Publication of Duncan Aviation

STRAIGHT TALK ABOUT WAAS/LPV

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DUNCAN AVIATION

www.DuncanAviation.aero/straighttalk

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EDITOR'S NOTE

A lot has changed since we published the first version of our Straight Talk About WAAS booklet in 2009. WAAS (Wide Area Augmentation System) was a relatively new proposition with great potential for all of aviation in the United States, with immediate benefits mainly for those who flew off the beaten paths or to less-popular airports. However, with congressional approval for the reorganization of the national airspace system and the mandatory avionics upgrades which have been enacted as a result, WAAS has again become a very relevant topic. In addition, the worldwide reorganization of inter-continental and trans-oceanic routes using ADS-B (Automatic Dependent Surveillance Broadcast) and FANS-1/A (Future Air Navigation System) is solely reliant upon hyper-sensitive WAAS GPS information.

In September 2007, the FAA commissioned WAAS GPS systems for use in the United States for IFR (Instrument Flight Rules) approaches. This long-awaited upgrade to GPS satellite navigation was a critical step in what is now known as NextGen. WAAS has become more than the main factor in the phasing out of ILS (Instrument Landing System) and VOR/NDB (VHF Omnidirectional Range/Non-Directional Radio Beacon) approaches, or even the emergence of WAAS GPS precision approaches at nearly all of the US public use airports. The FAA Flight Inspection Group is processing approximately 300 runway thresholds each year. WAAS has become the basis for the lateral reorganization of the entire domestic US airspace system. RVSM (Reduced Vertical Separation Minimum) was the first step in the vertical reorganization back in the early 2000s. The objective, as you know, is to put more aircraft safely into the same airspace by using the available technology. So why is WAAS important to business aviation operations?

- WAAS GPS sensors are the basis for the information needed by mandated ADS-B equipment
- WAAS enhances en route navigation and non-precision approach performance over GPS only
- WAAS allows operators to fly LNAV/VNAV (Lateral Navigation/ Vertical Navigation) procedures as low as 300 feet
- WAAS allows operators to fly LPV (Localizer Performance with Vertical Guidance) non-precision approaches and offers better missed approaches
- WAAS can use GPS as an alternate long-range navigation system
- WAAS eliminates RAIM (Receiver Autonomous Integrity Monitoring) prediction checks

The physical installation of a WAAS GPS system is only one piece of the process that is required to make the system of use to you, the business aviation operator. There have been some significant changes to the approval and certification process as well. Each of the subsequent topics will be covered in this publication:

- WAAS equipment selection, physical installation and modifications to existing equipment
- The certification and approval process for WAAS equipment in the aircraft
- The operational approval process
- The relationship between WAAS and ADS-B

Much has been written on the WAAS GPS topic and is available online. We believe our efforts in finding and condensing this information should address many of your concerns on installing and using WAAS GPS in your aircraft.

Duncan Aviation acknowledges the FAA WAAS groups, the FAA engineering and safety groups, Raytheon Corporation as the provider of the ground infrastructure, and the avionics manufacturers who are working on the products to make your flying safer, easier, and affordable.

An updated version of this Straight Talk booklet will be available online at www.DuncanAviation.aero/ /resources/ straight-talk/. Please use this information for your planning. Feel free to call us with any questions or comments.

WAAS WORKSHEET

The information on the WAAS Worksheet will be very useful when we discuss your WAAS/LPV and ADS-B options. To help us fully understand your current avionics systems, please attach photos of your flight deck. Refer to our locations map on page 29 to speak to a Duncan Aviation avionics expert near you.

1. Company
2. Location
3. Name Phone
   Cell
   E-mail
4. Aircraft Make Model
5. Serial Number Registration #
6. Type of FMS or GPS currently installed
7. Number of FMS or GPS installed (circle one) 1 2 3
8. Flight deck or avionics suite
9. Any existing flight deck modification syou think may be relevant

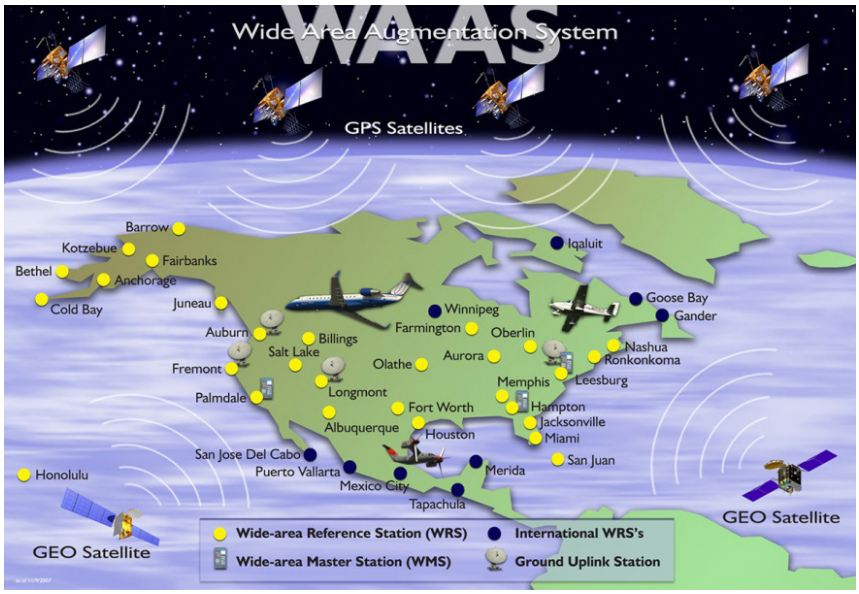
10. ATC Transponder type currently installed
11. TCAS system currently installed
12. Part 91 Part 135
13. Areas of Operation or Special Needs

WHAT IS WAAS?

In 2007, the FAA completed and certified a significant upgrade to the GPS system. This new WAAS system uses a network of more than 25 precision ground stations to provide corrections to the GPS navigation signal. The network of precisely surveyed ground reference stations is strategically positioned across North America, including Alaska, Hawaii, Puerto Rico, Canada, and Mexico, to collect GPS satellite data. Using this collected error information, a 'message' is developed to correct any signal errors. These correction messages are then broadcast through communication satellites to the airborne GPS receiver using the same frequency as GPS.

WAAS is designed to provide the accuracy, availability and integrity necessary to allow flight crews to rely on GPS for all phases of flight, from en route through GPS precision approach for all qualified airports within the WAAS coverage area. This provides a capability for the development of more standardized precision approaches, missed approaches, and departure guidance for approximately 4,100 ends of runways and hundreds of heliport/helipads in the US airspace.

WAAS will also provide the capability for increased accuracy in position reporting, allowing for more uniform and high-quality worldwide air traffic management. WAAS is a critical part of the FAA's NextGen program because the precise navigation information the onboard receivers process are being used by ADS-B and FANS-1/A solutions under development and those already developed.



This graphic depicts the WAAS infrastructure, two geostationary satellites, the U.S. ground reference stations and the international reference stations (Canada & Mexico). The GPS satellites at the top of the graphic represent the legacy network augmented by WAAS.

WAAS Overview

First, a few common acronyms explained. An expanded glossary can be found on page 22:

WAAS – GPS Wide Area Augmentation System
LPV Approach – Localizer Performance with Vertical guidance approach offering the lowest minimums of GPS systems. It is a non-precision approach using WAAS GPS.
LP Approach – Localizer Performance, no vertical guidance from GPS
LNAV/VNAV Approach – Designed for GPS/FMS equipment using baro altimeter data for vertical guidance

GPS has been widely used for aircraft navigation since the 1980s. While GPS is dramatically more accurate than the VLF/Omega/LORAN systems in use at that time, GPS was originally designed as a military system and was not FAA-certified for use as a sole means of navigation. As the Cold War was nearing its end, President Reagan released the system for civil use, followed by President Bill Clinton ending Selective Availability (SA) in an effort to make GPS more attractive for commercial uses.

With the much improved accuracy of GPS without SA and the demise of VLF/Omega, the FAA published Advisory Circulars that allowed GPS to be used for primary means of navigation, domestic and oceanic. But a greater need for GPS was evident, that of GPS precision approaches. On its own, GPS accuracy and reliability was not adequate to supplement or replace ILS/Localizer approaches.

The FAA proposed two upgrades to the GPS system. The first was for WAAS, a ground-based, satellite linked correction system with improved accuracies over wide geographic areas SBAS (Satellite-Based Augmentation System. The second is LAAS, a local (GBAS) Ground Station Broadcasting radio signals for a very limited area with better accuracy than WAAS. The FAA underestimated and Congress under-funded both WAAS and LAAS programs so both programs struggled in development.

In time, the FAA refined its plan and Congress funded WAAS. After years of hard work, the FAA announced WAAS as operational in 2003. WAAS leased space on a couple of existing satellites to prove the concept was valid and to work out the bugs. Those existing satellites were

not ideally located or equipped to make WAAS useable for precision approaches. However, GPS was being used for overlay approaches. The most important news on WAAS came in September of 2007. FAA and prime contractor, Raytheon, announced the commissioning of two new geostationary satellites for WAAS. These satellites are ideally positioned so that operators in North America have redundancy. In addition, each of these satellites broadcast an additional signal that GPS receivers will use to improve their overall accuracy. As the United States Air Force replaces the earlier GPS satellites with new Block II/III versions that have higher power and added reliability, better positional accuracy will be implemented.

Perhaps this summary will make it easier:

- Every IFR-certified and installed GPS unit allows the pilot to descend to LNAV (or Straight-in) and circling approaches
- Baro-VNAV-equipped GPS systems can also descend to LNAV/VNAV minima
- WAAS GPS receivers can descend to LNAV, LNAV/VNAV and LPV minima
- The real push for GPS LPV Non-Precision Approaches had begun

CAN SOMEONE PLEASE QUICKLY EXPLAIN ALL OF THESE APPROACH TYPES?

LPV (Localizer Performance with Vertical guidance) –is the most desired approach. It is similar to LNAV/VNAV except it is much more precise (40m lateral limit), enables descent as low as 200-250 feet above the runway and can only be flown with a WAAS receiver. LPV approaches are operationally equivalent to the legacy ILS, but are more economical because no navigation infrastructure has to be installed at the runway. There are over 3,600 LPV approaches in use today, serving nearly 1,700 airports. Over 1,000 of those airports are without ILS.

LP (Localizer Performance) –is a recent NPA procedure that uses the WAAS precision of LPV for lateral guidance and barometric altimeter data for vertical guidance. These approaches are needed at runways where, due to obstacles or other infrastructure limitations, a vertically guided approach (LPV or LNAV/VNAV) cannot be published. LP approaches can only be flown by aircraft equipped with WAAS receivers. The minimum descent altitude for the LP approach is expected to be approximately 300 feet above the runway.

LNAV/VNAV (Lateral Navigation/Vertical Navigation) –approaches use lateral guidance (556m lateral limit) from GPS and/or WAAS and vertical guidance provided by either the barometric altimeter or WAAS. Aircraft that don't use WAAS for the vertical guidance portion must have VNAV-capable altimeters, which are typically part of a FMS (Flight Management System). When the pilot flies an LNAV/VNAV approach, lateral and vertical guidance is provided to fly a controlled descent and a safer maneuver to the runway. The decision altitudes on these approaches are usually 350 feet above the runway.

GPS NPA (LNAV) refers to a Non-Precision Approach procedure which uses GPS and/or WAAS for LNAV). On an LNAV approach, the pilot flies the final approach lateral course, but does not receive vertical guidance for a controlled descent to the runway. Instead, when the aircraft reaches the final approach fix, the pilot descends to a minimum descent altitude using the barometric altimeter. LNAV approaches are less precise (556m lateral limit) and therefore usually do not allow the pilot to descend to as low an altitude above the runway. Typically, LNAV procedures achieve a MDA (minimum descent altitude) of 400 feet height above the runway.

WHAT IS THE TYPICAL LPV APPROACH PROCEDURE?

The charts below depict a typical published LPV approach procedure. The title denotes the approach as an RNAV (Area Navigation) procedure. Notice that each RNAV procedure typically includes three of the approach types previously described. This is done to ensure that as many aircraft as possible, of different types and with different equipment, can fly the approach and to provide operational flexibility if WAAS becomes unavailable.

Some aircraft may only be equipped with standard GPS receivers. They can fly to the LNAV decision altitude. Aircraft equipped with GPS and FMS can fly to the LNAV/VNAV decision altitude. WAAS-equipped aircraft certified for LPV can fly to LPV decision altitude. If for some reason the WAAS service becomes unavailable, all GPS or WAAS-equipped aircraft revert to the LNAV decision altitude and land safely using GPS-only.

WAAS OPERATIONAL FACTS

THE OPERATION OF WAAS GPS EQUIPMENT REQUIRES:

- Your FAA Approved Aircraft Flight Manual and Flight Manual Supplement
- The equipment manufacturer's operating/instruction manual
- FAA Aeronautical Information Manual
- Current WAAS NOTAMS
- Appropriate approach charts
- Appropriate training for the flight crew using WAAS procedures

ADVANTAGES OF USING WAAS GPS:

- Safety using lower minimums, LPV is typically 250 to 300 feet
- Accurate GPS meets air navigation performance requirements for precision approaches, non-precision approaches, en route and terminal phases of flight
- Better missed approaches
- Opens up thousands of WAAS approaches with thousands more to come
- Affords better weather minimums at many of the airports (some are LPV200 as low as 200 feet)
- Removes the GPS RAIM FDE checking requirement
- Removes the Low Temperature Approach requirement
- Increases airspace capacity under the FAA's NextGen programs with ADS-B

The FAA has announced the decommissioning of some existing Navaids including NDBs, Cat1 ILS, VORs and Marker Beacons. Watch your charts to see these changes.

Charting LPV

WAAS Channel Number: CH 97307

WAAS Channel Number is a reference number assigned to each approach chart.

Some of the WAAS FMSes will provide a shortcut to the chart.

WAAS Approach ID: W13A

W: WAAS

13: Runway 13

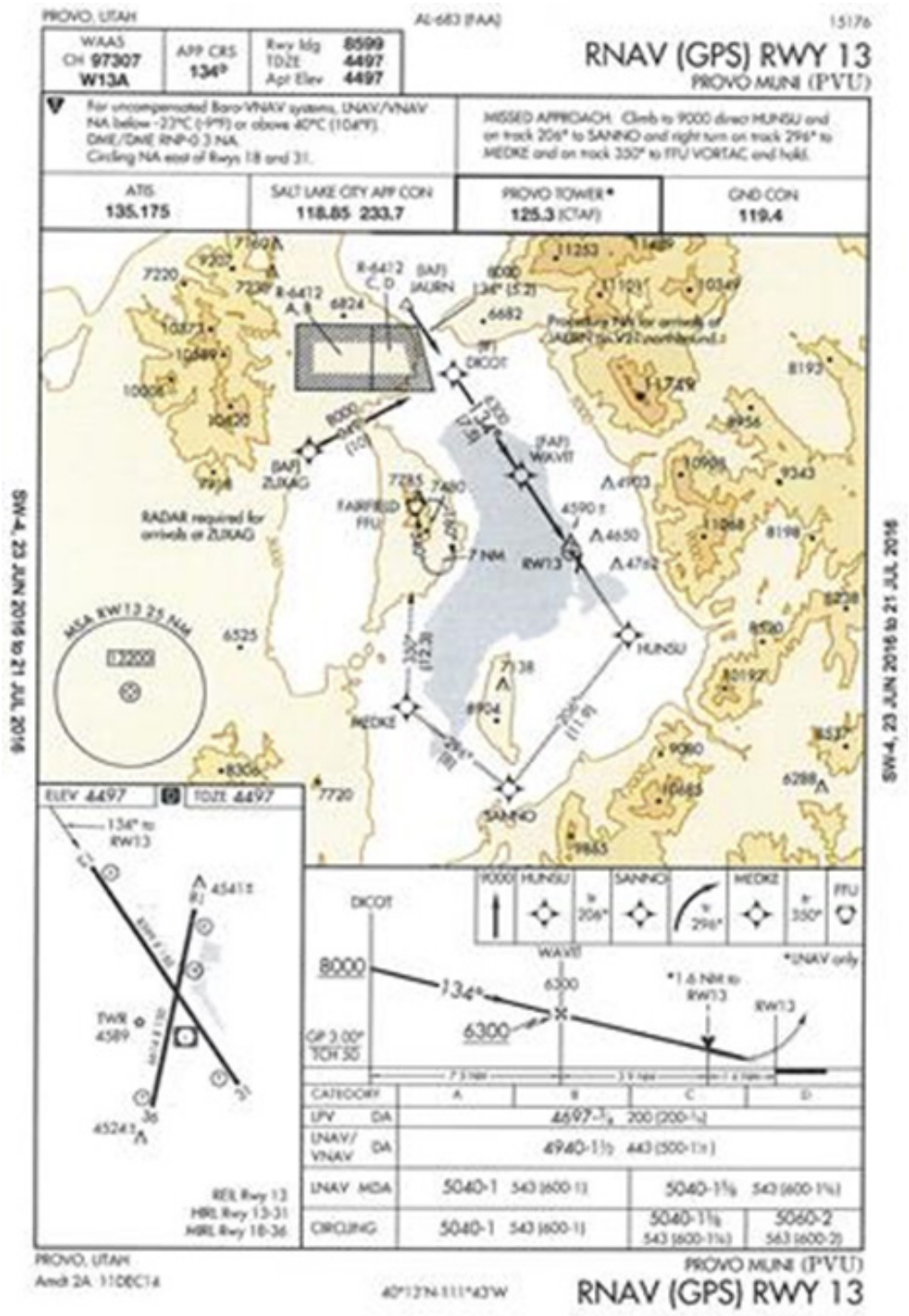
A: 1st WAAS Approach to RWY 13

Temperature Restriction

Does Not Apply if using WAAS Equipment

LPV Minimum Line

273 ft.



WAAS UPGRADES

UPGRADE SOLUTIONS

With the changes in regulation regarding the Engineering Assisted Field Approval, the challenge of performing every WAAS upgrade in accordance with an STC (Supplemental Type Certificate) has been minimized. The Engineering Assisted Field Approval option has certainly made WAAS upgrades with Universal equipment a lot simpler. Duncan Aviation has performed WAAS upgrades in accordance with this method several dozen times since it became an option in 2012. That list of aircraft includes a broad sampling of aircraft across the spectrum.

Because the upgrade to WAAS GPS and ADS-B is something the FAA really has a passion for, this Engineering Assisted Field Approval method has become quite popular.

WAAS UPGRADES AND EASA

At this time, WAAS upgrades performed in accordance to the Engineering Assisted Field Approval are not recognized by EASA. All operators who are planning or may be planning to sell to or change the aircraft registration to a EASA-member country may want to have the modification conformed to an existing STC or be recertified in accordance with its own STC. This is definitely something to consider on the front end of the upgrade.

Similar conditions apply when considering an ADS-B solution for your aircraft. As of this printing, an ADS-B solution for a particular aircraft must meet several guidelines established through existing STCs. One of those guidelines is what is known as the pairing of the new ADS-B equipment with the new, or previously modified WAAS equipment already installed in the aircraft. This means that while the whole modification can be field-approved with an FAA office, the data showing the aircraft's WAAS GPS receiver has been proven to communicate properly with the ADS-B capable Mode S Transponder. The only way to attain that proof is through the STC process.

Because of our many OEM Authorized Service Center agreements, we have access to STCs or factory service bulletin solutions for nearly every make/model business aircraft flying today. We also have access to the vast library of solutions owned by the avionics manufacturers, such as Universal Avionics, Rockwell Collins, Honeywell, Bendix-King, Garmin, and Freeflight. Duncan Aviation's ODA has developed or assisted in the development of many STCs;

including the Bombardier Challenger 601-3A/3R, Bombardier Learjet 45, Hawker 800 Series, Cessna 560 Series, and more.

Please feel free to contact any Duncan Aviation representative located on the map on page 27 of this booklet to discuss the many options you have for upgrading to WAAS GPS in your aircraft. The information collected from the WAAS Worksheet on page 5 will be critical to putting together an accurate proposal. There will likely be more than one option for you, so please feel free to call or email.

WAAS GPS CAPABLE UNITS

The selection of the WAAS units for installation in Part 25 aircraft depends on a number of factors:

- Dual systems may be required to meet FAR 25.1309 & AC 25.1309-1A
- Panel or pedestal mount systems must meet Class 3, TSO C145a – Airborne Navigation Sensors using the GPS augmented by WAAS
- Multiple box FMS systems with remote WAAS receiver must meet Class 3, TSO C146a – Stand Alone Airborne Navigation Equipment Using the GPS Augmented by WAAS
- What is the mission? There are now GPS WAAS sensors built specifically to feed navigation information to ADS-B and FANS-1/A systems, without any connection to onboard FMS systems
- The existing avionics, flight director and autopilot

The installation and certification of the WAAS units for LPV approaches must be done in accordance with the following documents:

- The WAAS/FMS equipment manufacturer's installation manual
- AC 43.13-2B [Large Aircraft] Acceptable Methods, Techniques and Practices–Aircraft Alterations
- AC 20-138D Airworthiness Approval of GPS Navigation Equipment for Use as a VFR and IFR Navigation System
- AC 90-94 "Guidelines for Using GPS Equipment"
- FAA Order 8900.1 Flight Standards Information Management System (FSIMS) Volume 4. Aircraft Equipment and Operational Authorizations, Chapter 1. Air Navigation, Communications and Surveillance
- Universal Avionics Report No. RPRT-2009-1004: Engineering Assisted Field Approval Process for the Installation Upgrade of Universal Avionics FMS Approved for 3D Coupled Approaches to Universal Avionics SBAS FMS with LPV Approach Capability

Initially, the approval process for GPS WAAS installation with LPV approach capability was strictly through the STC process in the case of a retrofit aircraft, and a TC or factory Service Bulletin in the case of new or forward fit aircraft.

Over time, and with assistance from the avionics industry, specifically Universal Avionics Systems Corp, the FAA has accepted an "Engineering Assisted Field Approval" process by which aircraft that currently have Universal FMSes installed that are 3D coupled for pseudo ILS approaches, can be upgraded to the new Universal Avionics WAAS FMS with LPV approach capability via a more robust field approval process, and not STC, TC, or Service Bulletin. This opens up the availability and lowers the cost of upgrading to WAAS LPV.

Duncan Aviation has FAA-delegated authority as an STC and MRA (Major Repair and Alterations) ODA (Organization Designation Authorization). This designation allows Duncan Aviation to sign an STC for aircraft alterations on behalf of the FAA with the authority to approve design data, tests and analysis, as well as make a finding of compliance to the regulations. To support its ODA authorization, Duncan Aviation has a team of experienced avionics, structural, aeronautical, and systems engineers. The ODA allows Duncan Aviation to complete STCs for interior and airframe modifications and avionics system upgrades.

FAQS - WAAS EQUIPMENT AND OPERATION

IS WAAS AVAILABLE FOR MY AIRCRAFT?

Due to the evolution of FAA guidance in terms of WAAS-LPV equipment certification procedures, WAAS equipment is now available for most aircraft. Duncan Aviation has developed STC solutions for the new Universal UNS-1xW, Honeywell NZ- 2000 v6.1, Rockwell Collins and other GPS–based FMSes for most aircraft. We have performed hundreds of Engineering Assisted Field Approvals for our customers.

WHAT MUST BE ACCOMPLISHED TO INSTALL GPS WAAS EQUIPMENT IN MY AIRCRAFT?

For GPS WAAS, you must use equipment certified by TSO-C145a or TSO-C146a and have the installation certified via an appropriate STC or Engineering Assisted Field Approval.
Safe flight using GPS equipment depends on airworthiness:
1) Does it have the appropriate TSO?
2) Was it installed per AC 20-138 or AC 20-130a?
3) Is it certified properly?

IF I UPGRADE TO A WAAS GPS SYSTEM, IS THE AIRPLANE CERTIFIED TO FLY LPV APPROACHES?

Simply purchasing and installing WAAS-capable equipment in your aircraft isn't enough. WAAS capable avionics do not automatically mean that you can fly the LPV minima line. You must comply with the certification and operational requirements as well.

WHAT IS THE EXTENT OF A WAAS UPGRADE?

The GPS-based flight management system will require factory modification or replacement. There will likely be some relatively minor wiring modifications involved in most upgrades. Depending on the avionics platform in the aircraft, there may be some factory modification to the display or flight control systems. Also, because of the new WAAS TSOs, the antenna will require replacement. The new antenna may also have a different footprint and require approved structural modification. Certification and approval are the final steps.

IF WAAS LPV REQUIRES REDUNDANCY, WHAT IF I DO NOT HAVE ROOM FOR A SECOND SYSTEM?

Some equipment manufacturers offer an "LPV Monitor." An LPV Monitor is basically a remotely mounted WAAS GPS sensor unit that serves as the second system, providing the required redundancy. This unit can operate without a dedicated CDU (Control Display Unit) on the flight deck.

HOW IS WAAS/LPV ANNUNCIATED?

Annunciation for WAAS/LPV can be displayed on some of the newer EFIS (Electronic Flight Instrument System) displays or by using external annunciation as depicted below. If the EFIS manufacturer doesn't offer a modification upgrade path to provide the proper annunciation on the displays, an external annunciation will be required.

WHAT IS THE LINK BETWEEN WAAS AND ADS-B?

ADS-B equipment requires the hypersensitive GPS information that only a WAAS sensor can provide. The ADS-B equipment then processes that information and sends it back out, usually via a Mode S Transponder, to air traffic control. It's accurate to say that WAAS GPS is the backbone to all of the NextGen technologies such as ADS-B, Link 2000+, and FANS-1/A.

CAN MY AIRCRAFT BE EQUIPPED WITH ONLY GPS FOR NAVIGATION AND BE LEGAL FOR FLYING IN IMC (INSTRUMENTAL METEOROLOGICAL CONDITIONS)?

The FAA has authorized GPS as the primary means of navigation in certain areas (oceanic and remote). The FAA requires that the aircraft have the appropriate equipment necessary for the route of flight. Furthermore, a GPS approach cannot be used for the alternate if it is also used for the destination when using earlier TSO-C129 equipment. WAAS allows the use of GPS for alternates based on LNAV, LPV, LP, or better performance. Therefore, it may be legal to fly a GPS-only equipped aircraft in IMC, but the circumstances are quite rigorous.

WHEN I INSTALL WAAS EQUIPMENT, WHAT WILL MY RNP LEVEL BE?

RNP stands for Required Navigational Performance. It is a metric of system navigational capability. The FAA is moving toward a performance-based national airspace system as a part of NextGen. The objective will be to continue to place more aircraft into available space on the horizontal plane. Your RNP number will basically represent the accuracy of your installed and certified GPS system. In the future, your ability to fly in certain areas may be governed by your ability to achieve precise navigational performance within

specific tolerances. RNP-0.3 will be used for approaches and it refers to .3 nautical mile accuracy. This accuracy may be achieved through various means (GPS, WAAS, FMS using automatic DME updates), but your aircraft will be certified to a particular RNP.

WHERE CAN I FIND A CURRENT LIST OF WAAS APPROACH PROCEDURES?

The following FAA website is updated several times each year:
http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/navservices/gnss/approaches/index.cfm
The website lists the approaches that have been completed and published. When you receive the published approach chart and you have the proper equipment with the proper certification, you are ready to fly the approach. If you need the status of a particular approach, the FAA maintains a website which provides the production plan for future WAAS procedures over a five-year window. It is available online at:
https://www.faa.gov/air_traffic/flight_info/aeronav/procedures/

CAN I USE AN ALTERNATE WITH A GPS APPROACH?

If you have approved WAAS equipment, you may plan to use any instrument approach authorized for use with your WAAS avionics as a required alternate. You must use the LNAV minima line for planning purposes in case vertical guidance is not available. WAAS also removes the RAIM and FDE prediction requirements necessary with standard GPS navigation procedures.

WILL WAAS PROVIDE PERFORMANCE COMPARABLE TO ILS?

WAAS LPV approaches are non-precision approaches designed to provide performance comparable to Category 1 ILS. The WAAS minima are shown on each approach chart. The initial airport survey determines the minimum height above terrain allowed. Approaches are being added monthly. The chart below shows some interesting facts and figures about WAAS accuracy and performance. It's probably a lot of extra information, but helps with perspective.

WAAS ACCURACY PERFORMANCE

	GPS Standard	GPS Actual	WAAS LPV-200 Standard	WAAS LPV-200 Actual
Horizontal 95%	36 m	2.74 m	16 m	1.08 m
Vertical 95%	77 m	3.89 m	4 m	1.26 m

TABLE 1 REQUIRED PERFORMANCE

LPV Performance	Full LPV Reg
Availability	99%
HAL	40 m
VAL	50 m
95% Accuracy	Vertical 2.0 m
	Horizontal 1.5 m
Probability of HMI	10-7 per approach
Time to Alarm	6.2 sec
Coverage	100% of Continental U.S

TABLE 2 WAAS LPV (full Localizer Performance with Vertical Guidance)

	WAAS Requirements	WAAS Actual Measured Performance
LPV CONUS 99% Availability	100% of Continental U.S	100% of Continental U.S
LPV Alaska 95% Availability	75% of Alaska	88% of Alaska
Vertical Accuracy	2.0 m 95% bound	.95 m 95% bound
Horizontal Accuracy	1.5 m 95% bound	.60 m 95% bound
Time to Alarm	6.2 sec	6.2 sec
Probability of HMI	10-7	0

CAN I RELY ON WAAS TO NOTIFY ME IF THERE ARE PROBLEMS?

For safety reasons, every 6.2 seconds, WAAS processors take one of two actions:

1. Correct user position outside the guaranteed accuracy protection limits (integrity) to get back within the protection limits. If WAAS is able to correct misleading information within six seconds, there is no lapse in system integrity.
2. Shut-off connections and notify the user not to use. If the system is unable to correct misleading information in the six-second timeframe, it becomes HMI (Hazardously Misleading Information) and should not be used for navigation.

WHAT IS MEANT BY "WAAS INTEGRITY"?

Integrity refers to usability of the satellite signal and means that the signal has not been corrupted. Integrity is the ability of a system to provide timely warnings to users when the system should not be used for navigation as a result of errors or failures in the system. WAAS improves upon the integrity of the basic GPS signal and detects much smaller errors more quickly.

CAN WAAS BE USED OUTSIDE THE US?

Canada has granted approvals for WAAS-equipped aircraft.
Mexico is working on WAAS implementation.
The following Satellite Based Augmentation Systems are under development. Most are believed to be compatible with a common specification outlined by ICAO. Outside of the North American continent, WAAS approaches are not used at all. However, the more accurate and sensitive WAAS information is the basis for the navigation information required by ADS-B and FANS-1/A.

WHAT DOES THE ACRONYM APV MEAN?

APV is the ICAO (International Civil Aviation Organization) term for an Approach with Vertical guidance and it refers to specific ICAO criteria adopted in May 2000. This approach classification allows the use of stabilized descent using vertical guidance without the accuracy required for traditional precision approach procedures. The US has developed criteria for LNAV/VNAV and LPV approach procedures that meet this approach classification. The LNAV/VNAV and LPV approaches provide guidance in both the lateral and vertical planes.

HOW SECURE IS WAAS GPS?

In our electronic information age, security of our devices has become a major concern. WAAS GPS is no different. LORAN (Long-Range Navigation) will continue to be modernized and system responsibility has been placed within the Department of Homeland Security, which has chosen LORAN as the backup for national infrastructure elements that currently depend on GPS. Today, high-accuracy GPS timing is essential to such critical elements as communications, utilities, banking and transportation and a severe GPS outage today could be crippling nationwide.

The low-powered GPS signals can be jammed by hackers or other adversaries, whereas the updated eLORAN (for Enhanced LORAN) offers near-GPS timing accuracy, high-powered jam-resistant signals and totally different failure modes. eLORAN receivers could track every ground-based LORAN station within reception range, which could provide 25 or more position and timing sources. Standalone eLORAN aviation units appear unlikely, although some manufacturers envision small eLORAN chips embedded as backups inside future GPS units. In addition, the US military is replacing the original GPS satellites with higher-powered and more secure satellites. This will also add to the security of GPS signals.

FAQS - WAAS REGULATORY & CERTIFICATION

WHAT ARE THE APPLICABLE TSOS & ADVISORY CIRCULARS?

Applicable TSOs:

TSO-C109 (09-Dec-1985): Airborne Navigation Data Storage System

TSO-C115b (30-Sep-1994): Airborne Area Navigation Equipment using Multi-sensor Inputs

TSO-C115c (19-Jan-2012): Flight Management Systems (FMS) using Multi-sensor Inputs

TSO-C129a (20-Feb-1996): Airborne Supplemental Navigation Equipment Using The Global Positioning System (GPS)

TSO-C146c (09-May-2008): Stand-Alone Airborne Navigation Equipment Using the Global Positioning System Augmented by the Satellite Based Augmentation System

TSO-C166b (02-Dec-2009): Extended Squitter ADS-B (Automatic Dependent Surveillance – Broadcast) and TIS-B (Traffic Information Service–Broadcast) Equipment Operating on the Radio Frequency of 1090 MHz (Megahertz)

TSO-C190 (20-Mar-2007): Active Airborne Global Navigation Satellite System (GNSS) Antenna

ETSO-C109 (24-Oct-2003): Airborne Navigation Data Storage System

ETSO-C115b (24-Oct-2003): Airborne Area Navigation Equipment using Multisensor Inputs

ETSO-C129a (24-Oct-2003): Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS)

ETSO-C166b (07-May-2012): Extended Squitter ADS-B (Automatic Dependent Surveillance – Broadcast) and TIS-B (Traffic Information Service – Broadcast) Equipment Operating on the Radio Frequency of 1090 MHz (Megahertz)

Applicable Advisory Circulars and other references:

AC 20-138D (28-Mar-2014): Airworthiness Approval of Position & Navigation Systems

AC 20-165A (07-Nov-2012): Airworthiness Approval of ADS-B (Automatic Dependent Surveillance – Broadcast) Out Systems

AC 25-15 (20-Oct-1989): Approval of Flight Management Systems in Transport Category Airplanes

AC 90-45A (21-Feb-1975): Approval of Area Navigation Systems for use in the US National Airspace System

AC 90-100A (01-Mar-2007): US Terminal and RNAV (En-Route Area Navigation) Operations

AC 91-49 (23-Aug-1977): General Aviation Procedures for Flight in North Atlantic Minimum Navigation Performance Specifications Airspace

AC 120-33 (24-Jun-1977): Operational Approval of Airborne Long Range Navigation Systems for Flight within the North Atlantic Minimum Navigation Performance Specifications Airspace

EASA AMC 20-4: Airworthiness Approval and Operational Criteria For the Use of Navigation Systems in European Airspace Designated For Basic RNAV Operations

EASA AMC 20-5: Airworthiness Approval and Operational Criteria for the use of the NAVSTAR GPS (Global Positioning System)

EASA AMC 20-27A (12-Sep-2013): Airworthiness Approval and Operational Criteria For RNP APCH (RNP APPROACH) Operations including APV BAROVNAV Operations

EASA AMC 20-28 (24-Sep-2012): Airworthiness Approval and Operational Criteria related to Area Navigation for Global Navigation Satellite System Approach operation to Localizer Performance with Vertical guidance minima using Satellite Based Augmentation System

EASA AMC 20-12: Recognition of FAA Order 8400.12a For RNP-10 Operations

EUROCAE ED-102A (01-Jan-2012): MOPS for 1090 MHz Extended Squitter ADS-B (Automatic Dependent Surveillance – Broadcast) & TIS-B (Traffic Information Services – Broadcast)

JAA TGL-10 (11-Jan-2000): Airworthiness and Operational Approval for Precision RNAV Operations in Designated European Airspace

RTCA/DO-229D (13-Dec-2006): Minimum Operational Performance Standards for Global Positioning System/ Wide Area Augmentation System Airborne Equipment

RTCA/DO-236B (28-Oct-2003): Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation

RTCA/DO-254 (19-Apr-2000): Design Assurance Guidance for Airborne Electronic Hardware

RTCA/DO-283A (28-Oct-2003): Minimum Operational Performance Standards for Required Navigation Performance for Area Navigation
RTCA/DO-260B (02-Dec-2009): Extended Squitter ADS-B (Automatic Dependent Surveillance – Broadcast) and TIS-B (Traffic Information Service – Broadcast) Equipment Operating on the Radio Frequency of 1090 MHz (Megahertz)

Universal Avionics Report No. RPRT-2009-1004: Engineering Assisted Field Approval Process for the Installation Upgrade of Universal Avionics FMS Approved for 3D Coupled Approaches to Universal Avionics SBAS FMS with LPV Approach Capability

WHAT ARE THE DIFFERENCES BETWEEN THE WAAS ETSOS, TSOS, ACS, AMCS, STCS, ETC.?

An ETSO or TSO is a Technical Standard Order and it describes the minimum performance standard for a system or component. The E designates the document as one developed specifically for European use. For a WAAS system to be installed and certified properly, the equipment must meet the standards set forth in TSO-C145A or TSO-C146A. Most general aviation WAAS receivers will comply with TSO-C146A, which applies to panel or pedestal mounted navigation equipment, as opposed to sensors that provide data to a flight management system.
An AMC or an AC is a piece of regulatory guidance issued by an Aviation Authority. ACs are issued by the FAA, and AMCs are issued by EASA. These documents contain guidance necessary for the installation and subsequent certification of a particular system, in this case, WAAS GPS systems and equipment.
STCs are documents issued by the FAA approving an installation or modification. The STC defines the product design change, states how the modification affects the existing type design of the aircraft and lists applicable serial numbers of the aircraft affected by the modification.
Safe flight using GPS equipment depends on airworthiness:

1) Does the equipment meet performance standards set forth in the appropriate TSO?
2) Was the equipment installed in accordance with AC 20-138D or AC 20-130A?
3) Is the modification documented properly? Was it installed in accordance with a TC, STC, or Engineering Assisted Field Approval?

KEY TERMS

ADS-B (Automatic Dependent Surveillance – Broadcast)– An aircraft surveillance technology in which an aircraft determines its position using the accuracy of WAAS GPS signals and periodically rebroadcasts it, enabling it to be tracked by ATC (Air Traffic Control) as a replacement for secondary radar. It can also be received by other aircraft to provide situational awareness and allow self-separation.

APV (Approach with Vertical Guidance) – There are three approach categories: Precision, Non-Precision, and APV. APV approaches are an ICAO recognized term for an approach using a navigational system for course and glidepath deviation, but not to the standards of a Precision Approach. An example would be Barometric VNAV.

EGNOS (European Geostationary Navigation Overlay Service)—is an SBAS developed by the European Space Agency, the European Commission, and EUROCONTROL. It supplements the GPS, GLONASS and Galileo systems by reporting on the reliability and accuracy of the positioning data. It is very similar to WAAS GPS.

Engineering Assisted Field Approval - Universal Avionics Systems, in conjunction with the FAA, have established an Engineering Assisted Field Approval process for aircraft that currently have Universal FMSes that are 3D coupled for pseudo ILS approaches installed. This robust field approval process allows these aircraft to be upgraded to the new Universal Avionics WAAS Flight Management Systems with LPV approach capability. Refer to Universal Avionics Report No. RPRT-2009-1004, Engineering Assisted Field Approval Process for the Installation Upgrade of Universal Avionics FMS Approved for 3D Coupled Approaches to Universal Avionics SBAS FMS with LPV Approach Capability.
FANS-1/A (Future Air Navigation System)—is a range of avionics systems which provide direct data link communication between the pilot and the ATC. The communications include ATC clearances, pilot requests, and position reporting. ATC services are now

provided to aircraft equipped with FANS-1/A in other Oceanic airspaces such as the North Atlantic. Although many of FANS-1/A's known deficiencies with respect to its use in high density airspace were addressed in later versions of the product (FANS-1/A+), it has never been fully adopted for use in continental airspace.

GAGAN (GPS-Aided GEO Augmented Navigation) is an SBAS implemented by the Indian government. It is a system developed to improve the accuracy of a GNSS (Global Navigation Satellite System) receiver by providing reference signals. Similar to WAAS GPS.

GBAS (Ground Based Augmentation System). A LASS (Local Area Augmentation System) where GPS correction signals are sent to the aircraft from ground based transmitters.

GPS NPA (Non-Precision Approach) is a procedure that uses GPS and/or WAAS for LNAV.

GPS Overlay Approach – These procedures, available in 1994, authorized use of approved GPS receivers to fly existing non-precision instrument approaches. The only difference was that course guidance could come from the GPS system. These procedures are identified with or GPS in the title. The advantage for these procedures was twofold. First, overlay approaches provide the aviator greater position awareness than using the ground NAVAID. Second, although they didn't provide lower minima, GPS overlays also introduced and validated GPS approaches to aviation. This initial validation was critical for future GPS improvements.

GRAS (Ground Based Augmentation System) is a system in Australia that uses VHF ground based transmitters instead of satellites for the GPS augmentation. The compatibility with WAAS has not been determined.

HMI (Hazardously Misleading Information)

H/VPL (Horizontal/Vertical Protection Levels). There is a one in a 100 million chance that the GPS will be in error by more than the H/VPL. You will be locked out of LPV if the required levels are not met. Other approaches will be offered if their H/VPL are not met.

LAAS (Local Area Augmentation System) is an all-weather aircraft landing system based on real-time differential correction of the GPS signal. Local reference receivers located around an airport send data to a central location at the airport. This data is used to formulate a

correction message, which is then transmitted to users via a VHF datalink. A receiver on an aircraft uses this information to correct GPS signals, which then provides a standard ILS-style display to use while flying a precision approach. The FAA has stopped using the term LAAS and has transitioned to the ICAO terminology of GBAS. The FAA has indefinitely delayed plans for federal GBAS acquisition; the system can be purchased by airports and installed as a Non-Federal navigation aid.

LNAV/VNAV Approach (Lateral Navigation/Vertical Navigation Approaches) use lateral guidance (556m lateral limit) from GPS and/or WAAS and vertical guidance provided by either the barometric altimeter or WAAS. Aircraft that don't use WAAS for the vertical guidance portion must have VNAV-capable altimeters, which are typically part of a FMS. When the pilot flies an LNAV/VNAV approach, lateral and vertical guidance is provided to fly a controlled descent and a safer maneuver to the runway. The decision altitudes on these approaches are usually 350 feet above the runway.

LP Approach (Localizer Performance Approach) is a GPS approach with Localizer performance and pilot-guided vertical descent. A new non-precision WAAS approach, called LP is being added in locations where the terrain or obstructions do not allow publication of vertically guided LPV procedures. This new approach takes advantage of the angular lateral guidance and smaller position errors provided by WAAS to provide a lateral only procedure similar to an ILS Localizer. LP procedures may provide lower minima than a LNAV procedure due to the narrower obstacle clearance surface. LPV Approach (Localizer Performance with Vertical Guidance approach) offers the lowest minimums of GPS systems. This approach requires WAAS GPS receivers.

MSAS (Multifunctional Transport Satellite Augmentation system) is an SBAS system used in Japan that uses their MTSAT satellites. Tests have been accomplished successfully and MSAS was commissioned for aviation use in 2007.

NextGen (Next Generation Air Transportation System) is a new National Airspace System due for implementation across the United States in stages between 2012 and 2025. NextGen proposes to transform America's ATC system from a radar-based system with radio communication to a satellite-based one. GPS technology will be used to shorten routes, save time and fuel, reduce traffic delays, increase capacity, and permit controllers to monitor and manage aircraft with greater safety margins.

Radio communications will be increasingly replaced by data exchange and automation will reduce the amount of information the air crew must process at one time. As a result of these changes, planes will be able to fly closer together, take more direct routes and avoid costly delays.

RAIM (Receiver Autonomous Integrity Monitoring) is a technology developed to assess the integrity of GPS signals in a GPS receiver system. It is of special importance in safety-critical GPS applications. RAIM is considered available worldwide if 24 GPS satellites or more are operative. If the number of GPS satellites is 23 or less, RAIM availability must be checked using approved FDE (Fault Detection and Exclusion) software.

RNP (Required Navigation Performance) is a type of performance-based navigation that allows an aircraft to fly a specific path between two 3D-defined points in space. SBAS, such as WAAS, EGNOS, etc. RNP also refers to the level of performance required for a specific procedure or a specific block of airspace. For example, an RNP of 10 means the aircraft navigation system must be able to calculate its position to within a square with a lateral dimension of 10 nautical miles. An RNP of 0.3 means the aircraft navigation system must be able to calculate its position to within a square with a lateral dimension of 3/10 of a nautical mile.

RVSM (Reduced Vertical Separation Minimum) is the reduction of the standard vertical separation required between aircraft flying between FL290 and FL410 inclusive, from 2,000 feet to 1,000 feet. This therefore increases the number of aircraft that can safely fly in a particular volume of airspace.

SA (Selective Availability) is the military scrambling of GPS. It is no longer active.

STC (Supplemental Type Certificate) is the result of an aircraft modification deemed invasive enough to the way an aircraft was originally certified (Type Certificate) that it requires a very stringent process to safely perform the modification. The two objectives of aircraft certification are to encourage and foster the development of civil aviation and to ensure aviation safety. One method used by the FAA to fulfill these objectives is the aircraft certification system through which aircraft design and modification must be approved. Title 14 of the Code of Federal Regulations (14 CFR) and the CAR (Civil Air Regulations) define the minimum required safety standards for FAA certification. By demonstrating compliance with these regulations, an aircraft modifier may obtain the necessary FAA approval for a modification.

Types of aircraft certification design approvals are determined by the magnitude and complexity of the change. Aircraft modifications can be subdivided into minor and major changes (14 CFR part 21, section 21.93). The type of FAA approval is applicable to a given modification. STCs are required for most major changes to existing TC (Type Certificate) products affected by a modification or installation when the change is not so intensive as to require a new TC (14 CFR part 21, section 21.19).

SAAAR (Special Aircraft and Aircrew Authorization Required) S Approaches are specially authorized and have stringent requirements. Refer to AC 90-101 for details.

VLF/Omega – A now defunct navigation product. The Very Low Frequency portion used US Navy high-powered transmitters that were designed for submarine communications and navigation. The Omega system was a synchronized low frequency pulsed transmitter system.

WAAS (Wide Area Augmentation System) is a major improvement to GPS. A combination of 25 WRS (WAAS Ground Reference Stations) monitor the GPS constellation signals and send corrections through two WMS (WAAS Master Stations) up to two geosynchronous satellites. These satellites then transmit the corrections to a WAAS–enabled FMS/GPS receiver.

WAAS Channel Number – A reference number assigned to each approach chart. If used by a particular manufacturer, the channel number provides a shortcut to the chart.

WAAS Containment – Similar to LNAV/VNAV and ILS approaches, LPV procedures evaluate the Glideslope Qualification Surface. Because of the smaller integrity limit and angular guidance, the size of the obstacle trapezoid is smaller than LNAV/VNAV. In 2003, the minimum HAT (Height Above Touchdown) value was established at 250 feet. In March 2006, it was announced that the WAAS minimum HAT would be lowered to 200 feet if all other airport infrastructure requirements are met.

WAAS Alerting The WAAS horizontal integrity limit is 40 meters on final as opposed to 556 meters for basic GPS. More importantly, WAAS provides vertical integrity, which basic GPS does not. WAAS eliminates the requirements for RAIM predictions, but crews still must check WAAS NOTAMs. Additionally, on procedures with an inverse W, crews must plan using non-precision approach requirements since

vertical NOTAMs are not provided. The inverse W symbols will be removed as the vertical signal availability improves at airports. Avionics equipment guidance is found in TSO-C145 - VNAV and LNAV.

Why would one fly LNAV/VNAV or LNAV minima if they could fly LPV? The reason is that some GPS and RNAV (GPS) approaches have LNAV/VNAV, but not LPV minima. Also, if the WAAS system has an outage, the pilot can still fly the LNAV portion. Think of flying the localizer-only approach when the ILS glideslope is out of service.

DUNCAN AVIATION LOCATIONS

www.DuncanAviation.aero/locations