) commencing at the initial approach fix and concluding at the missed approach point or the missed approach holding fix, as appropriate.

(p) Pressure altitude. Altitude in the earth's atmosphere above mean standard sea level pressure datum plane, measured by a pressure (barometric) altimeter set to standard pressure (29.92 inches of mercury).

(q) Pseudo-range. The distance from the user to a satellite plus an unknown user clock offset distance. With four satellite signals it is possible to compute position and offset distance.

(r) Receiver Autonomous Integrity Monitoring (RAIM). A technique whereby a civil GPS receiver/processor determines the integrity of the GPS navigation signals using only GPS signals or GPS signals augmented with altitude. This determination is achieved by a consistency check among redundant pseudo-range measurements. At least one satellite in addition to those required for navigation must be in view for the receiver to perform the RAIM function.

(s) Stand alone GPS navigation system. Stand alone GPS equipment is equipment that is not combined with other navigation sensors or navigation systems such as DME, Loran C, Inertial, etc. Stand alone GPS equipment can, however, include other augmentation features such as altimetry smoothing, clock coasting, etc.

(t) Supplemental air navigation system. An ECAA approved navigation system that can be used for navigation provided an alternate navigation system, which meets all of the regulatory requirements for the route of flight, is also installed on the aircraft.

(u) System availability. The percentage of time (specified as 98 percent) that at least 21 of the 24 GPS satellites must be operational and providing a usable navigation signal.

(v) Terminal area operations. Those flight phases conducted on charted SIDs on STARs, or other flight operations between the last en route fix/waypoint and an initial approach fix/waypoint.

(w) Track Angle Error. Track angle error is the difference between the desired track and actual track (magnetic or true).