



The Ottawa Flying Club

Introduction to the Garmin GNS 430

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Topics for Tonight

- History of Navigation
- Radio Navigation
- GPS Primer
 - ✓ Rules
 - ✓ Certifications
- GPS in IFR
 - ✓ Approaches
 - ✓ Planning
- Garmin GNS 430



History of Navigation

- Latitude
 - ✓ In Northern Hemisphere, angle between Polaris and horizon
- Longitude – Much Trickier
 - ✓ Lunar Distance
 - ✓ The Moon and Mars (Vespucci)



Columbus

India's a pretty big target...if we head West, we should hit it.

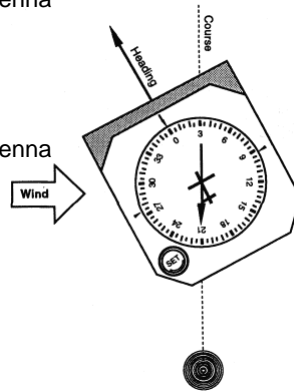
History of Navigation

- Time = Longitude
 - ✓ Earth rotates 360° in 24 hours
 - ✓ Must know time at a precise point on Earth (e.g., Greenwich, England)
 - ✓ Calculate local time using solar/astronomical observation
- 1761 – John Harrison Invents H4
 - ✓ Invention of the marine clock allows for precise calculation of longitude



History of Radio Navigation

- 1920s: Radio Direction Finder
 - ✓ Tune radio station (NDB) with directional antenna
 - ✓ Use Triangulation to obtain a fix
 - ✓ Loop antennae, rotated by hand
- 1930s: ADF
 - ✓ Tune radio station (NDB) with directional antenna
 - ✓ Use Triangulation to obtain a fix
 - ✓ Solenoid (v. antenna), rotated with a motor
 - ✓ Electronics calculate the angle (yay!)



History of Radio Navigation

- 1930s: Lorenz
 - ✓ 2 slightly-divergent beams gave accurate track
 - ✓ "Blind Landing" aid for German WWII bombers
- 1950s: VOR

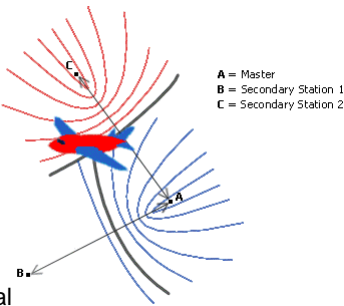


A single master signal is sent out continually from the station, and a highly directional second signal is sent out that varies in phase 30 times a second compared to the master. This signal is timed so that the phase varies as the secondary antenna spins, such that when the antenna is 90 degrees from north, the signal is 90 degrees out of phase of the master. By comparing the phase of the secondary signal to the master, the angle can be determined **without any physical motion in the receiver**. This angle is then displayed in the cockpit of the aircraft, and can be used to take a fix just like the earlier RDF systems, although it is, in theory, easier to use and more accurate.

Source: [Wikipedia.org](https://en.wikipedia.org/wiki/VOR)

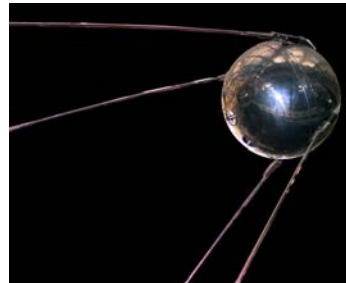
1960s: Hyperbolic Systems

- Based on the measurement of difference of signal arrival times from multiple synchronized transmitters
- Omega
 - ✓ Global navigation system
 - ✓ Nine VLF transmitters (10 – 14 KHz)
 - ✓ Shut Down in 1997, due to success of GPS
 - ✓ Some stations now used for submarine communications
- LORAN
 - ✓ LOnG Range Aid to Navigation
 - ✓ Range of about 1,200 miles
 - ✓ Issues with skywaves causing multiple signal reception via different paths



History of Radio Navigation: GPS

- 1949: NIST creates Atomic Clock
 - ✓ Originally used to study Einstein's Physics and Nature of the Universe
- Oct 4, 1957: Sputnik Launched
- Oct 5, 1957: MIT determines Sputnik's location precisely, based on Doppler Shift
 - ✓ First step in proving that ground position can be determined by homing in on satellite-generated signals



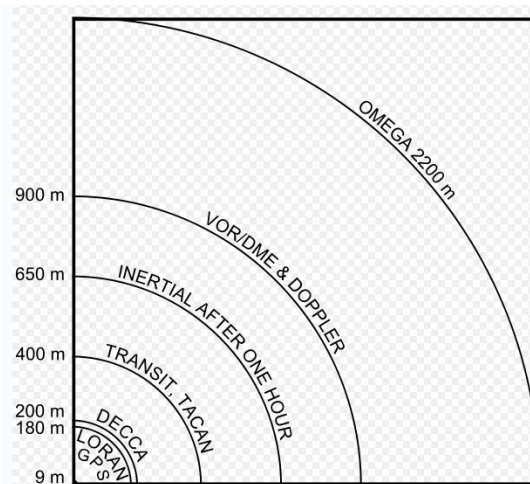
← June 26, 1993

24th NavStar Satellite Launched



Global Positioning System is born

← Accuracy of GNSS



Global Navigation Satellite System (GNSS)

- Constellation of 24 GPS Satellites
- Satellites Continually Broadcast Navigation Message
 - ✓ 3-part message, transmitted in 30 second "frames"
 - Time message was sent, satellite health information
 - Precise orbit of satellite – location, direction, speed (ephemeris)
 - Overall system health and general location of all satellites (almanac)
- Receivers Calculate Distance to Satellites
 - ✓ Arrival time of signal used to calculate distance – "pseudorange" – to the satellite (based on speed of light).
 - ✓ Adjusts for ionospheric and atmospheric errors based on internal day/night signal delay models and information sent in almanac
- Four Pseudoranges for 3-D Solution
 - ✓ Also used to resolve time differences b/w Satellite clocks and receiver



Sources of Errors

- Atmospheric Errors
 - ✓ Inconsistencies of Atmospheric conditions – atmospheric density, ionospheric effects, humidity – effect speed of light
 - ✓ Most significant challenge in improving accuracy
 - ✓ Mitigated with "almanac" and with Satellite Based Augmentation
- Multipath Effects
 - ✓ Signal bounce from terrain, buildings, hard ground, etc.
 - ✓ Causes signal delay = position inaccuracy
 - ✓ Mitigated in moving vehicles, with specialized antennae, FDE
- Selective Availability (Currently Disabled)
 - ✓ Intentional introduction of slow, changing random errors
 - ✓ "True" accuracy encrypted in GPS signal
- Relativity



Satellite Navigation – SatNav (GNSS)

- Two Global Navigation Satellite Systems in Space
 - ✓ U.S. GPS (NAVSTAR-GPS)
 - ✓ Russian GLONASS (incomplete as of 2008)
 - ✓ Galileo (European) due in 2010
- Two Services
 - ✓ Precise Positioning Service (PPS): Military
 - ✓ Std Positioning Service (SPS): Civilian
- GNSS Based on GPS is Only System Approved for Aviation Use in Canada
 - ✓ GNSS approved for En-Route, Terminal and Approach phases of IFR flight
 - ✓ Reference AIC 27/05 / CAP Special Notice

Ref: AIM 3.16



GNSS Performance Requirements

- Accuracy
 - ✓ **Position error**: difference between estimated and actual position
- Integrity
 - ✓ Measure of **trust** in correctness of information.
 - ✓ Ability to **inform user** when system cannot be used.
 - ✓ Measured in terms of horizontal and vertical limits, and time-to-alarm
- Continuity
 - ✓ **Probability** that system will be capable of performing its function throughout the phase of flight.
- Availability
 - ✓ Portion of **Time** during which system will deliver required Accuracy, Integrity and Continuity for a specific phase of flight.



Reading GNSS Info

- Can Be Read Off of GPS Receiver
- Also Off Traditional Instrument “Heads”
 - ✓ VOR/LOC/ILS
 - ✓ Must Indicated Information Source (GPS / VLOC)



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15



TSO

- FAA *Technical Standard Order*
- Lays Out Minimum Standards for Certifications / Design Approvals
- TSO C129a: Minimum Performance Standards (MPS) for Airborne Supplemental Nav Systems to use GPS
- TSO C145a: MPS for GPS with WAAS
- TSO C146a: MPS for Standalone Airborne Nav Systems for GPS with WAAS
- Current GNSS Approvals Require Retention of Traditional Ground Aids



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16



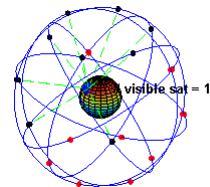
← Error Mitigation: GPS Augmentation

- Required for *Accuracy* and *Integrity* Requirements for Aviation
 - ✓ Continuity and Availability also
- Three Categories:
 - ✓ Aircraft Based (ABAS) – RAIM / FDE
 - ✓ Satellite-Based (SBAS) – WAAS
 - ✓ Ground-Based (GBAS) – LAAS



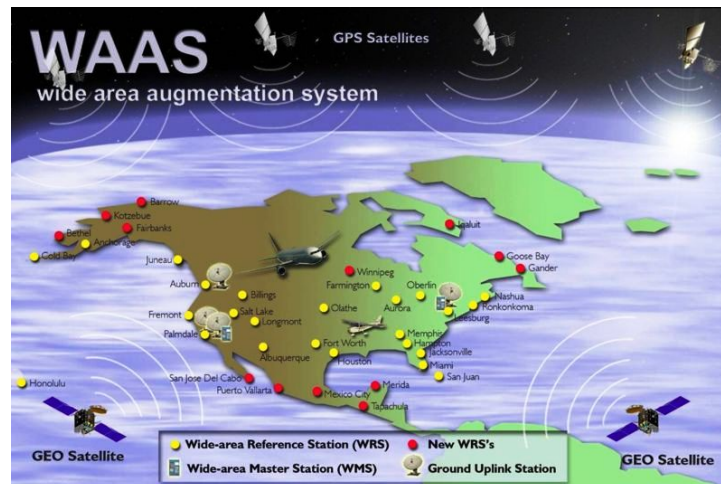
← Aircraft-Based Augmentation: RAIM

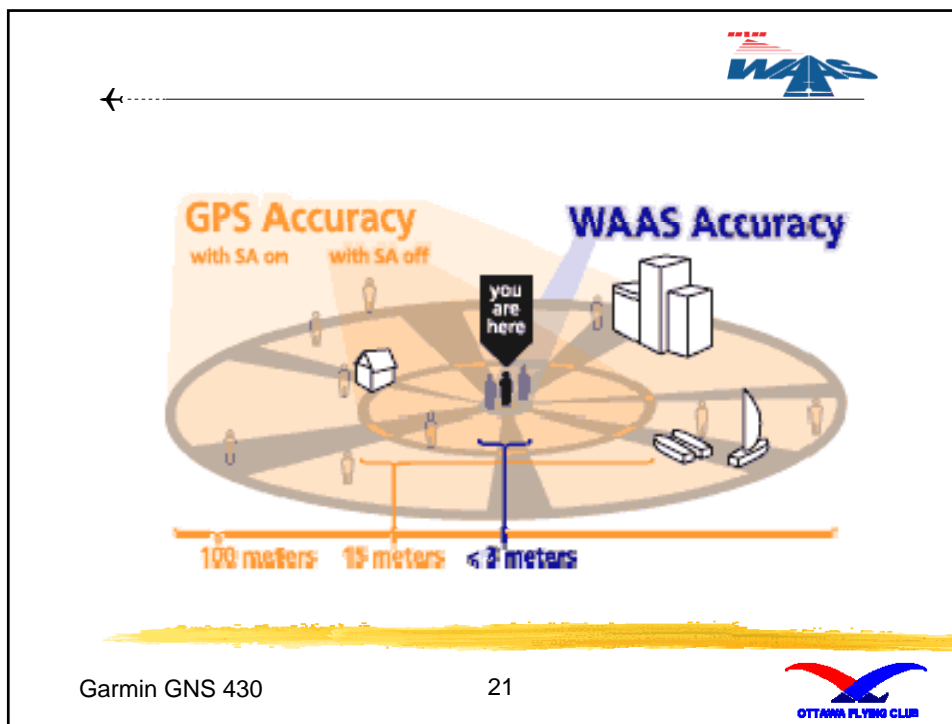
- Receiver Autonomous **Integrity** Monitoring
- Uses Extra Satellites to Compare/Detect Problems
- RAIM Alert – Too Few Satellites
 - ✓ Number of visible satellites / geometry do not support alert limits (2 NM en-route, 1 NM terminal, 0.3 NM approach)
 - ✓ Will continue to provide navigation solution
- RAIM Alert – Unhealthy Satellite
 - ✓ Satellite Range Error – control centre marks satellite as unhealthy
 - ✓ Flags on HSI / CDI, 'WARN' Annunciation
- RAIM Alert = Discontinue Use
- Use of Aircraft Altitude Encoder ("Baro Encoder") Input
 - ✓ Reduces number of satellites required by RAIM
 - ✓ Supported by most TSO 129a Installations (e.g., KLN 89)



In Addition to RAIM: FDE

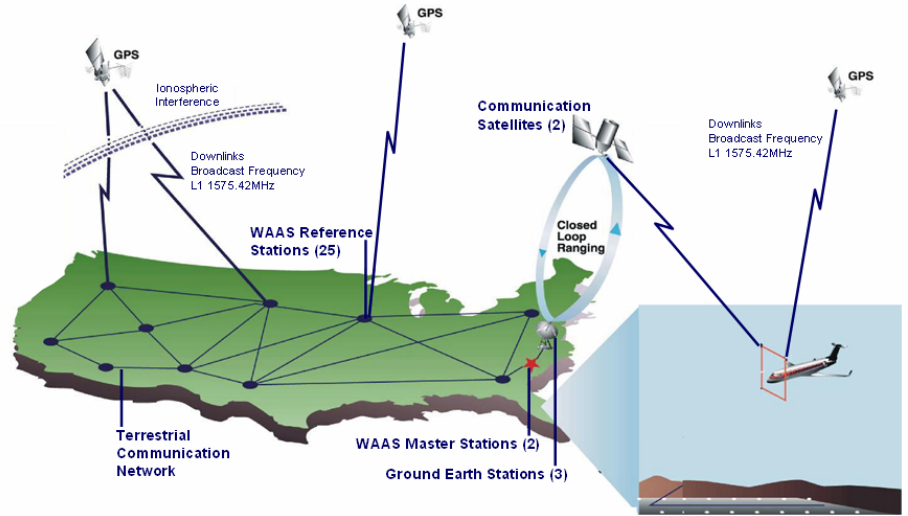
- ←
- Fault Detection and Exclusion
- Receiver Detects Unhealthy Satellite and Excludes It
 - ✓ Requires a minimum of 6 satellites in view
- No RAIM Alert
 - ✓ With 1 satellite excludes, still have the 5 required for RAIM
 - ✓ Continued Navigation
- RAIM / FDE Availability Based on Satellite Geometry (not signal measurement)
 - ✓ Predictability





- ## ← Satellite-Based Augmentation (WAAS)
- Uses Precisely-Surveyed Gnd-Based Reference stations
 - ✓ Monitor satellite signals, transmit information to 3 "Master" stations
 - ✓ Corrections uploaded to geostationary satellites, transmitted to receiver
 - Corrects Ionospheric, Orbital, Clock errors
 - Also Provides Integrity Information and Alarms (6-8 sec)
 - Available Whenever Geostationary Satellites in View
 - Accuracy Supports Advanced Flight Operations
 - ✓ Lateral guidance similar to localizer
 - Vertical Guidance!
 - ✓ Not subject to altimeter setting errors
 - ✓ Not subject to non-standard temperatures or lapse rates
 - ✓ Bye-bye, Cold Temperature corrections!
 - WAAS for En-Route, Terminal, NPA Since 2003
- Garmin GNS 430 22 OTTAWA FLYING CLUB

Satellite-Based Augmentation (WAAS)



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23



Ground-Based Augmentation

- AKA Local-Area Augmentation (LAAS)
- Information Sent From Ground Station to Receiver
 - ✓ Service typically within 30 km
- Incredibly Accurate
- Goal: Support All Precision Approach Categories
 - ✓ Maybe surface movement guidance, too
- Under Development
 - ✓ No ETA

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24



Ground-Based Augmentation



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25



GNSS in Air Navigation

- GNSS Can be Used for all En-Route & Terminal Operations
 - ✓ Including airways/air routes, navigation to / from ground-based aids on specific tracks, RNAV, etc.
- Must Retain Traditional Radio Aids as Backup
 - ✓ Due to **availability** requirements, AIM 3.16.3
- VOR / ADF Reception Not an Issue on Airways / Air Routes
 - ✓ Can Fly Below MEA
 - ✓ RAIM Alert – Up You Go
- DME Distance?
 - ✓ Nope: say distances in MILES



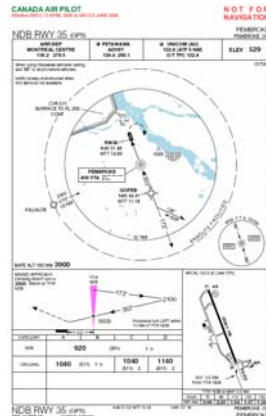
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26



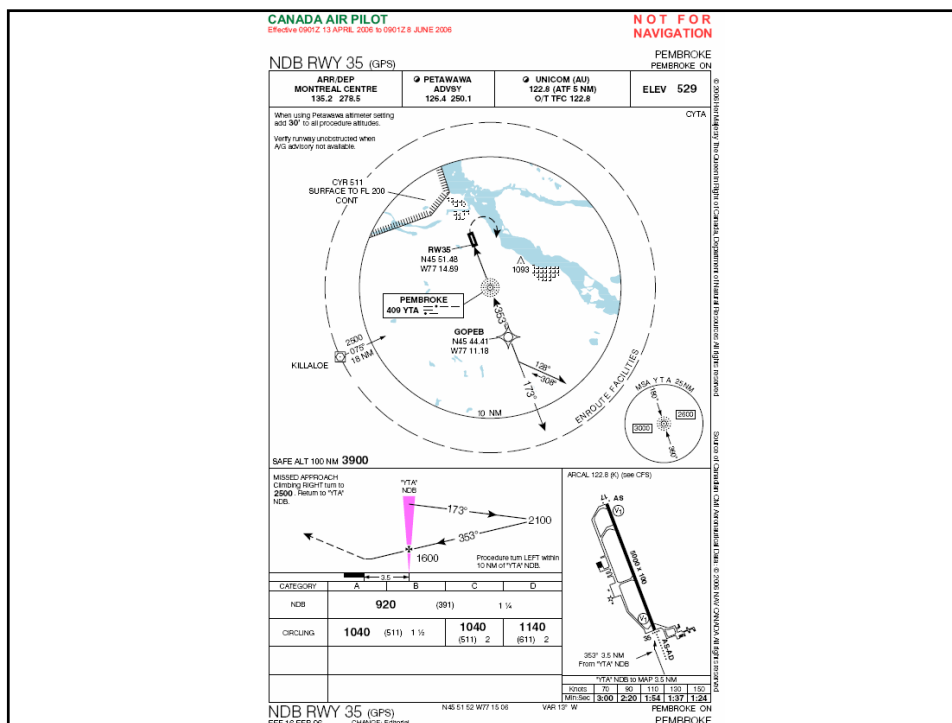
GPS Overlay Approaches

- Initial Answer to “GPS Approach”
- VOR or NDB Approaches Flown with GNSS
 - ✓ No Localizer Overlays
- Identified in CAP with “GPS” or “GNSS” in Small Caps
- Radio Phraseology
 - ✓ “Request GPS Overlay Runway xx”
- Must Have Access to Underlying Radio Aids
 - ✓ But don’t have to monitor them
 - ✓ Can fly GPS Overlay if underlying aid is temporarily out of service



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27



GNSS Approach Types

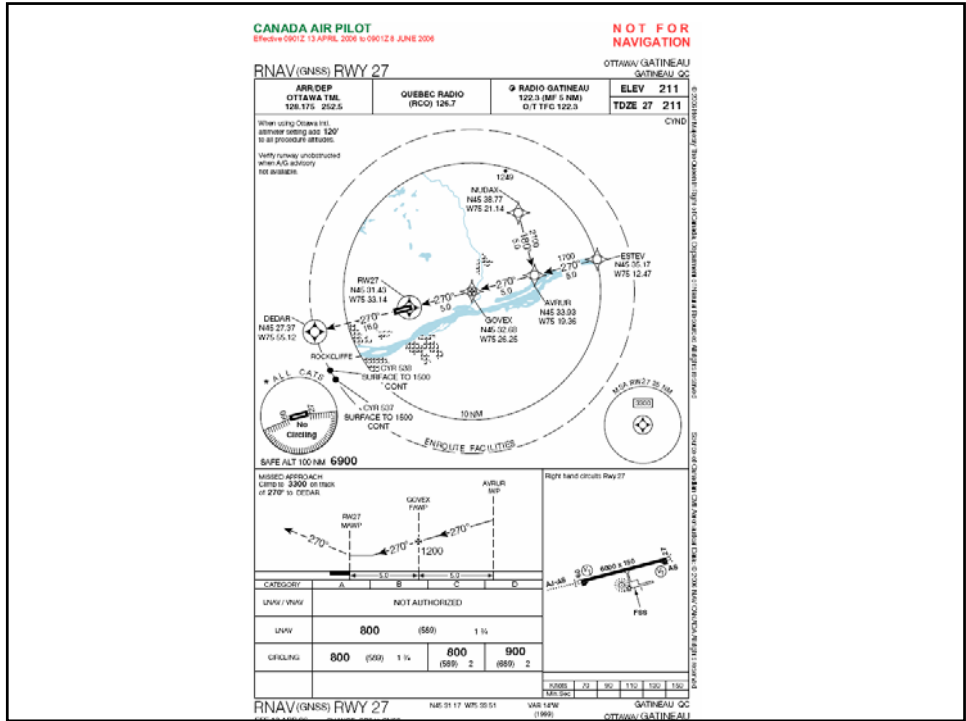
- LNAV
 - ✓ Lateral Navigation
 - ✓ Similar to NDB (but more accurate)
- LNAV/VNAV
 - ✓ Lateral and Vertical Navigation
 - ✓ More accurate than LNAV – generally, lower minima
 - ✓ MDA of 350'
- LPV
 - ✓ Localizer performance with Vertical Guidance
 - ✓ Introduces glide path to GNSS approaches
 - ✓ Decision **Altitude** of 250'
 - ✓ GPS-Only Approach (WAAS required)



Approach Procedures

- GNSS Adds Third *Approach and Landing Operation*
- APV (Appr and landing operations with vert guidance)
- GNSS Approaches
 - ✓ **RNAV (GPS) RWY XX** or **RNAV (GNSS) RWY XX**
 - ✓ "Cleared to RNAV RWY 27 Approach"
- Load Approach from Current Database
- Takes Advantage of GNSS Capabilities
 - ✓ "T" or "Y" pattern - bye-bye Procedure Turn!
- Up to 4 Sets of Minima on an Approach Plate
 - ✓ LPV – Localizer performance with vertical guidance (APV)
 - ✓ LNAV/VNAV – lateral/vertical navigation (APV)
 - ✓ LNAV – Lateral guidance only (NPA) – MDA
- Vertical Guidance is **ADVISORY** for LNAV
 - ✓ Glide path may be shown, but respect the Step-Downs and the MDA





GNSS and WAAS in Domestic Airspace

Phase of Flight	SatNav Capability
En-Route	Non-WAAS or WAAS
Terminal	Non-WAAS or WAAS
Non-Precision Approach (LNAV)	Non-WAAS or WAAS
LNAV/VNAV	WAAS 2 or 3 (for lateral and vertical)
LNAV/VNAV	Non-WAAS or WAAS (for lateral) BARO VNAV (for vertical)
LPV (localizer performance w/ vert guidance)	WAAS 3 (for lateral and vertical)

- Avionics Installations Must be TC-Approved
 - ✓ Panel-Mounted - Handhelds cannot be used
 - ✓ Must meet appropriate equipment standards (the TSOs)

AIM 3.16.5

Flight Planning

- ←
- Equipment Suffix: G
 - ✓ On IFR Flight Plan, indicates IFR-approved GPS or WAAS equipment
 - ✓ Equipment requirements for approaches: Pilot's responsibility
 - ✓ Non-TSO okay for VFR Flight Plan (conveys ability to follow direct routings)
- GPS Availability NOTAM
 - ✓ Only really applicable to non-WAAS equipment
 - ✓ Query KNMH (<https://www.notams.jcs.mil>)
 - ✓ No NOTAMs regarding RAIM availability, but can be calculated
- WAAS NOTAM
 - ✓ NOTAM issued if service predicted to be unavailable for 15 minutes
 - ✓ Also issued for unscheduled changed in GPS constellation
 - ✓ LPV NOT AVBL 0511211200 TIL 0511211240
LPV AND WAAS-BASED LNAV/VNAV NOT AVBL 0511211205 TIL 0511211235
- Database Must Be Current
 - ✓ AND: Should verify **accuracy** of data (mandatory for approaches)
 - ✓ Report Jeppesen DB errors at: navdatatechsupport@jeppesen.com AIM 3.16.6/7



Flight Planning

SOME INSTRUMENT PROCEDURES NOT IN LATEST JEPPESEN UPDATE

Because the FAA published an unprecedented number of changes and new approaches in a single update cycle, Jeppesen was unable to completely update its charts and databases in time for the current charting cycle deadline, the company told AOPA Sept. 25. As a result, some new procedures (mostly RNAV approaches) that appear in the FAA's instrument approach plates are not included in the [Jeppesen GPS database](#).

Jeppesen says it expects to have resolved the issue in time for the next database update cycle.

AOPA Newsletter, Sept 26, 2008

← Flight Planning: Alternate Wx Minima

- Can Take Credit for Published LNAV if:
 - ✓ Usable approach at Destination is served by traditional aid (completely independent of GNSS)
 - ✓ PIC confirms availability of RAIM or WAAS at alternate ± 60 minutes of ETA to alternate
 - For GPS equipped aircraft, check GPS NOTAM KNMH: not more than one satellite out, RAIM unavailable for not more than 15 minutes in period
 - For WAAS equipped aircraft: check national (CYHQ) and FIR notams (if WAAS is out, use TSO C129/C129a procedures)
 - ✓ PIC confirms availability of approach-level RAIM at least once before flight's mid-point (TSO C129/C129a only)
 - Can use avionics' "RAIM Prediction" feature
- LNAV/VNAV is Considered NPA



AIM 3.16.12

← Proper Use of GNSS

- Use only IFR-Certified Avionics for IFR
- Use a Valid Database
- Verify Your Required Information is in the Database
- Do Not Design Your Own Approaches
- Never Fly Below Published Minima
- VFR Receivers are Great in VFR, but Do Not Replace Charts
- Watch Where You Place Your Hand-Helds
- When VFR, do NOT Fly Into MVFR or IFR
- Learn to Use Your Equipment Before You Get In the Air (3.16.5.2)



AIM 3.16.16