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

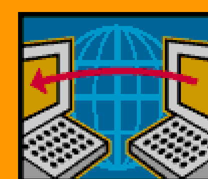
NTSB info is Available at

www.ntsb.gov/aviation

GNS 430 Simulator Available at

www.garmin.com/software/simulators

GPS info is Available at



gps.faa.gov/

Agenda

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
   d. GPS usage in lieu of ADF/DME
   e. GPS approach requirements (“In-the-box”, Alt Appch Requirements)
   f. Generic GPS (T-Shaped) Stand-Alone Approach

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

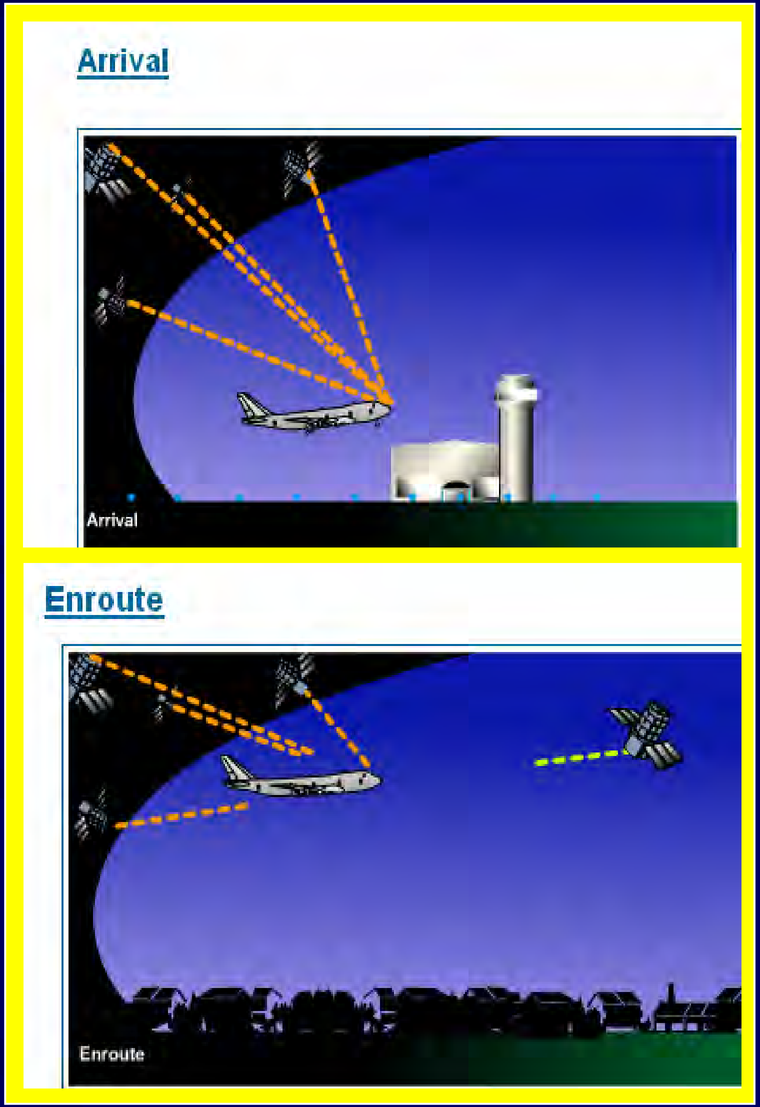
Fatal USA Airplane Accidents in 2005

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

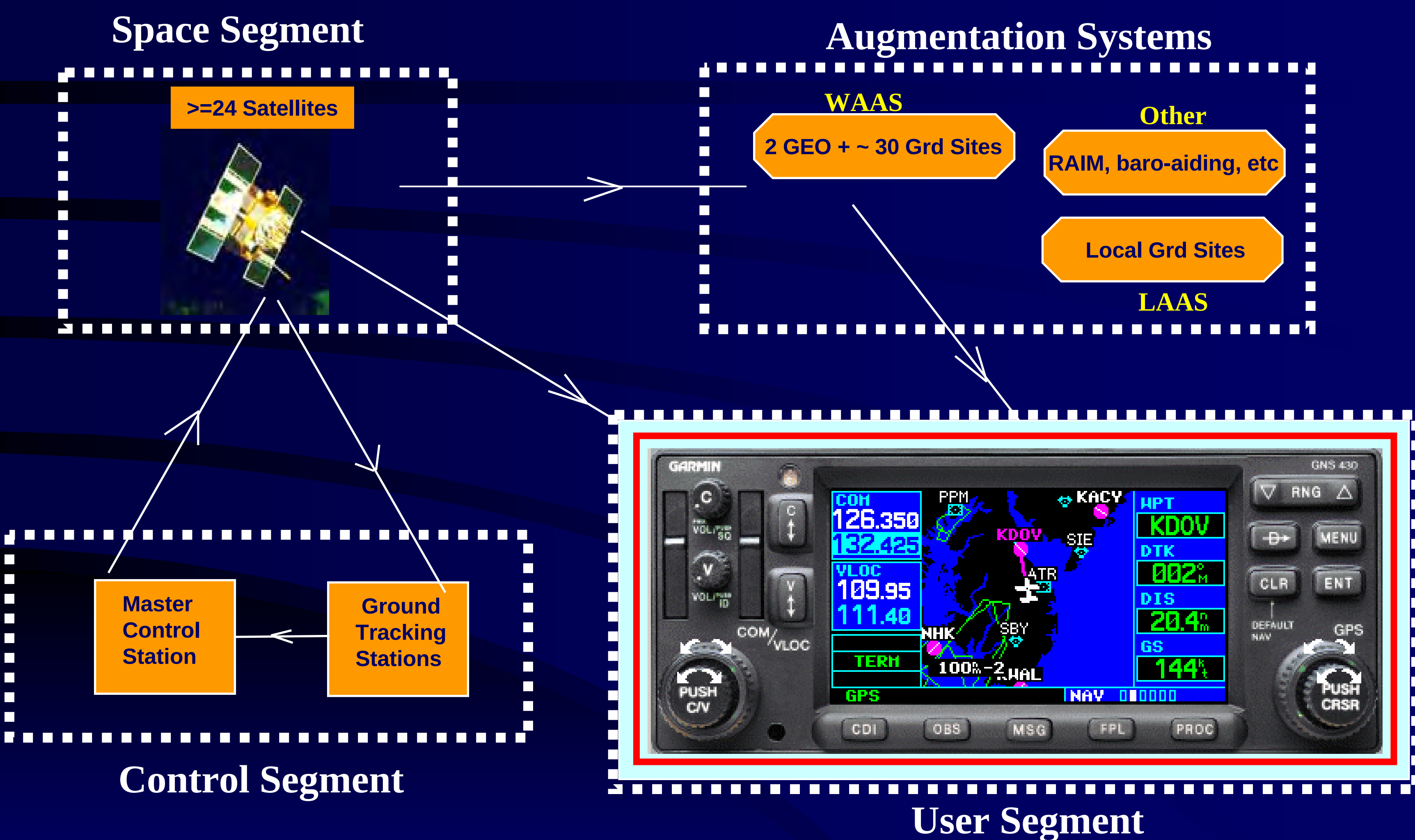
Date	Accident #	Aircraft	Location	# Fatal	Type	Cat
01/13/05	NYC05FA042	N49BA, EMB-110-P1	Swanzey, NH	1	IFR Appch Dev	ILS
03/26/05	IAD05FA047	N770G, Pilatus PC-12	Bellefonte, PA	6	IFR Appch Dev	ILS
06/01/05	LAX05FA193	N6574U, Mooney M20C	Van Nuys, CA	1	IFR Appch Dev	ILS
06/27/05	NYC05FA109	N5155N, Cessna 182Q	Groton, CT	4	IFR Appch Dev	ILS
10/19/05	MIA06FA008	N5HU, Cessna P337H	Port St Lucie, FL	1	IFR Appch Dev	UNK
11/06/05	DFW06FA021	N4171Z, Piper PA-34	Tomball, TX	2	IFR Appch Dev	LOC
11/16/05	CHI06FA032	N1153C, Aer Cmdr 500B	Gaylord, MI	1	IFR Appch Dev	VOR
12/01/05	NYC06FA040	N64PW, Beech B-55	Nantucket, MA	1	IFR Appch Dev	ILS
12/23/05	LAX06FA066	N5942S, Beech 36	Livermore, CA	2	IFR Appch Dev	ILS
12/28/05	LAX06FA071	N781RS, Learjet 35A	Truckee, CA	2	IFR Appch Dev	GPS

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



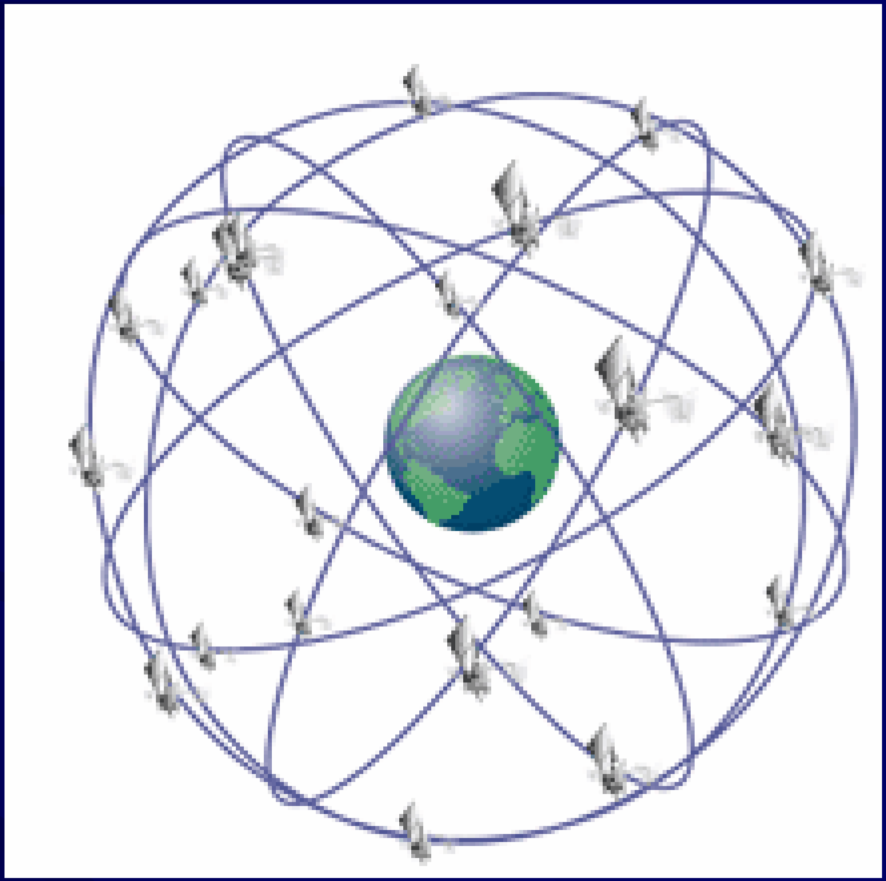
Space Segment
GPS Satellite Constellation

- 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

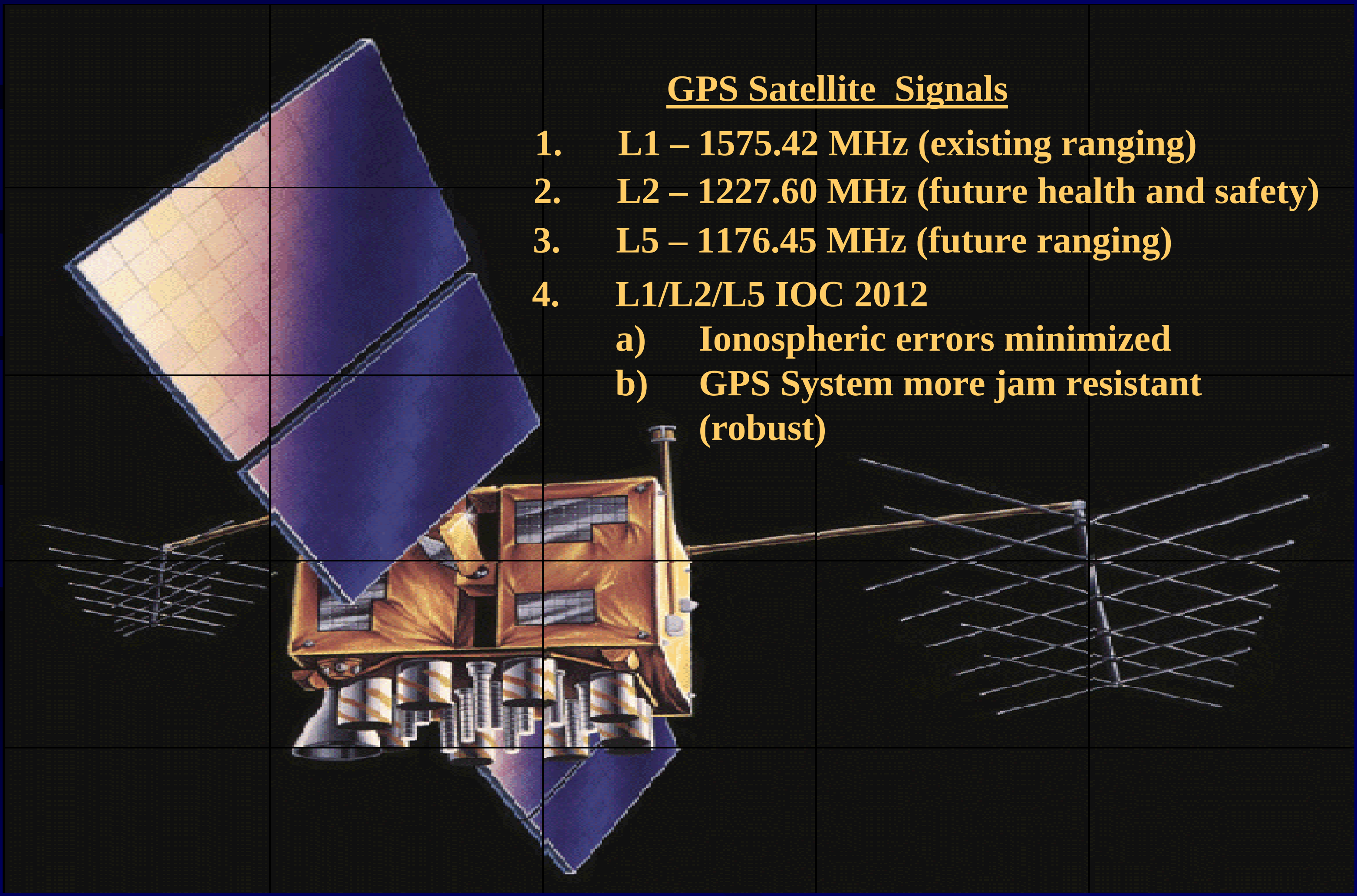
$$.000000001\text{sec} \times 186{,}000\,\frac{\text{Miles}}{\text{Sec}} \times 5280\,\frac{\text{Feet}}{\text{Mile}} \sim 1\text{ ft}$$

Light Travels Approximately 1 Foot in One Billionth of a Second

(Telecom Providers Use GPS Clock Data for Timing Accuracy)



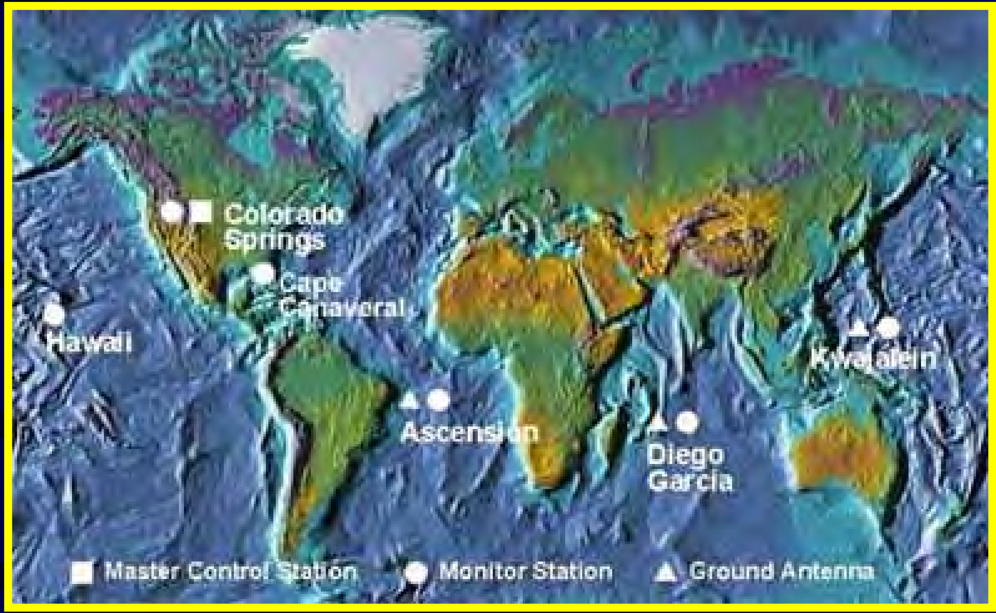
GPS Space Segment
(GPS Block IIF Satellite)



GPS Satellite Signals

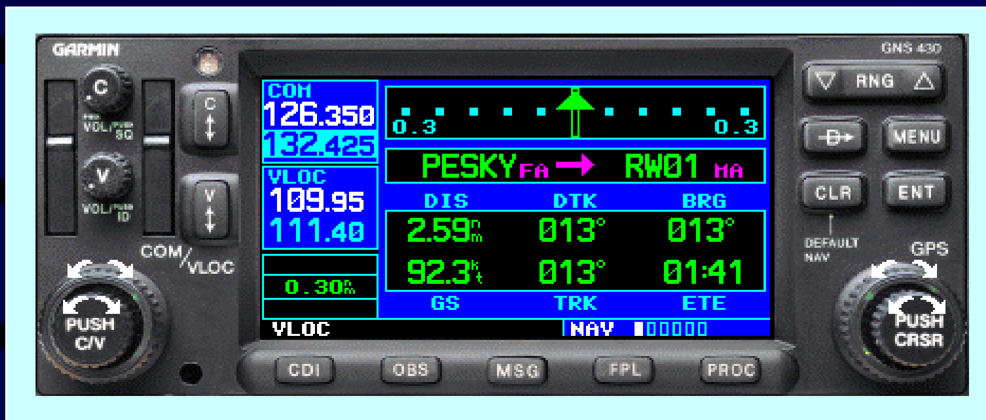
1. L1 – 1575.42 MHz (existing ranging)
2. L2 – 1227.60 MHz (future health and safety)
3. L5 – 1176.45 MHz (future ranging)
4. L1/L2/L5 IOC 2012
   a) Ionospheric errors minimized
   b) GPS System more jam resistant (robust)

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**

GPS User Segment
(The GPS Receiver)



- 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

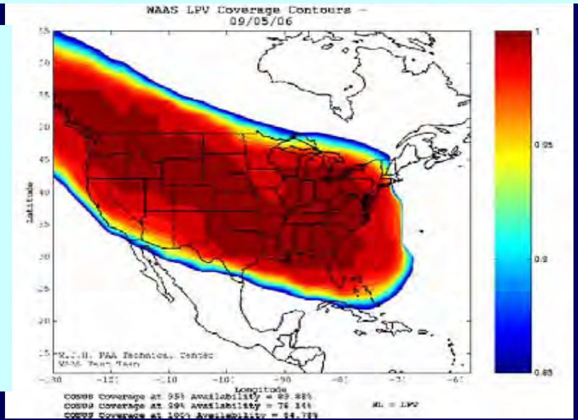
- **Horizontal Navigation System Accuracy (95%) = 10 meters (30 ft)**
- **Vertical Navigation System Accuracy (95%) = 20 meters (60 ft)**

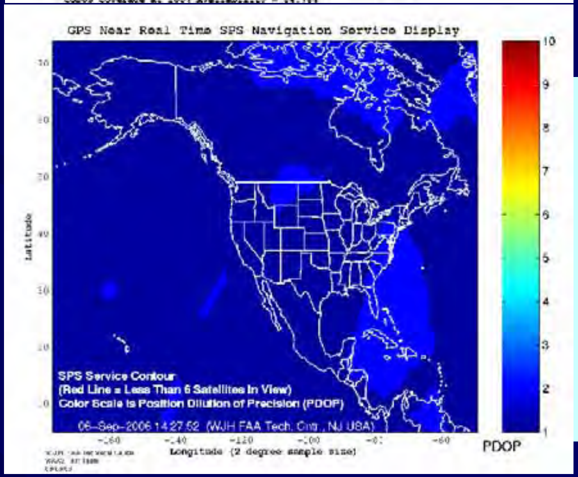
GPS User Segment
Integrity Assurance (RAIM & WAAS)

- **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 <u>real-time</u> GPS & WAAS integrity data at http://www.nstb.tc.faa.gov/vpl.html

WAAS (LPV) Coverage





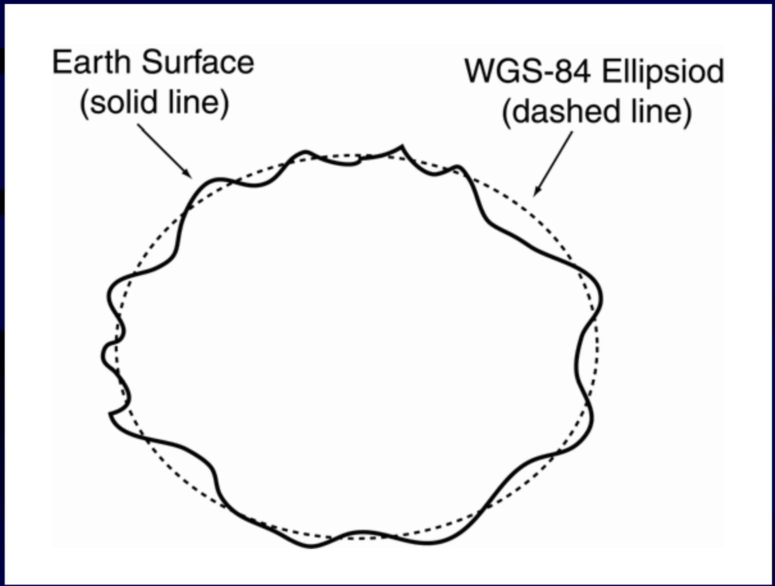
GPS Standard Positioning Service

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.**

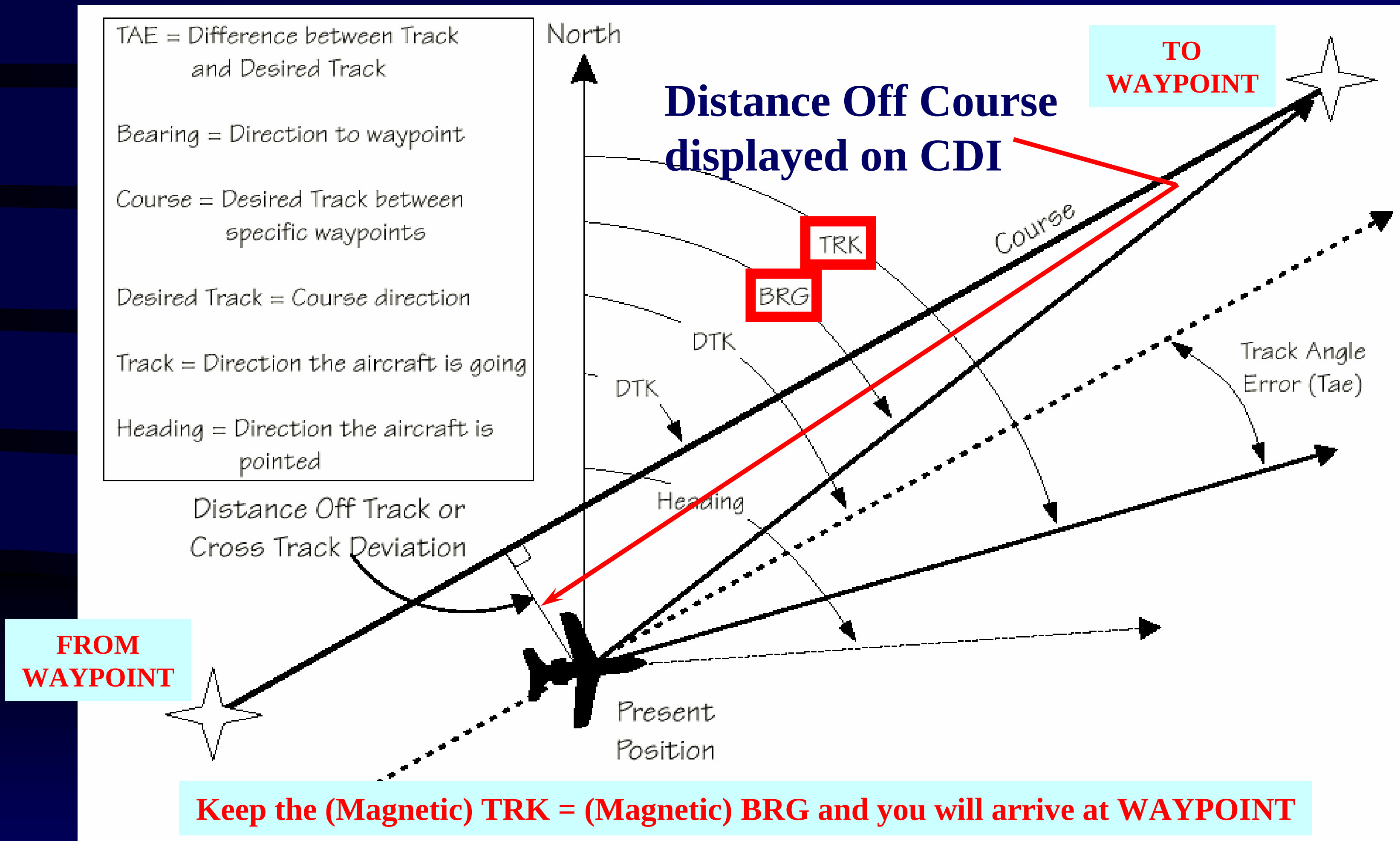
GPS User Segment
GPS Geodetic Model – WGS84

Mean Sea Level is NOT the same as the WGS-84 ellipsoid



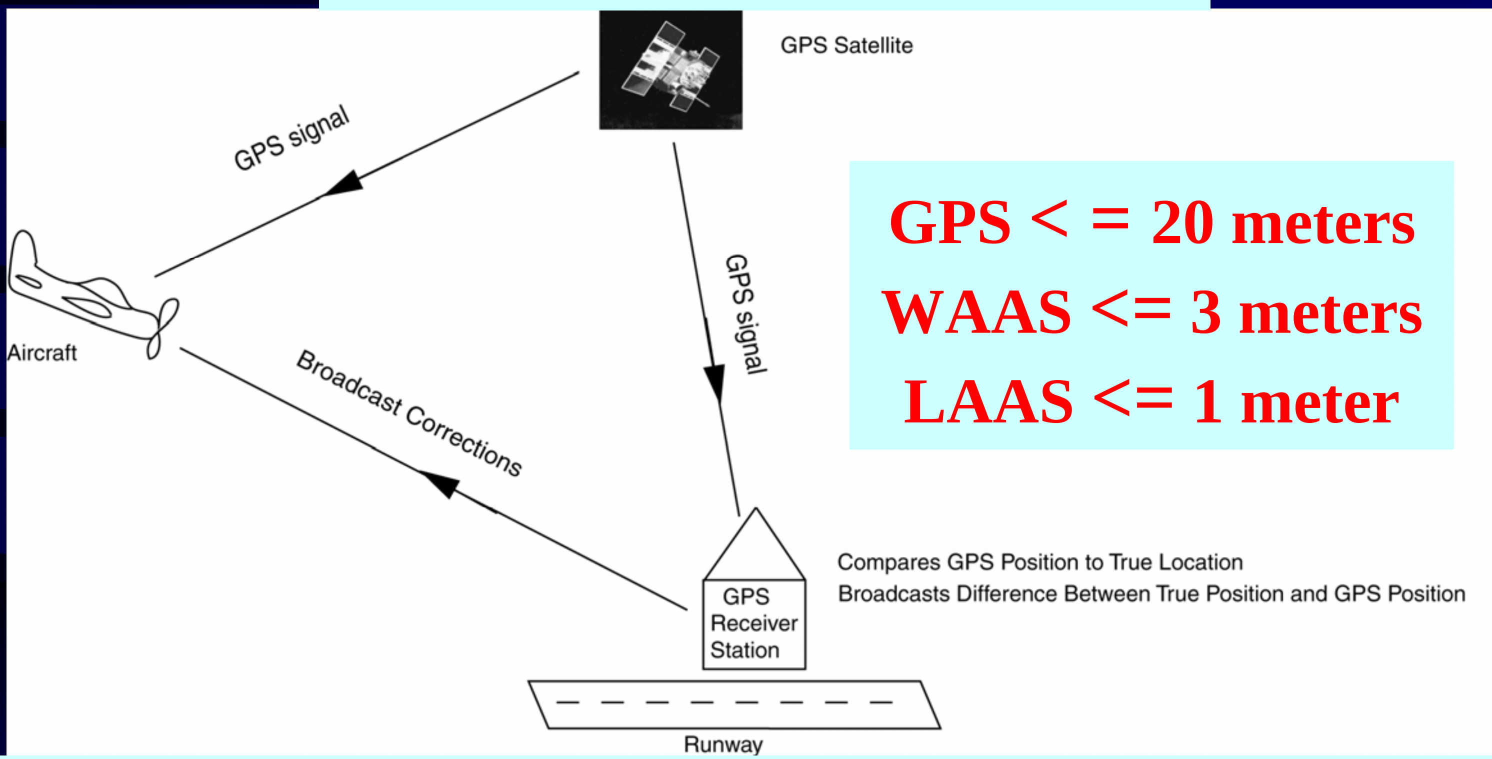
- **WGS-84 (World Geodetic System 1984) is the system of coordinates used by GPS**
- **In the WGS-84 system of coordinates, an ellipsoid is defined to approximate the average mean sea level.**
- **Computed GPS altitude is the height above the WGS-84 ellipsoid, and all US Airport survey data also done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

GPS User Segment
RNAV Terminology and GPS/Nav Display



GPS Augmentation Systems
Local Area Augmentation System (LAAS) Technology

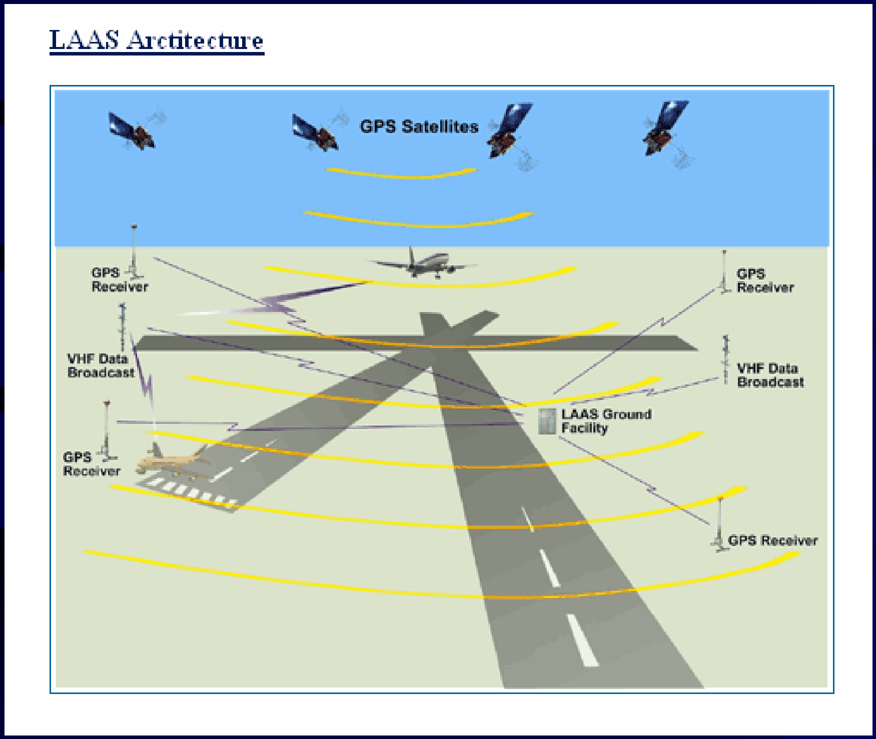
LAAS Concept



GPS < = 20 meters
WAAS <= 3 meters
LAAS <= 1 meter

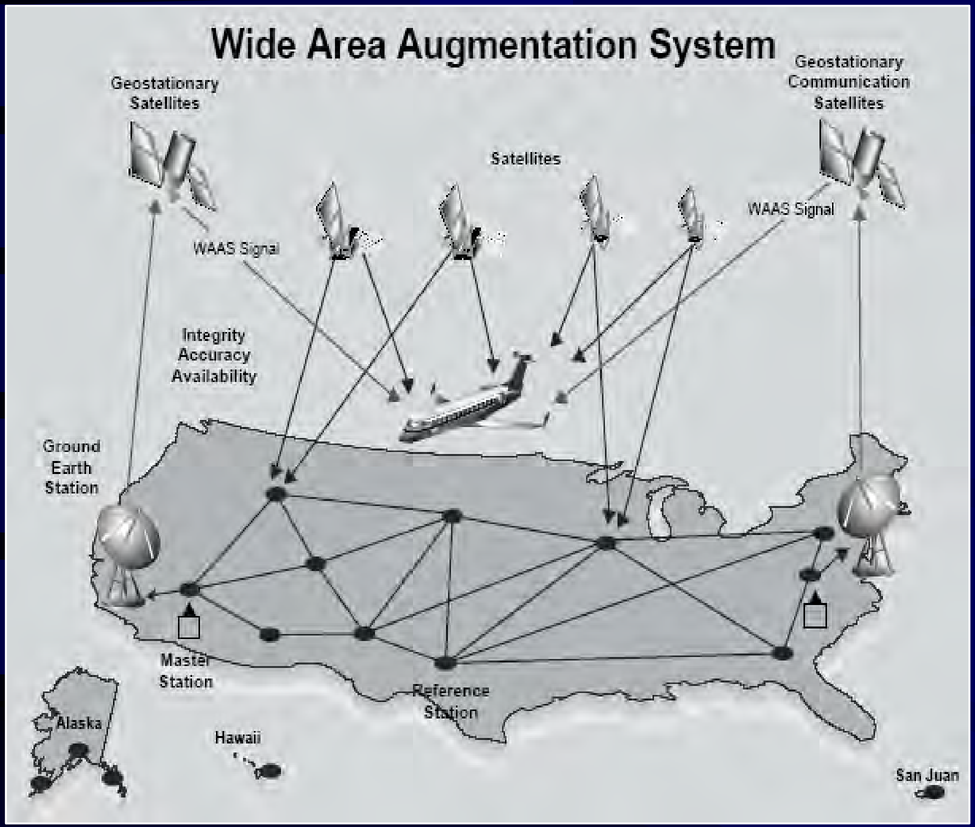
The aircraft receives the GPS signals as well as the broadcast corrections from the GPS receiver station, improving availability and integrity of the stand-alone GPS system position.

GPS Augmentation Systems
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.

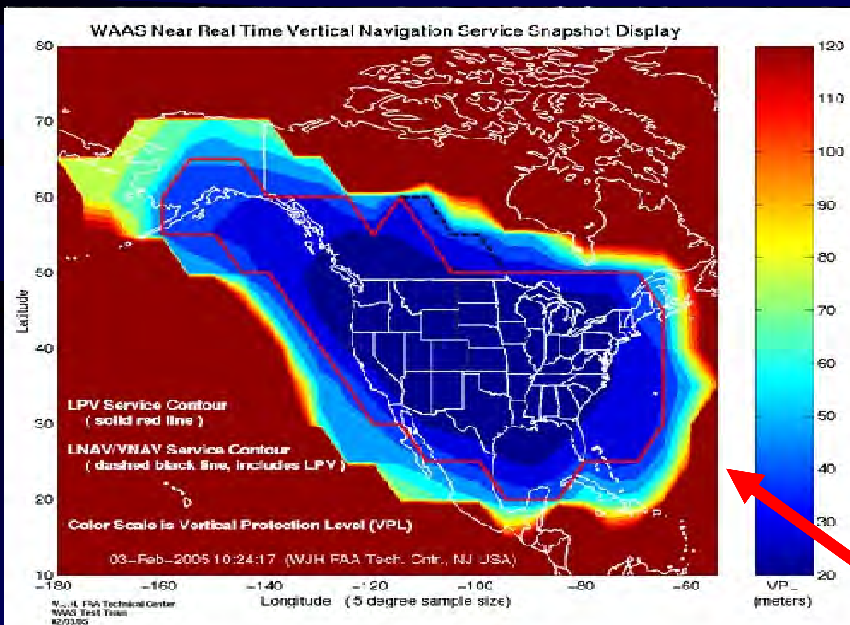
GPS Augmentation Segment
Wide Area Augmentation System (WAAS)



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

WAAS Benefits & Coverage (Continental US)

In October 2004, FAA approved the first WAAS-equipped avionics for LPV approach operations, the Garmin 480. An LPV approach is 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)**



Garmin GNS 480 only **GPS WAAS Approved**

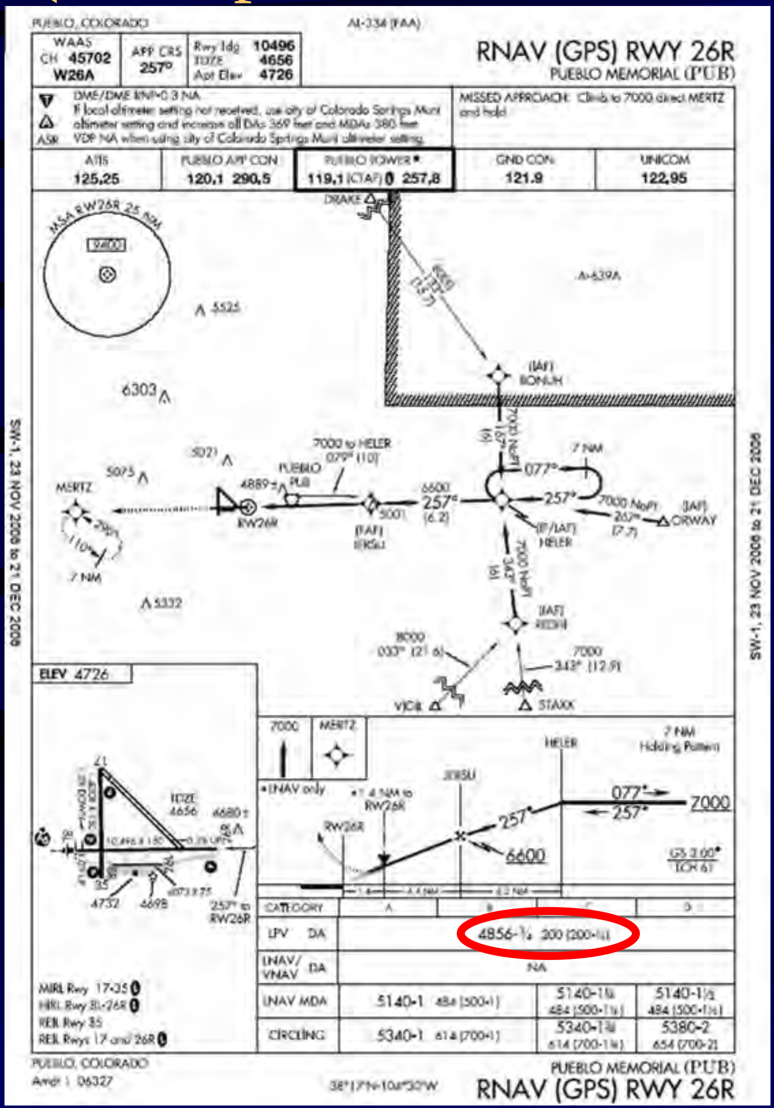
Garmin GNS 430/530 WAAS IOC JAN07

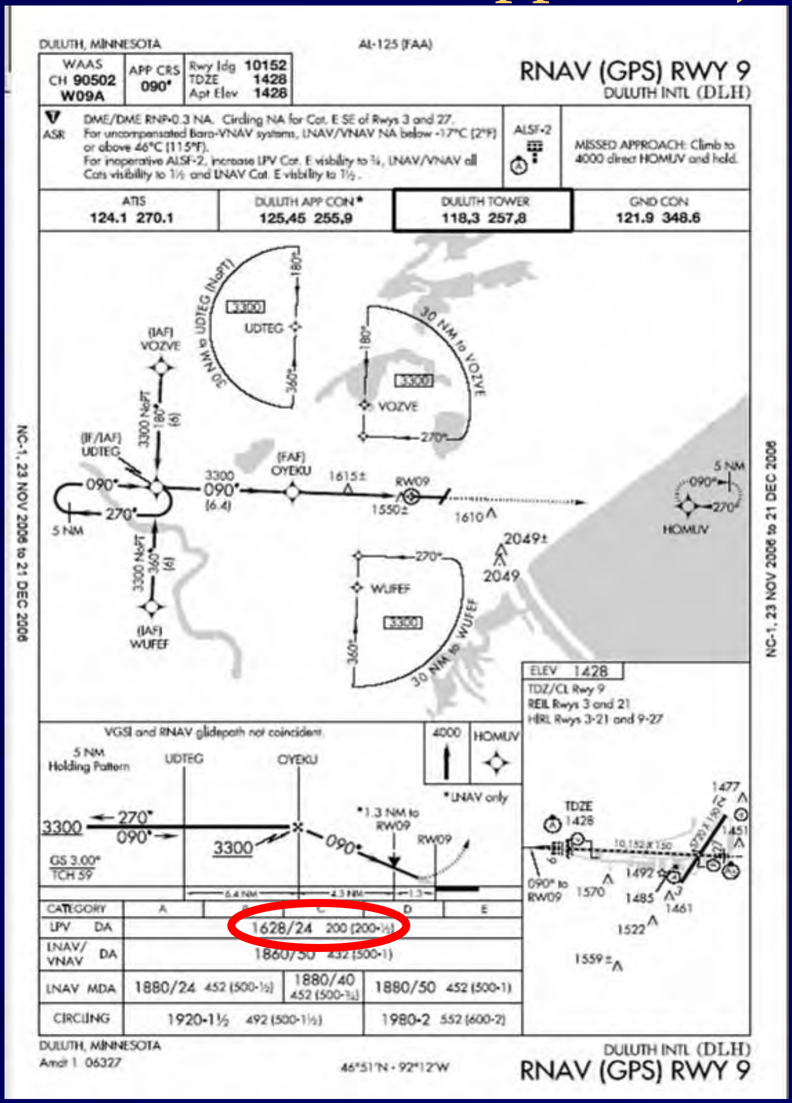
For near real-time WAAS coverage go to http://www.nstb.tc.faa.gov/vpl.html

(Eastern Region Selected) WAAS LPV Approaches

State	APT	Airport	Approach	HAT
PA	ABE	Allentown / Lehigh Valley Intl	RNAV (GPS) RWY 31	257
PA	A00	Altoona-Blair County	RNAV (GPS) Z RWY 21	313
PA	FKL	Franklin / Venango Regional	RNAV (GPS) RWY 21	263
PA	HZL	Hazleton Muni	RNAV (GPS) RWY 10	451
PA	FWQ	Monongahela / Rostraver	RNAV (GPS) RWY 8	402
PA	FWQ	Monongahela / Rostraver	RNAV (GPS) RWY 26	276
PA	PNE	Philadelphia / Northest Philadelphia	RNAV (GPS) RWY 6	374
PA	PNE	Philadelphia / Northest Philadelphia	RNAV (GPS) RWY 24	314
PA	PHL	Philadelphia Intl	RNAV (GPS) RWY 9L	250
PA	PHL	Philadelphia Intl	RNAV (GPS) RWY 9R	250
PA	PHL	Philadelphia Intl	RNAV (GPS) RWY 17	308
PA	PHL	Philadelphia Intl	RNAV (GPS) RWY 27L	250
PA	PHL	Philadelphia Intl	RNAV (GPS) RWY 27R	256
PA	AFJ	Washington County	RNAV (GPS) RWY 27	506
DC	DCA	Washington / Ronald Reagan Washington National	RNAV (GPS) RWY 33	256
MD	FDK	Frederick Muni	RNAV (GPS) Z RWY 23	394
MD	GAI	Gaithersburg / Montgomery County Airpark	RNAV (GPS) RWY 14	269
MD	GED	Georgetown / Sussex County	RNAV (GPS) RWY 4	420
MD	GED	Georgetown / Sussex County	RNAV (GPS) RWY 22	310
MD	DMW	Westminster / Carroll County Regional	RNAV (GPS) RWY 16	341

GPS User Segment
(Examples of 200 HAT WAAS Cat I LPV Approach)



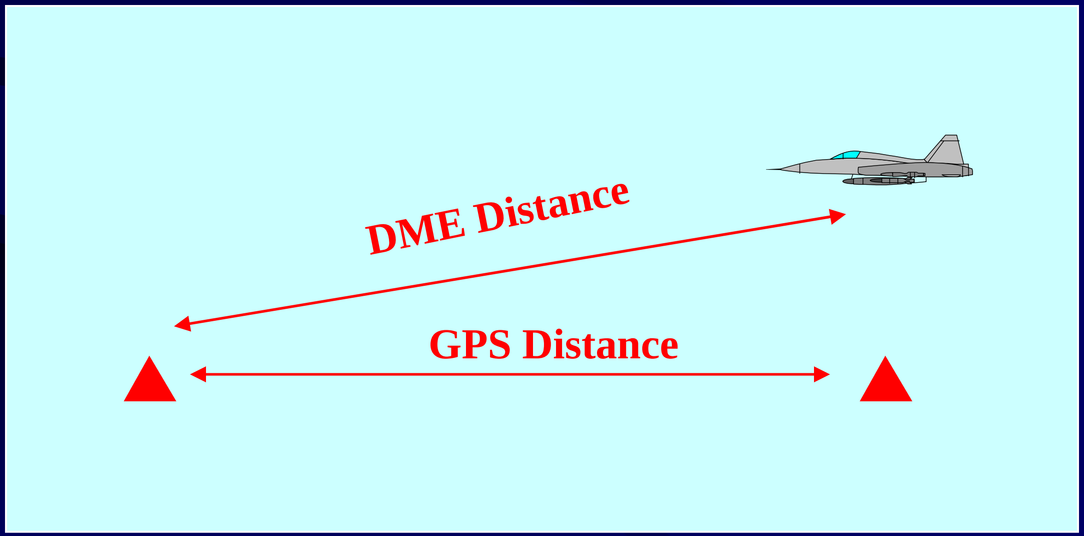


Future WAAS LPV Approaches (see avnweb.jccbi.gov/schedule/production)

State	APT	Airport	Approach	Date
DE	KEVY	Middletown/Summit	RNAV (GPS) RWY 17, AMDT 1	11/23/2006
DE	KEVY	Middletown/Summit	RNAV (GPS) RWY 35, ORIG	11/23/2006
MD	K2W6	Leonardtown	RNAV (GPS) RWY 11, ORIG	1/18/2007
PA	K40N	Coatesville/Chester County G O Carlson	RNAV (GPS) RWY 11, ORIG	5/10/2007
PA	K9D4	Myerstown/Decks	RNAV (GPS) RWY 19, ORIG	1/18/2007
PA	KBTP	Butler/Butler County/K W Scholter Fld	RNAV (GPS) RWY 8, ORIG	11/23/2006
PA	KCXY	Harrisburg/Capital City	RNAV (GPS) RWY 26, ORIG	9/28/2006
PA	KFKL	Franklin/Venango Regional	RNAV (GPS) RWY 21, AMDT 1	8/3/2006
PA	KLBE	Latrobe/Arnold Palmer Regional	RNAV (GPS) RWY 23, ORIG	5/10/2007
PA	KOYM	St Marys/St Marys Muni	RNAV (GPS) RWY 28, AMDT 1	11/23/2006
PA	KOYM	St Marys/St Marys Muni	RNAV (GPS) RWY 10, AMDT 1	11/23/2006
PA	KPHL	Philadelphia/Philadelphia Intl	ILS RWY 17, AMDT 7	12/20/2007
PA	KPHL	Philadelphia/Philadelphia Intl	CONVERGING ILS RWY 17, AMDT 5	12/20/2007
PA	KPHL	Philadelphia/Philadelphia Intl	RNAV (GPS) RWY 17, AMDT 2	12/20/2007
VA	KCHO	Charlottesville/Charlottesville-Albemarle	RNAV (GPS) Z RWY 21, ORIG	9/28/2006
VA	KCJR	Culpeper/Culpeper Regional	RNAV (GPS) RWY 4, ORIG	5/10/2007
VA	KCJR	Culpeper/Culpeper Regional	RNAV (GPS) RWY 22, ORIG	5/10/2007
VA	KLNP	Wise/Lonesome Pine	RNAV (GPS) RWY 24, ORIG	11/23/2006
VA	KMKJ	Marion/Wytheville/Mountain Empire	RNAV (GPS) RWY 26, ORIG	11/23/2006
VA	KMTV	Martinsville/Blue Ridge	RNAV (GPS) RWY 30, AMDT 1	11/23/2006
VA	KROA	Roanoke	RNAV (GPS) RWY 6, AMDT 1	9/28/2006

GPS Terminology and IFR Requirements
GPS/Distance & VOR/DME Depiction Differences

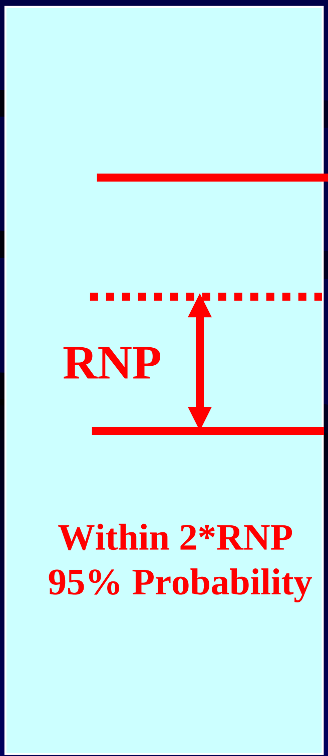
1. Magnetic tracks defined by VOR radials (changes infrequently) are determined by magnetic variation (always changing) at the VOR
2. GPS receiver uses true north at the current position and has a magnetic model to convert to a magnetic heading
3. Variation in distances will occur, since GPS distance-to-waypoint values are along track (straight line) distances, while VOR/DME distances are slant range distances



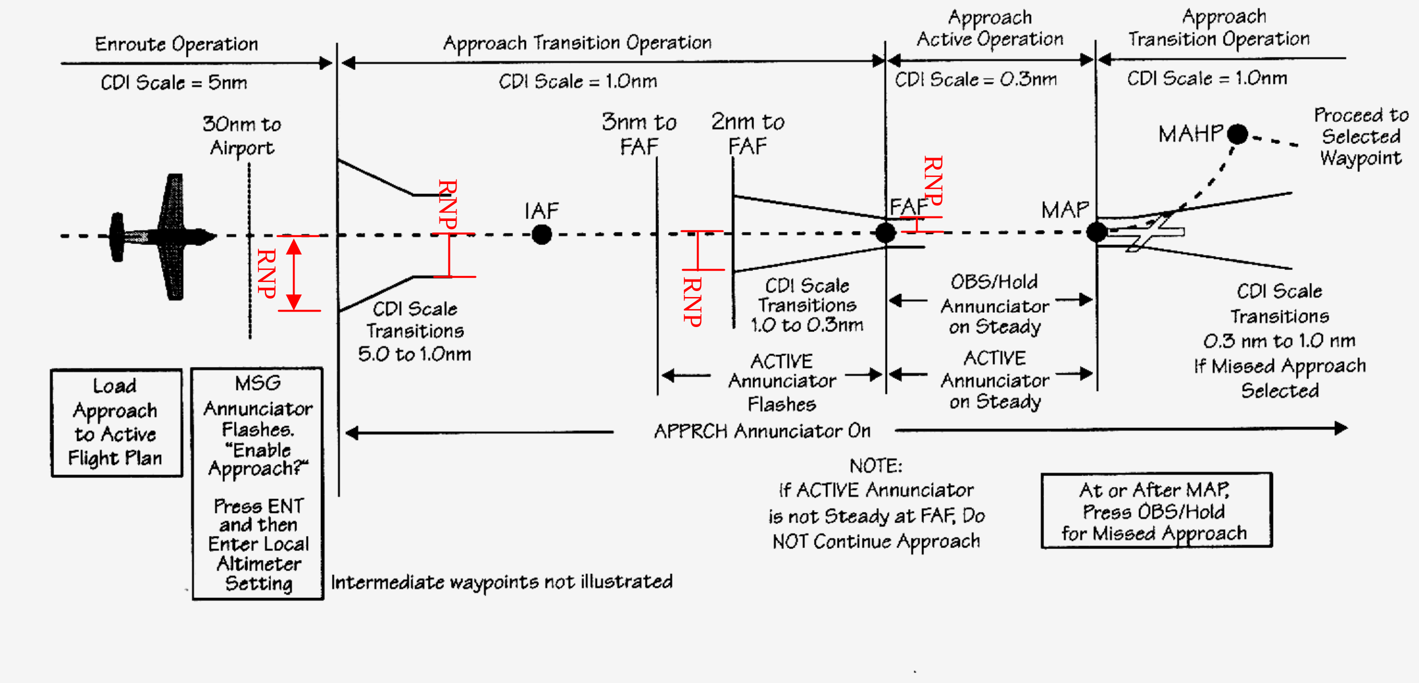
GPS Terminology and IFR Requirements
RNAV Required Navigation Performance (RNP) in US

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



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 !!

Start Date	Database Cycle
12/22/05	0513
01/19/06	0601
02/16/06	0602
03/16/06	0603
04/13/06	0604

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

GARMIN GNS 430 ACKNOWLEDGEMENT SCREEN AT START-UP

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**

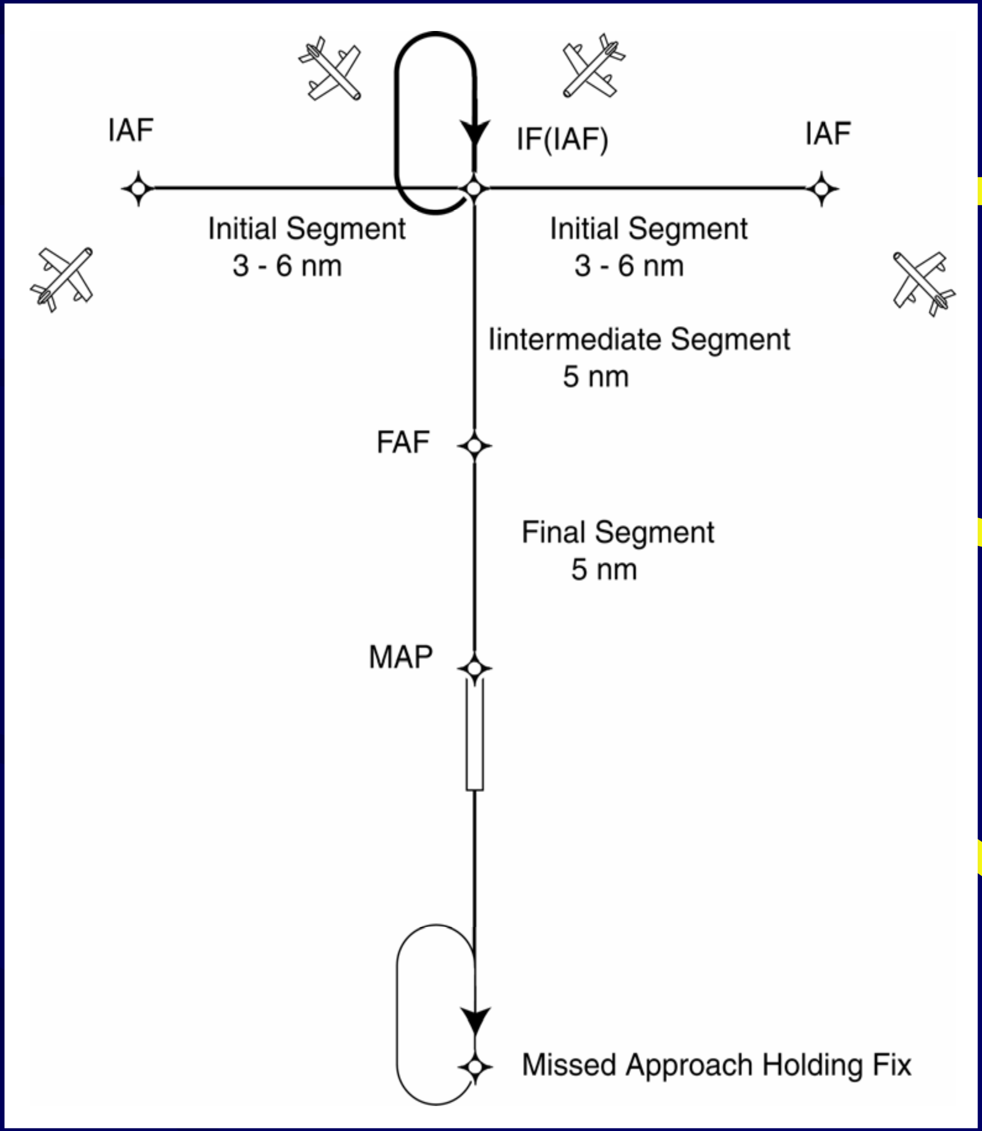
*********** NOTAMs ***********

!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

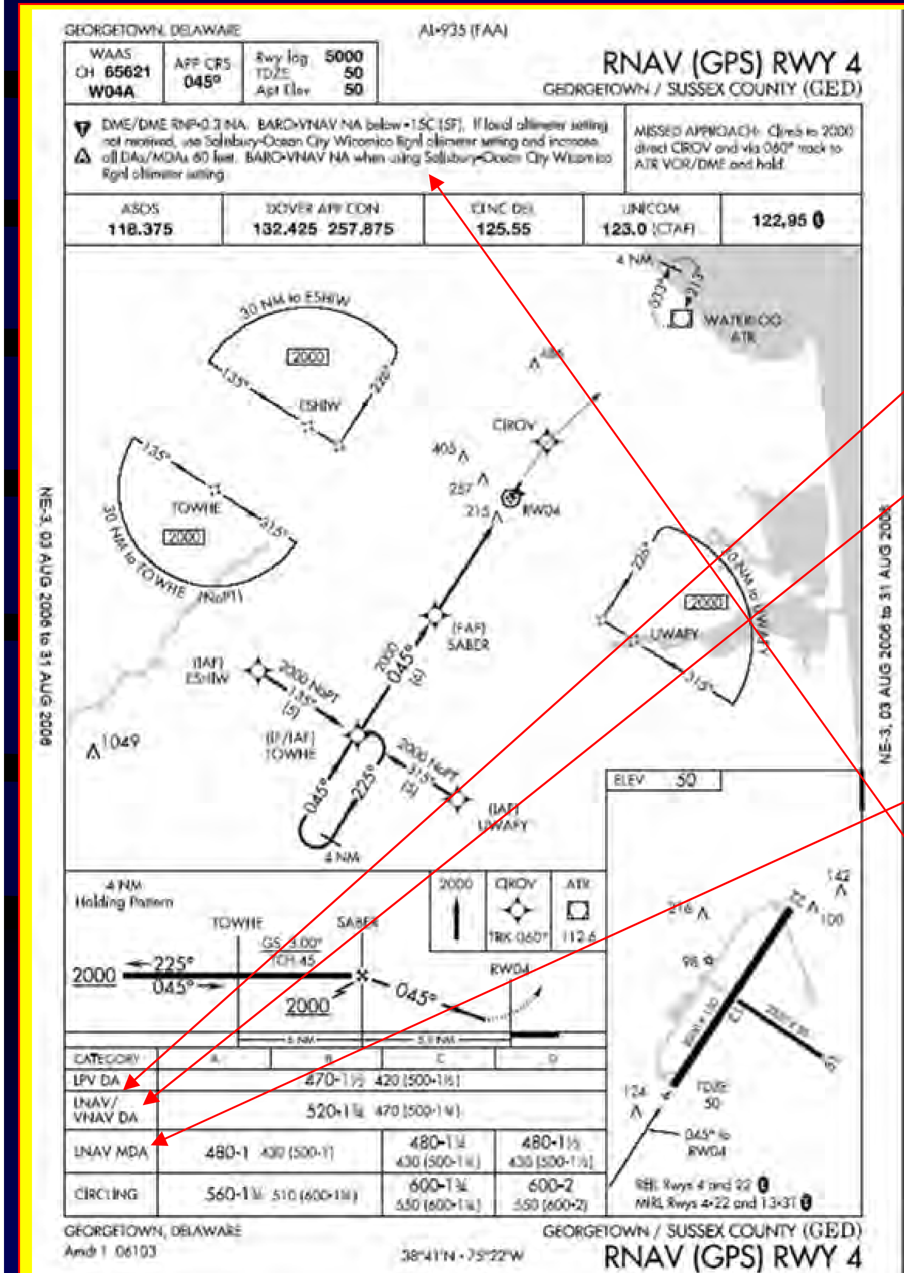
- The basic “T” design aligns the instrument approach procedure on runway centerline with the missed approach point
- Missed approach point (MAP) is at runway threshold
- No procedure turns are needed
- Holding pattern at IF/FAF for pilots that elect to execute a procedure turn (PT) to meet descent gradient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



GPS User Segment (Garmin GNS 430)

Garmin GNS 430

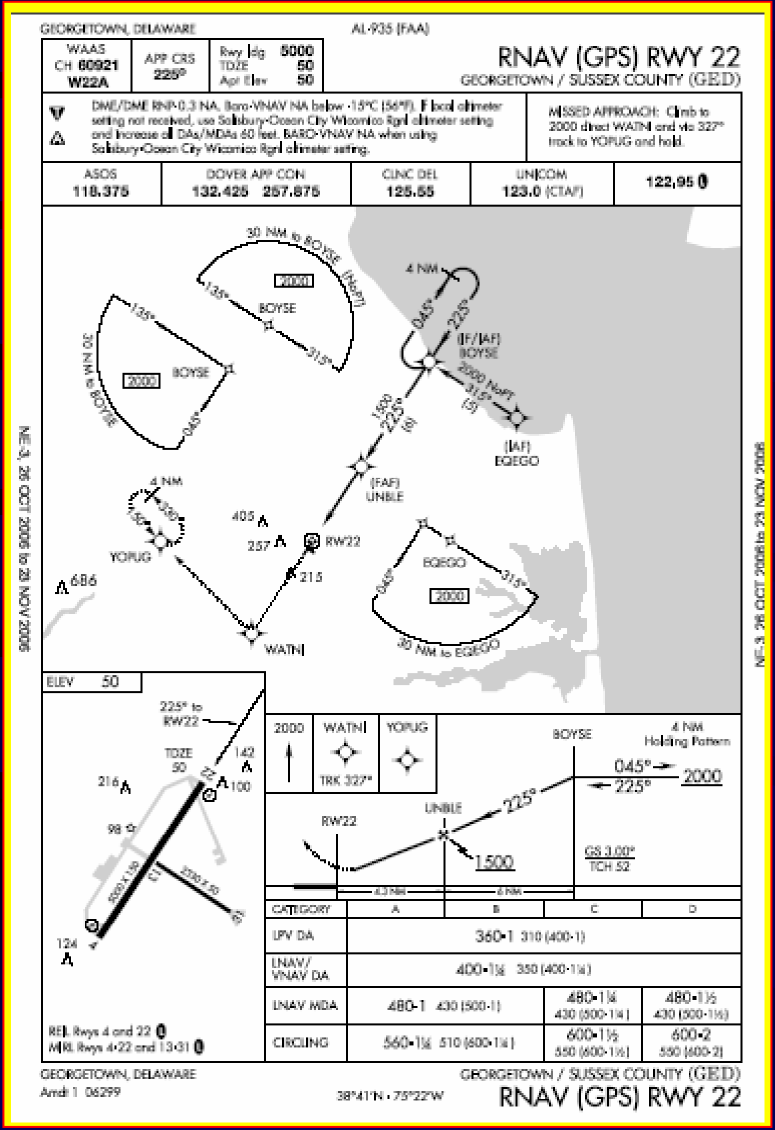
- **The GNS 430 contains several receivers:**
  - **GPS (database updated on 28 day cycle)**
  - **VOR**
  - **Localizer**
  - **Glideslope**
- **Certificated for Enroute, Term & Appch Opns**
- **Types of Approaches Permitted:**
  - **Non-precision standalone LNAV GPS approaches and overlay approach – 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**

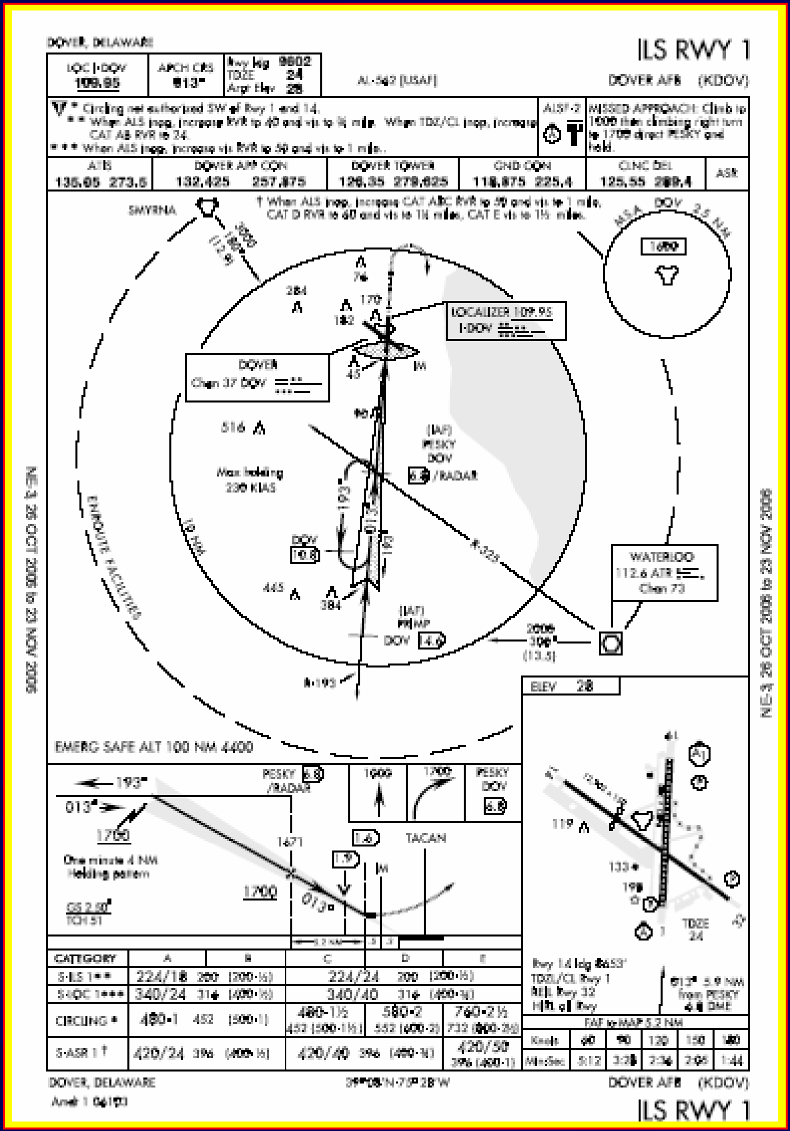


RNAV (GPS) RWY 04 GED Approach (Georgetown, DE)

- **LPV => localizer performance with vertical guidance (WAAS)**
- **LNAV/VNAV => Lateral Navigation, Vertical Navigation (RNAV approaches with vertical guidance). Less precise approach than precision LPV approach (Chelton System Approved for these Minima)**
- **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 User Segment





GPS References for Pilots

- Aeronautical Information Manual (AIM),
  Sections 1-1-19/20, 5-4-5/6/7 , U.S. Dept of Trans, FAA, (2006).
- AC 90-94 - Guidelines for Using GPS Equipment for IFR En Route and Terminal Operations and for Nonprecision Instrument Approaches in the U.S. National Airspace System, FAA, Dec 1994.
- Garmin GNS430 GPS User Manual
  www.garmin.com/products/gns430/manual.html
- Instrument Flying Handbook, FAA-H-8083-15, U. S. Dept of Trans, FAA, Flight Standards Office, (2002).
- AC 20-138A –Airworthiness Approval of Global Navigation Satellite System (GNSS) Equipment
- 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