Instrument Approach Deviations, GPS Approaches - Bob Carpenter, FAASTEAM, FMFA Ch Instructor (see www.fmfa.org)

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NTSB info is Available at www.ntsb.gov/aviation

GNS 430 Simulator Available at www.garmin.com/software/simulators

GPS info is Available at gps.faa.gov/

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West Chester, PA (Brandywine, KOQN)
1. US Instrument Approach Deviation Accidents for 2005

2. GPS System
   a. Satellite Segment
   b. Ground Segment
   c. User Segment (GPS Receiver, RAIM, RNAV Mag Bearing and Track)
   d. Augmentation Systems (LAAS and WAAS)

3. GPS Terminology, IFR Requirements
   a. GPS/Distance & VOR/DME depiction differences
   b. RNP in US (Enroute, Terminal, Approach Phases of Flight)
   c. Alternate Airport Rules if GPS Approach to be used at Primary
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4. Garmin GNS430 GPS Overview
   a. COM and VOR/LOC function, CRSR, INNER, OUTER
   b. CDI, OBS, MSG, FPL, PROC, RNG,
      DIR,MENU,ENT,CLR,CRSR,INNER,OUTER

5. Garmin GNS430 GPS PC-Simulated Approaches
   a) GPS RNP .3 Abbreviated (Approach WaypointTransition Selection)
   b) GPS RNP .3 Full Approach
   c) ILS (For Situational Awareness Only, Deletion of Holding Pattern)
Instrument Approach Deviations

Fatal USA Airplane Accidents in 2005

1. 92 Fatal Accidents with 192 fatalities

2. 10 Fatal Accidents with 19 fatalities involving Instrument Approach Deviations

3. What techniques and methods can help us improve on this record? GPS as used in Aviation shows promise in allowing pilots to navigate in the USA NAS and to safely accomplish non-precision and precision approaches in the 21st Century

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Navstar Global Positioning System (GPS)

1. GPS Program initiated in 1973. Based on Transit and other spaced-based positioning systems.

2. Currently, Civil GPS User computes his 3-dimensional position from each satellite using the L1 GPS signal.

3. Additional ground and/or space based techniques can improve on the GPS accuracy.

4. For the Civil User, L2 and L5 GPS Signals, acting in concert with current L1 GPS Signal will make the GPS a very robust navigational system (IOC 2012).
The GPS System

Space Segment
- >=24 Satellites
- Master Control Station
- Ground Tracking Stations

Control Segment

Augmentation Systems
- WAAS
  - 2 GEO + ~30 Grd Sites
- Other
  - RAIM, baro-aiding, etc
  - Local Grd Sites
  - LAAS

User Segment

West Chester, PA
(Instrumt Appch Dev, GPS Appchs)
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Brandywine, KOQN(Prepared by: Instrumt Appch Dev, GPS Appchs - West Chester, PA)
Space Segment
GPS Satellite Constellation

- At least 24 Satellites in circular Earth orbits (29 currently)
- Nominally 6 orbital planes at approximately 55 degrees inclination
- 4 satellites in each orbital plane
- Each circular orbit 11,000 miles high
- Orbital periods almost 12 hours
- Each satellite carries 4 atomic clocks accurate to less than one billionth of a second (Cesium and Rubidium)
- At least 5 satellites are in view from anywhere on Earth

\[
\frac{0.00000001 \text{sec}}{\text{sec}} \times 186,000 \frac{\text{Miles}}{\text{Sec}} \times 5280 \frac{\text{Feet}}{\text{Mile}} \sim 1 \text{ ft}
\]

Light travels approximately 1 foot in one billionth of a second

(Telecom Providers Use GPS Clock Data for Timing Accuracy)
GPS Space Segment
(GPS Block IIF Satellite)

GPS Satellite Signals
1. L1 – 1575.42 MHz (existing ranging)
2. L2 – 1227.60 MHz (future health and safety)
3. L5 – 1176.45 MHz (future ranging)
4. L1/L2/L5 IOC 2012
   a) Ionospheric errors minimized
   b) GPS System more jam resistant (robust)
GPS Control Segment
(6 Monitoring and 1 Master Control Station)

1. Stations track GPS satellites and collect their signals and relay info to the Master Control Station (MCS) at Falcon AFB, Colorado Springs
2. MCS Determines GPS satellite positions (ephemeris) and uploads this information into each satellite
3. GPS Satellites broadcast their positions (and other satellites in the GPS Constellation) to GPS users
Using the computed distances to at least 4 satellites, the receiver computes its 3-dimensional position.

Each GPS receiver uses all GPS Satellites in view with 5 needed for RAIM.

UnAided (UnAugmented) GPS Receiver

- Horizontal Navigation System Accuracy (95%) = 10 meters (30 ft)
- Vertical Navigation System Accuracy (95%) = 20 meters (60 ft)
GPS User Segment
Integrity Assurance (RAIM & WAAS)

- **Receiver Autonomous Integrity Monitoring (RAIM)**
  - RAIM algorithms that check integrity of GPS data need a minimum of 5 satellites
  - Without RAIM capability, the pilot has no assurance of accuracy of GPS position.
  - RAIM can be used when WAAS is not available

- **Wide Area Augmentation System**
  - WAAS does not need RAIM because of its built-in integrity checks
  - FAA requires WAAS to have 6 second alert time for bad satellite data.

Near real-time GPS & WAAS integrity data at http://www.nstb.tc.faa.gov/vpl.html
GPS User Segment -- RAIM Outages

- **Causes of RAIM Outages**
  - Insufficient number of satellites
  - A failure of one of the GPS satellites

- **Be Prepared for RAIM Outages**
  - Enroute – monitor other navigational equipment
  - Approach – fly to MAP and execute Missed Approach

- The solar maximum should arrive by 2011 and researchers say that the flares associated with it could potentially make current GPS vulnerable to RAIM outages. GPS RAIM may have lower availability as a result.
GPS User Segment
GPS Geodetic Model – WGS84

- WGS-84 (World Geodetic System 1984) is the system of coordinates used by GPS.
- In the WGS-84 system of coordinates, an ellipsoid is defined to approximate the average mean sea level.
- Computed GPS altitude is the height above the WGS-84 ellipsoid, and all US Airport survey data also done in terms of WGS-84.

Mean Sea Level is NOT the same as the WGS-84 ellipsoid.
GPS User Segment
RNAV Terminology and GPS/Nav Display

TAE = Difference between Track and Desired Track
Bearing = Direction to waypoint
Course = Desired Track between specific waypoints
Desired Track = Course direction
Track = Direction the aircraft is going
Heading = Direction the aircraft is pointed

Distance Off Course or Cross Track Deviation

Distance Off Course displayed on CDI

FROM WAYPOINT

Keep the (Magnetic) TRK = (Magnetic) BRG and you will arrive at WAYPOINT

TO WAYPOINT
The aircraft receives the GPS signals as well as the broadcast corrections from the GPS receiver station, improving availability and integrity of the stand-alone GPS system position.

GPS Augmentation Systems
Local Area Augmentation System (LAAS) Technology

LAAS Concept

GPS <= 20 meters
WAAS <= 3 meters
LAAS <= 1 meter
GPS Augmentation Systems
LAAS - Continued

1. Will provide Category II-III type approaches for airports
2. LAAS-capable VHF receiver needed
3. Each of the GPS Stations receive GPS signals
4. Each GPS Station forwards its corrections to the LAAS ground facility
5. VHF transmitter forwards its corrections to aircraft
6. FAA may wait for L5 before implementation
7. Beyond Category III, the LAAS will provide the user with a navigation signal that can be used as an all weather (airport) surface navigation capability for taxiing.
GPS Augmentation Segment
Wide Area Augmentation System (WAAS)

1. Will provide enroute navigation plus Category I-type approaches
2. WAAS Capable Receiver Needed
3. Each of the Wide Area Reference Stations receive GPS signals
4. Each Wide Area Reference Station forwards its corrections to a Wide Area Master Station
5. Two Area Master Stations forward their Master corrections to three Ground Uplink Stations (GUS)
6. GUS forward the correction info to Geostationary Satellite
7. Geostationary Satellite (GEO) rebroadcasts correction info to GPS/WAAS receivers (users)
8. 1m horizontal and 2m vertical accuracy (95%) since 2003
In October 2004, FAA approved the first WAAS-equipped avionics for LPV approach operations, the Garmin 480. An LPV approach is a new type of approach designed by the FAA to take advantage of the very precise three-dimensional guidance that WAAS can provide and LPVs can be flown only using WAAS. LPV → Loc Perf w/Vert Guidance (200 ft AGL)

For near real-time WAAS coverage go to http://www.nstb.tc.faa.gov/vpl.html
## Eastern Region Selected WAAS LPV Approaches

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GPS User Segment
(Examples of 200 HAT WAAS Cat I LPV Approach)
Future WAAS LPV Approaches (see avnweb.jccbi.gov/schedule/production)

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GPS Terminology and IFR Requirements

GPS/Distance & VOR/DME Depiction Differences

1. Magnetic tracks defined by VOR radials (changes infrequently) are determined by magnetic variation (always changing) at the VOR

2. GPS receiver uses true north at the current position and has a magnetic model to convert to a magnetic heading

3. Variation in distances will occur, since GPS distance-to-waypoint values are along track (straight line) distances, while VOR/DME distances are slant range distances
GPS Terminology and IFR Requirements

RNAV Required Navigation Performance (RNP) in US

1. The RNP Level is a value typically expressed as a distance, in nautical miles, from the procedure, route or path within which an aircraft would typically operate.
   a) US Std Approach RNP LEVEL (SPS GPS or WAAS) = 0.3 NM
   b) US Std Terminal (Approach/Arrival) RNP LEVEL = 1.0 NM
   c) US Std Enroute RNP LEVEL = 2.0 NM

2. RNAV is not just GPS - one can get RNAV with DME-DME for example.

Garmin GX60 RNP Levels for Enroute, Terminal, Approach

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RNP

Within 2*RNP
95% Probability

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GPS Terminology and IFR Requirements
GPS as Substitute for ADF and DME – AIM 1-1-19, AC 90-94

- Operators in the USA NAS are authorized to use GPS equipment certified for IFR operations in place of VOR, ADF and DME equipment (See AIM 1-1-19).
- Approved IFR GPS instrument approach operations include: Locating DME fixes, flying DME arcs, determining cross-bearing fixes, navigating to/from and holding over VOR/NDBs, flying above FL240
- Database must be current and RAIM or WAAS used for integrity monitoring!!

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Each Year Contains 13 GPS Database Cycles of 28 Days Effective at 0901Z Every 4th Thursday

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West Chester, PA
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GPS User Segment

General Requirements for GPS Operations under IFR

- Must be approved IAW TSO C-129 and the database current (Hand-held GPS are NOT approved for IFR Operations)
- GPS operation must be conducted in accordance with FAA approved Flight Manual and/or FAA-approved Flight Manual Supplement onboard aircraft
- Aircraft using GPS must be equipped with approved, operational alternate means of navigation appropriate to the flight (not required if GPS is WAAS)
- Active monitoring of alternate nav equipment is not required if GPS receiver uses RAIM or WAAS
- Active monitoring of alternate nav equipment is required when RAIM capability is lost
- Authorization to fly GPS approaches is limited to U.S. airspace.
- GPS Approach must be “IN THE BOX”
GPS User Segment
GPS NOTAMs

• GPS satellite outages are issued as GPS NOTAM’s (Notices to Airmen) for known or scheduled outages
• DUATS, FAA briefers, and Automated Flight Service Stations will provide GPS RAIM availability during briefings. Get RAIM prediction if flying a GPS departure procedure.
• In general, WAAS-equipped aircraft need not worry about GPS NOTAMs but there are also WAAS NOTAMs

********** NOTAMs **********
!GPS 05/026 GPS PRN 4 OTS WEF 9905250600-9905251800
!GPS 05/027 GPS PRN 27 OTS WEF 9905270430-9905271100
Generic GPS (T-Shaped) Stand-Alone Instrument Approach

- The basic “T” design aligns the instrument approach procedure on runway centerline with the missed approach point
- Missed approach point (MAP) is at runway threshold
- No procedure turns are needed
- Holding pattern at IF/FAF for pilots that elect to execute a procedure turn (PT) to meet descent gradient requirement
- There are many modifications of basic “T” Design (see AIM 1-1-19)
GPS User Segment
(Garmin GNS 430)

- The GNS 430 contains several receivers:
  - GPS (database updated on 28 day cycle)
  - VOR
  - Localizer
  - Glideslope

- Certificated for Enroute, Term & Appch Opns

- Types of Approaches Permitted:
  - Non-precision standalone LNAV GPS approaches and overlay approach – using SPS GPS receiver
  - VOR approaches – using VOR receiver
  - ILS approaches – using Loc/GS receiver
  - LPV, LNAV/VNAV, LNAV – using WAAS if approved

- WAAS capable units available from Garmin
- Std GNS 430 may be upgraded to WAAS for $1500
- Can fly DPs and STARs, since are in the database
RNAV (GPS) RWY 04 GED Approach (Georgetown, DE)

- LPV => localizer performance with vertical guidance (WAAS)
- LNAV => Lateral Navigation (RNAV and GPS approach with RNP = 0.3)
- MDA for RNP=0.3, DA for other
- RNAV units using DME/DME for RNP=0.3 are not authorized
- How do I choose correct GPS transition (ESHIW, UWAFY, TOWHE, VTF)?
GPS References for Pilots

- Garmin GNS430 GPS User Manual
- GPS TSO-C129a Airborne Supplemental Navigation Equipment Using the GPS
- TSO-C145a, Airborne Navigation Sensors Using the GPS Augmented by WAAS
- GPS/WAAS TSO-C146a, Stand-Alone Airborne Navigation Equipment

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