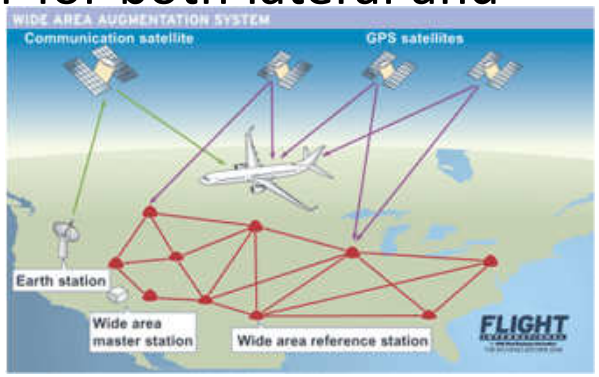
GPS Approaches

GPS Terminology

- Receiver Autonomous Integrity Monitoring (RAIM) – Process used by a GPS receiver to determine the integrity of the GPS' position using only GPS signals.
- Wide Area Augmentation System (WAAS) – Ground based signal that augments satellite GPS signals, to improve the GPS' accuracy, integrity, and availability
  - WAAS uses a network of ground-based reference stations to measure small variations in GPS signals. The measurements are then routed to master stations, which compute the Deviation Correction (DC) and send correction messages to WAAS satellites every 5 seconds or better
  - Provides position accuracy of 25 ft or better for both lateral and vertical measurements



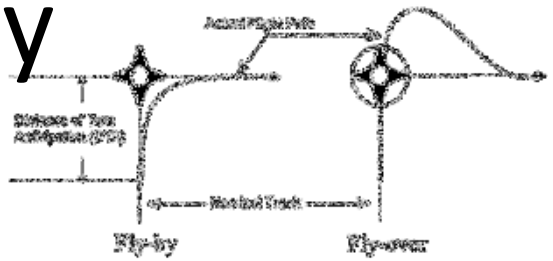
GPS Terminology

- Track (TRK or TK) – provides aircraft's precise track along the ground.
  - This isn't heading – it is the actual direction the aircraft is moving, corrected for wind, deviation, and variation
- Desired Track (DTK) - course line to the next waypoint
- Bearing (BRG) - direction you need to go to get to the waypoint from your present position

GPS Terminology

- Distance – Unlike DME distances are not based on slant distance
- Non-Sequential Mode (Susp or OBS button) –
  - When you enter a series of waypoints in the GPS, it assumes that, as you cross each one, it should automatically switch to the next waypoint
  - Sequencing is useful, unless you need to do something different like a hold or a procedure turn. In these instances, you will cross a particular waypoint more than once before you want to activate the next waypoint. As a result, every GPS allows you to turn off the auto-sequencing function (Suspend)
- Moving Map
  - Track-Up - display rotates the map around to your direction of flight
  - Desired Track Up - display will put the direction you're supposed to go at the top of the map - can be dangerous, since you could go off course enough to depart the map display
  - North-Up display - places north at the top of the map – more like a paper chart.

GPS Terminology



- Waypoints
  - GPS approaches make use of both fly-over and fly-by waypoints
    - Fly-by waypoints are used when an aircraft should begin a turn prior to reaching the waypoint separating the two route segments. This is known as turn anticipation
      - Approach waypoints, except for the MAWP and the missed approach holding waypoint (MAHWP), are normally fly-by waypoints.
    - Fly-over waypoints are used when the aircraft must fly over the point prior to starting a turn.
  - Approach charts depict fly-over waypoints as a circled waypoint symbol
  - Understand bank angle / turn rate that your GPS uses and whether your GPS considers wind and airspeed for turn anticipation. Over/under banking can prove troublesome on approaches.

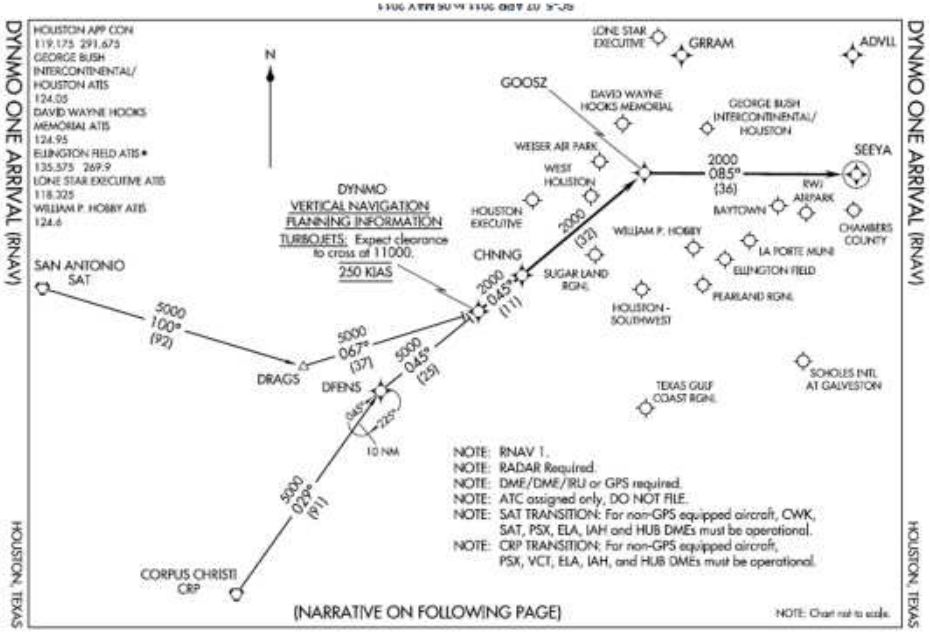
How it Works

- GPS is based on the concept of ranging and triangulation from a minimum of four satellites above the mask angle (lowest usable angle above horizon)
  - Each satellite transmits a specific course/acquisition (CA) code containing
    - Satellite's ephemeris (exact position in space)
    - GPS system time
    - Health and accuracy of the data
  - Accuracy +/- 50’ horizontally, 10’ with WAAS
  - Do not use non-WASS GPS altitude information – error can be up to 500 meters (1600’)
- Pseudo-range (distance determined by time measurement) is derived by your GPS receiver/processor
  - Using pseudo-range and position information from at least four satellites, the GPS receiver computes, by triangulation, a three-dimensional position (latitude, longitude, altitude) and time solution
- Navigational values are computed by the GPS using the position/time solution describde above and its built-in database

Potential Errors

- Loss of signals due to antenna position or higher terrain
- Signal interference / jamming
  - Harmonic interference from UHF transmission
  - Multipath – reflected signals
  - Satellite transmission errors
  - Selective availability (DoD can turn off service)

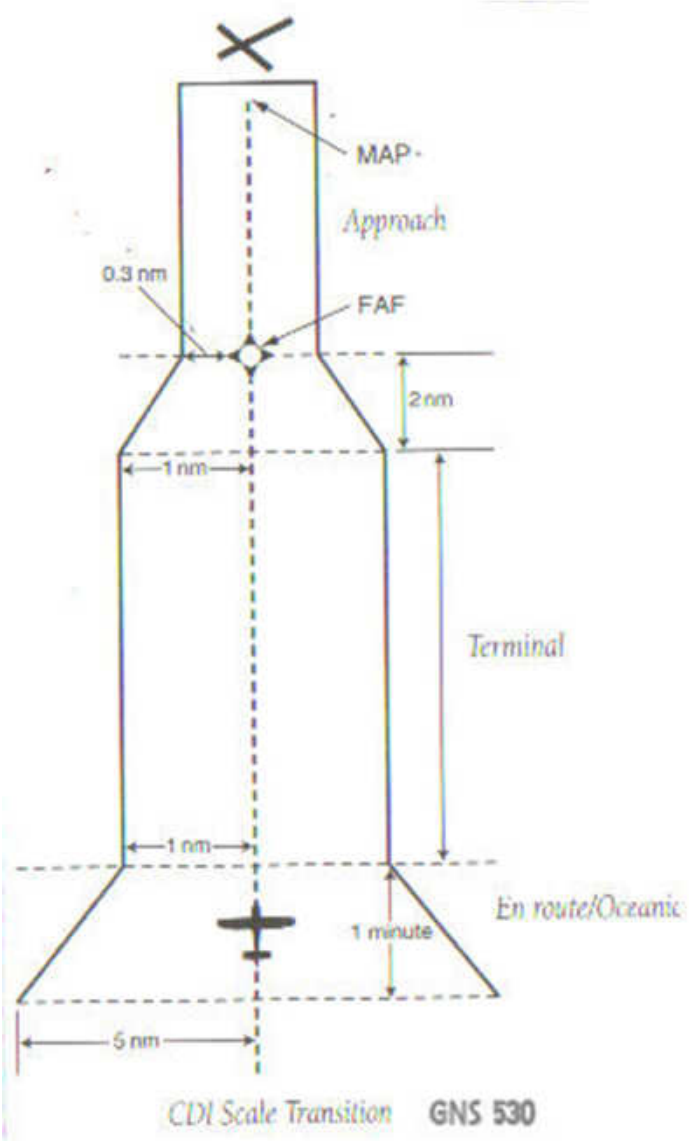
Approach Begins With STAR



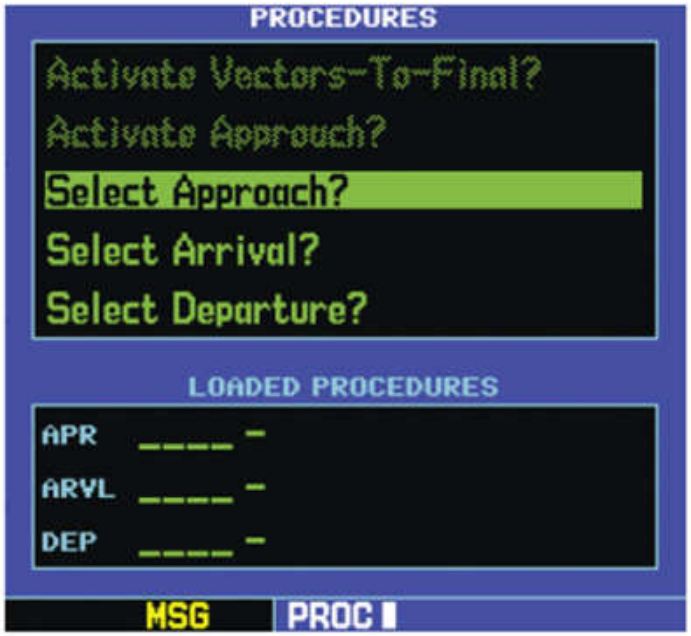
- GPS is different than other avionics – Sensitivity must be sequenced by the GPS for enroute, terminal and approach segments

GPS Variable CDI Sensitivity

- Enroute – 5 nm (>30 nm)
- Terminal – 1.0 nm (.2nm dot) (30 nm to 2 nm)
- Approach - .3 nm (360’ per dot)(<2nm)
- CDI progressively steps up sensitivity – can be deceptive as to off course distance
- Approach mode should be armed before the airplane is within 30 miles of the airport
- Arming the approach mode activates sequencing of CDI sensitivity - this change in CDI sensitivity is why you must "load" and "activate" an approach rather than flying “direct to” each of the approach fixes



Loading the STAR

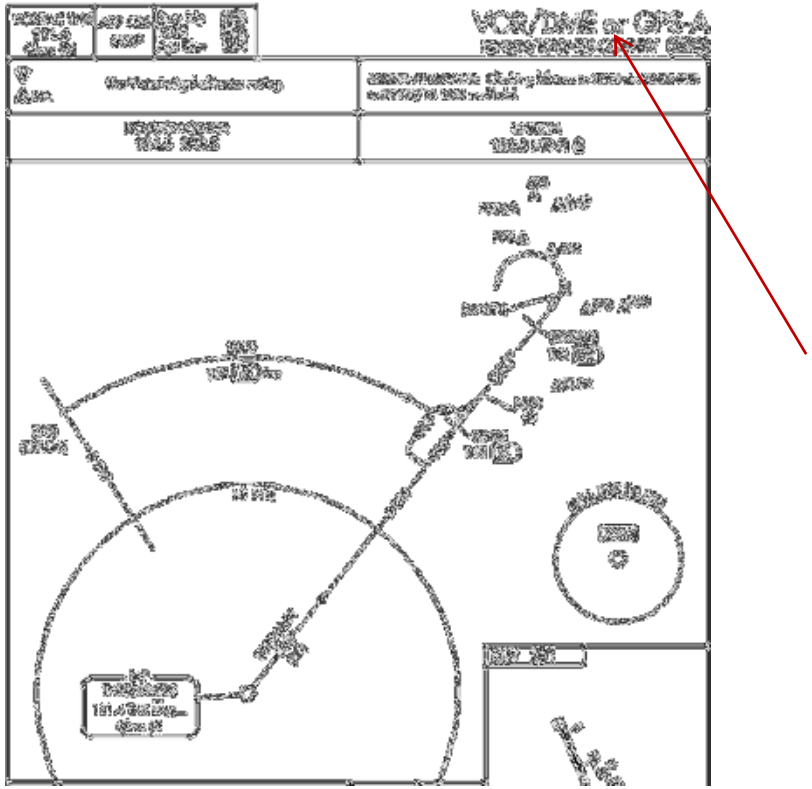


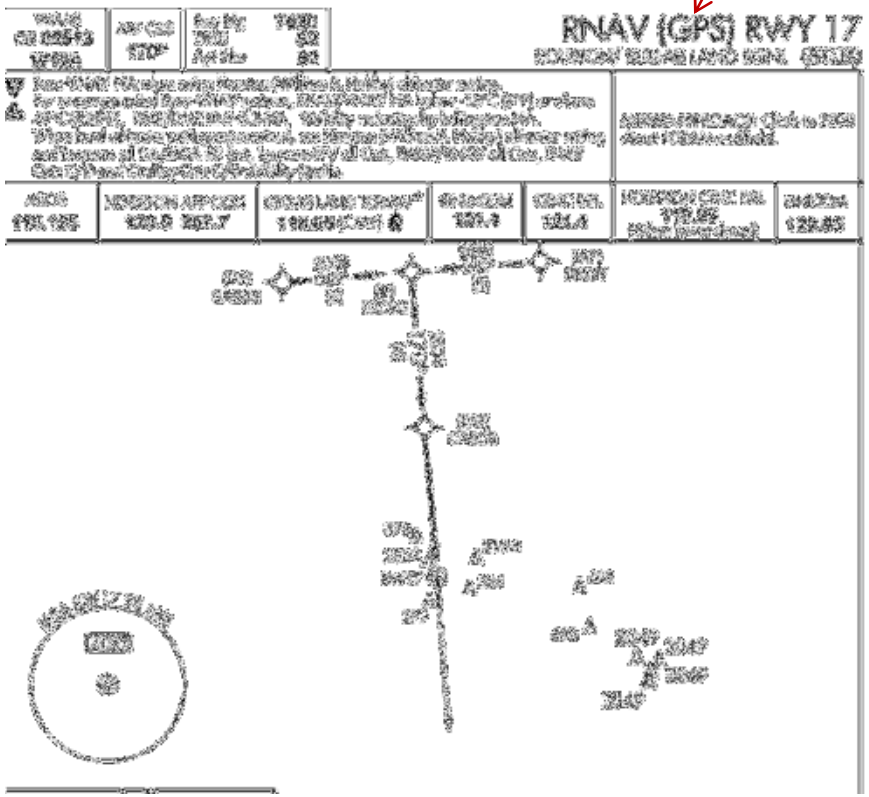
- Select arrival and then enter the name of the arrival
- The GPS will then ask for the transition to be used
- When an approach has been loaded in the flight plan, GPS receivers will give an "arm" annunciation 30 NM straight line distance from the airport
- You need to know how to operate your GPS – all of them are different

General GPS Approach Categories

- GPS overlay procedure – Procedure allows pilots to use GPS to fly an existing non-precision instrument approach based on the location of conventional ground navaids
  - A Phase III GPS overlay procedure is published with “or GPS“ in addition to the ground based procedure designation. Phase II GPS approaches have no GPS reference in the title
- GPS stand-alone procedure - An instrument approach procedure based solely on GPS without reference to conventional ground navaids
  - Identified as “RNAV (GPS) procedure name”
  - RAIM or equivalent monitoring functions must be available
  - Most use “T” format

Approach Categories





Using GPS for DME or Overlay Approaches

- GPS receivers may be used to fly all nonprecision approaches that can be retrieved from the GPS' database, **except** localizer, localizer directional aid (LDA), and simplified directional facility (SDF) approaches.
- Approach overlay program has three phases.
  - Phase I ended in 1994
  - Phase II - GPS can be used as the primary guidance to fly an overlay to an existing nonprecision approach without actively monitoring the applicable NAVAID. Ground-based NAVAID(s) must be operational and the aircraft's avionics must be operational. Avionics need not be operating if RAIM is available. Pilots can tell Phase II approach - "GPS" is not included in the title of the approach.

Using GPS for DME or Overlay Approaches

  - Phase III approaches include "or GPS" in the title of the procedure. Neither traditional avionics nor ground based NAVAIDs need be installed, operational, or monitored. However, if the GPS does not use RAIM, the ground-based NAVAIDs and traditional avionics must be installed and operating.
- Mixture of nonprecision Phase II, Phase III, and GPS stand alone approaches will exist for some time.
- Most nonprecision instrument approaches (except localizer, LDA, and SDF) are available under Phase II. Eventually, these approaches will become Phase III approaches.
- FAA continues to develop stand alone GPS approaches.

Types of Approaches
LNAV / VNAV / LPV

- If your GPS is non-WAAS (TSO C129), then you only get lateral guidance and you fly the approach like any other non-precision approach, descending as indicated on the profile view of the approach chart.
- With a WAAS GPS receiver, the approach minimums you use depend on the course sensitivity the GPS displays when you are flying the approach
  - The GPS will display the sensitivity level a few miles outside the FAF
  - Course sensitivity depends on WAAS signal integrity and may vary from day to day and hour to hour.

Types of Approaches

	LNAV	LNAV/VNAV	LPV
Lateral Navigation	X	X	X
Vertical Guidance	Descend incrementally based upon fixes	X – Internally generated descent path - average DH of 350 feet – vertical accuracy of 20-50 meters	X – Equivalent to localizer precision
Type of Approach	Non-precision approach		
Equipment requirements		Flown with barometric vertical navigation or WAAS	WAAS generated vertical guidance - equivalent to localizer
Use		Used only on the handful of approaches for which no LPV minimums are designated, since LNAV/VNAV minimums are almost always higher than LPV minimums	

Types of Approaches
LPV / LNAV - The Extremes

- LNAV - lateral navigation only, no descent guidance
- LPV (localizer performance with vertical navigation) – An approach with WAAS generated vertical guidance to a Decision Altitude (DA)
  - Provides lateral and vertical guidance similar in precision to an ILS
  - Usually to a DA no lower than 250 HAT and no less than 1/2 mile visibility
  - VNAV sensitivity will be annunciated at the last fix before the final approach fix

Types of Approaches
LNAV/VNAV

- Provides lateral and vertical navigation
- Final approach segment's obstacle environment surfaces are treated somewhat like an ILS but without the precise measurements of the curvature of the earth or other precise anchor points that an LPV approach uses
  - The WAAS G/S is in essence emulating a barometric VNAV glide slope without the temperature errors.
  - There is no taper down of lateral obstacle clearance.
- You probably don’t have one

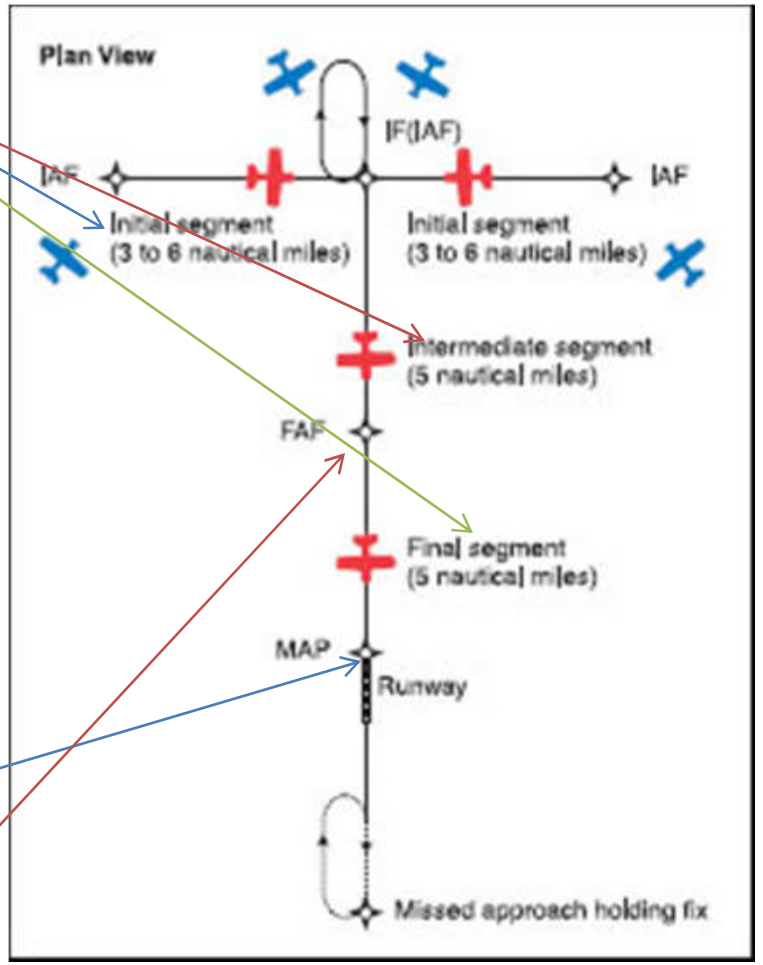
Types of Approaches
LNAV+V - lateral navigation with advisory descent guidance

- provides only ***advisory*** guidance and is considered a non-precision approach –
- There is no vertical guidance provided for in the FAA procedure
  - It is strictly a Jeppesen add on, and if done correctly, will allow you to fly the approach without violating any stepdown fixes in the final approach segment
  - Do not descend below any step-down altitude listed on the approach chart's profile view.
  - You may see LNAV+V on some RNAV approach charts that only have LNAV minima, but you may also see it on an RNAV approach where the required signal integrity for LPV is unavailable.
  - RNAV approaches with only circling minima and with an approach course that is more than 30 degrees out of alignment with any runway will not display advisory guidance.
  - The *advisory* vertical guidance should be the constant glide angle required to get you to MDA a just before the missed approach point.

Stand Alone Approach

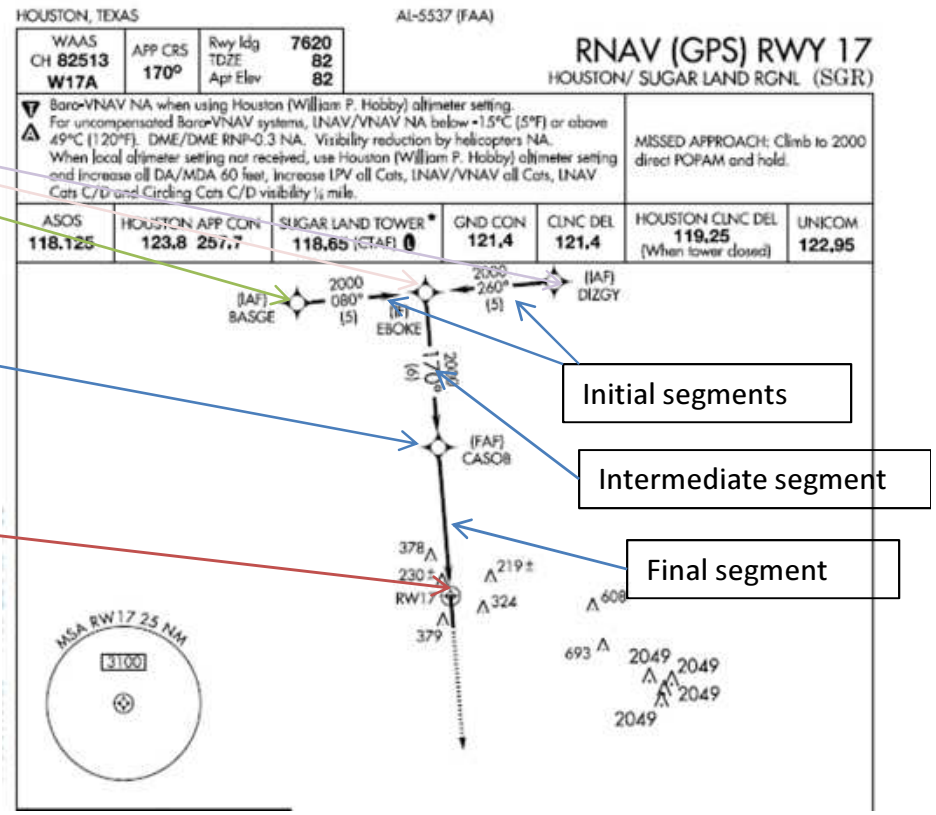
Basic “T” Design of Terminal Arrival Area (TAA)

- 3 segments as with other approaches
- Eliminates or reduces the need for feeder routes, departure extensions, and procedure turns or course reversal
- Standard TAA has three IAFs: straight-in, left base, and right base with NoPT
- The arc boundaries of the three areas of the TAA are published portions of the approach and allow aircraft to transition from the en route structure directly to the nearest IAF BUT in all cases you have the option to go directly to the holding pattern
- Aligns the procedure on the runway centerline
- Missed approach point is located at the threshold
- The FAF is 5 NM from the threshold, and the intermediate fix (IF) is 5 NM from the FAF



Stand Alone
Basic “T” Design of Terminal Arrival Area (TAA)

- IAFs
- FAF
- MAP



TAA approach enables simple transitions to avoid inaccurate & disorienting procedure turns

Stand Alone Approach Improved MAP's

- Significantly safer Missed Approach Climb Procedures
- Focus on Straight Ahead Navigation
- Plenty of time between course changes
- Realistic expectation of ATC intervention prior to hold entry
- Alternate MAP's offer non-GPS dependent version

GPS A, etc.

- Just like that old VOR-A
- Final Approach Course more than 30˚ misaligned from the runway centerline
- For various reasons, the FAA uses GPS approaches the same way
  - Terrain
  - Traffic & Airspace
- Multiple “off-centerline” approaches work down the alphabet

Which Transition?

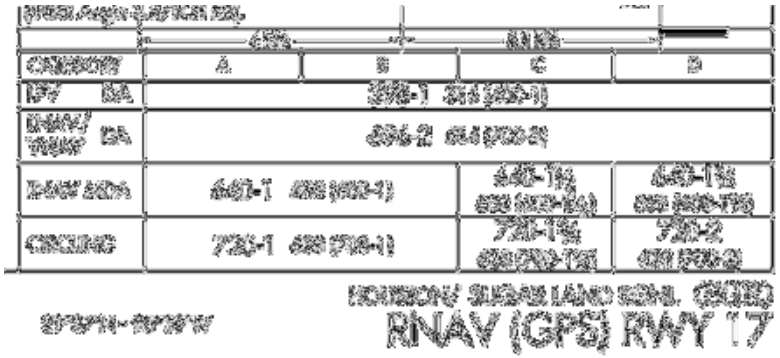
- If you are on the “approach side” of the “T-arms”
  - Select the closest arm as a transition
  - Select the center of the arms, but now the depicted hold in lieu of a procedure turn must be performed
- If you are “outside” of the “T-arms”
  - You may fly directly (when cleared) to the center of the “T arms” & disregard the hold
  - You may not fly directly to the FAF

Stand Alone
Basic “T” Design of Terminal Arrival Area (TAA)

- Load the approach
- Select the IAF transition
- Select hold or no – hold – most often no course reversal
- ACTIVATE the approach

Stand Alone
Basic “T” Design of Terminal Arrival Area (TAA)

- T Design approaches generally support the 3 levels of GPS approach precision
- Which one used depends on the type of GPS equipment being used and signal sensitivity available



Stand Alone
Basic “T” Design of Terminal Arrival Area (TAA)

- Follow the magenta brick road
- Note that before the FAF, usually at the last intermediate fix before the FAF, the GPS sensitivity will change to either LNAV, LNAV+V, L/VNAV, or LPV.

GPS CDI

- Fly the CDI the same as you fly an ILS for vertical guidance or a VOR if LNAV only
- Indicators
  - LNAV Flag
  - VNAV Flag
  - GPS / NAV indicator (VLOC)
  - OBS Ring

Measures distance off course – not degrees off course!!
Enroute - dot = 1 NM
Terminal - dot = .2 NM
Approach - dot = 365’

Flying the Approach
Before the Initial Segment

- Preflight – Plan the approach – Must be familiar with “all available information concerning a flight” prior to departure and FDC Notams
- Enroute – Get weather (ATIS, FSS, etc.) to help determine likely approaches and review
- Calculate / review performance data, approach speeds, and power settings – confirm aircraft and weather are appropriate for the ILS procedure for aircraft’s certified category or, if higher, speed flown
- Set navigation / communication and automation - The navigation equipment required to fly an approach is indicated by the title of the procedure and chart notes
- Approach review and briefing

NOTAMS

- Prior to any GPS IFR operation, the pilot must review appropriate NOTAMs and aeronautical information.
- UNRELIABLE is an advisory to pilots indicating the expected level of service may not be available

NOTAMS

- **Satellite out of service NOTAM**
  - Satellite OOS - GPS 07/009 GPS PRN [pseudo random noise signal] 3 OTS WEF [with effect from] 0607171600-0607172230

- **Degraded WAAS NOTAM**
  - APC 07/034 APC WAAS LNAV/VNAV AND LPV MNM UNREL WEF 0607180554-0607180609
  - IKFDC KFDC WAAS ATLANTIC SATELLITE UNAVBL, WAAS LPV AND LNAV/VNAV MNM UNAVBL EAST OF 110 DEGREE WEST LONGITUDE FOR CONUS AND PUERTO RICO WEF 0709241600

- **Unreliable GPS**
  - KZFW FORT WORTH (ARTCC),TX. [Back to Top] 03/014 - NAV GPS IS UNRELIABLE AND MAY BE UNAVAILABLE WITHIN A CIRCLE WITH A RADIUS OF 365 NM AND CENTERED AT 331127N/1063447W OR THE LOCATION ALSO KNOWN AS 98.7 DEGREES AND 35.6 NM FROM THE TRUTH OR CONSEQUENCES /TCS/ VOR AT FL400; DECREASING IN AREA WITHA DECREASE IN ALTITUDE TO A CIRCLE WITH A RADIUS OF 310NM AT FL250; A CIRCLE WITH A RADIUS OF 235NM AT 10,000FT MSL AND A CIRCLE WITH A RADIUS OF 245NM AT 4000FT AGL.THE IMPACT AREA ALSO EXTENDS INTO THE MEXICAN FIR. 0200-1000 DLY. 29 MAR 02:00 2011 UNTIL 02 APR 10:00 2011. CREATED:27 MAR 13:17 2011
  - In order for a GPS receiver to perform RAIM, a minimum of five satellites with satisfactory geometry must be visible. RAIM is not available 100% of the time, even when all GPS satellites are operational. Also, satellites occasionally need to be taken out of service for maintenance, further reducing the availability of RAIM

- **Ground based transceiver OOS NOTAM**
  - !ANI ANI NAV GBT OTS WEF 0709211600-0709211900

Vectors to Final

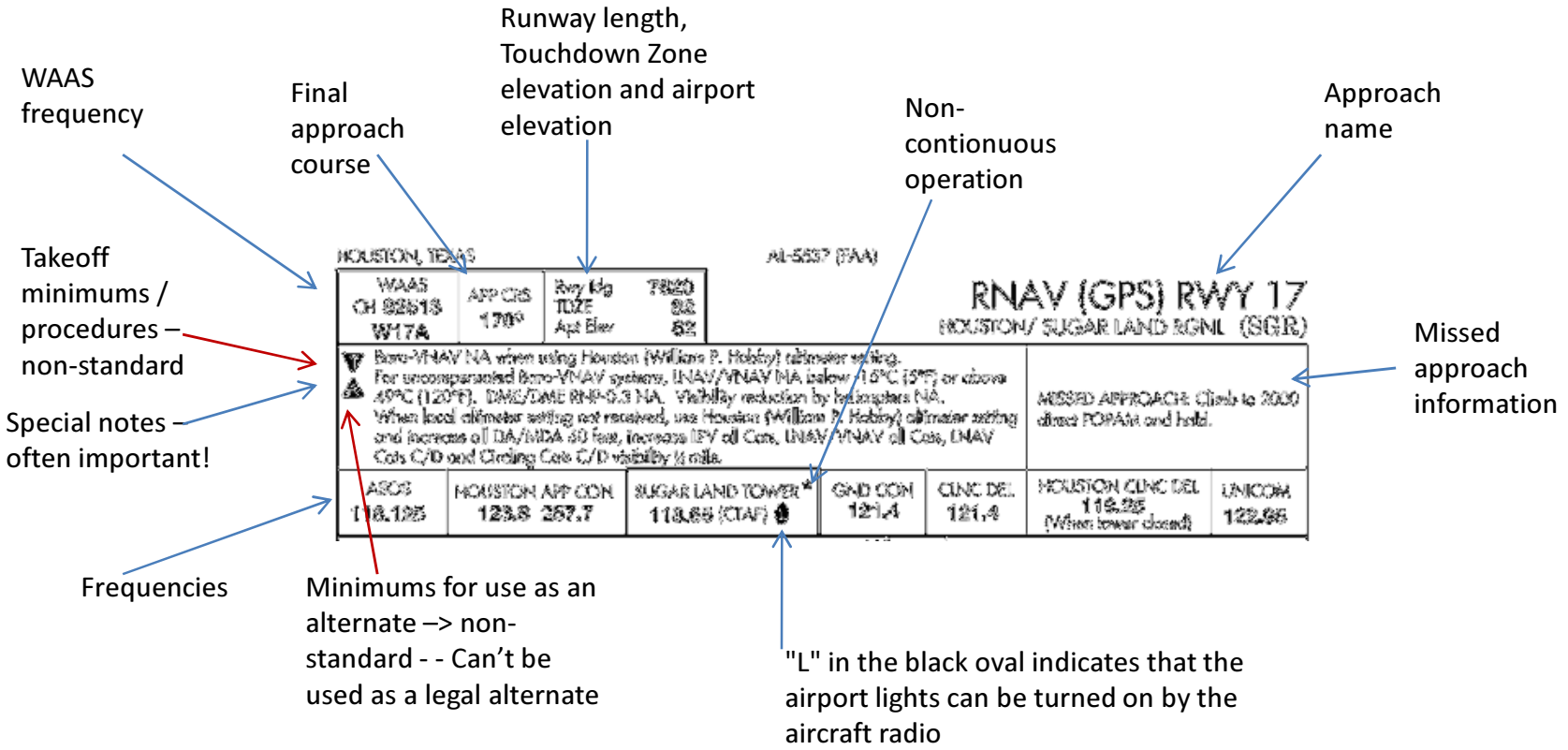
- Use it with caution because ATC is restricted from clearing you direct to any waypoint inside the Intermediate Fix (IF) or vectoring you any closer than 3 miles from the FAF on an RNAV approach.
- Vectors-to-Final will only display the FAF and MAP
- When receiving vectors to final, most receiver operating manuals suggest placing the receiver in the nonsequencing (susp) mode on the FAWP and manually setting the course. This provides an extended final approach course in cases where the aircraft is vectored onto the final approach course outside of any existing segment which is aligned with the runway.

Initial Segment

- Complete brief of the approach
- Begin landing checklist – complete before final segment
- Reset comm and nav radios with required frequencies
- Comply with the clearance and approach
- Finish reducing power to approach settings
- Configure aircraft for landing - Flaps

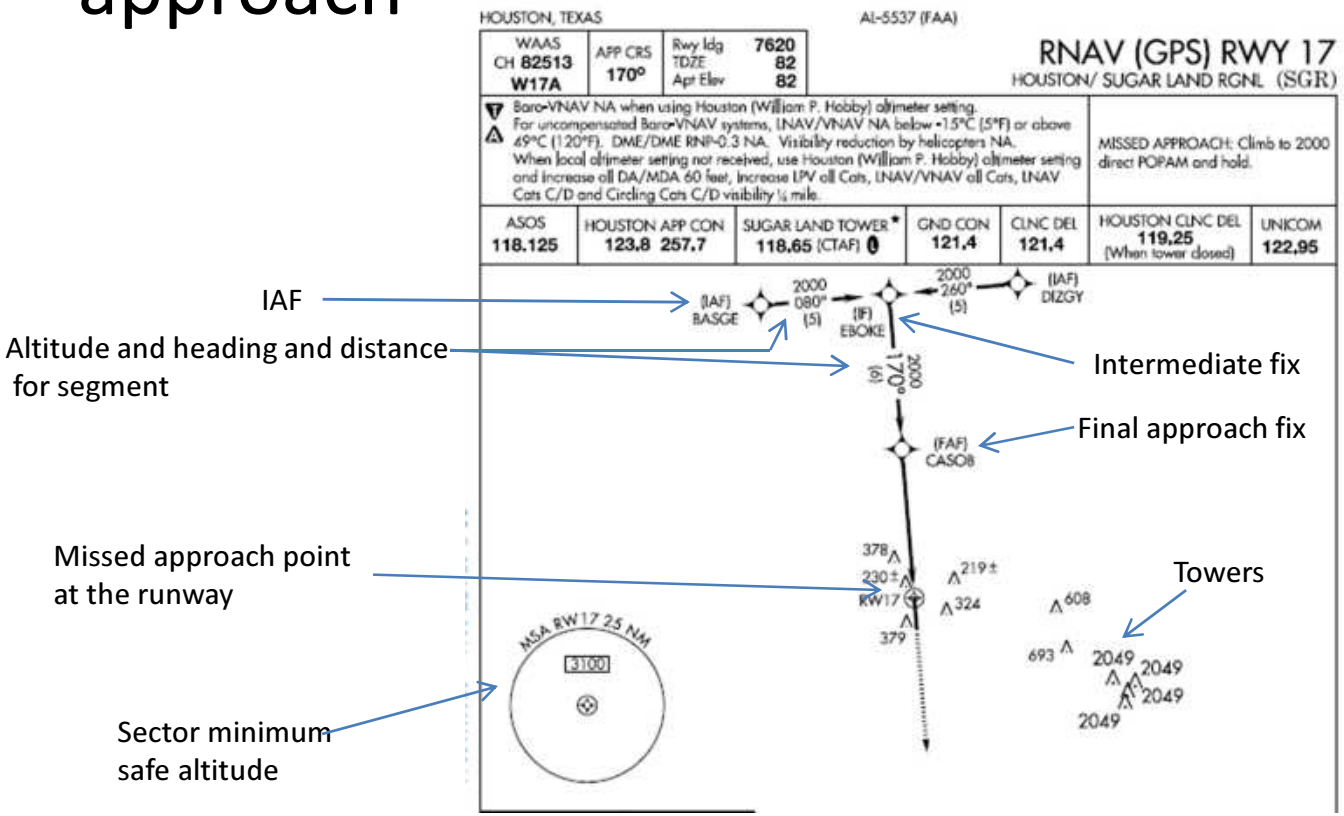
Initial Segment - Briefing

- Brief and review approach to assure you can execute it - Complete before end of segment



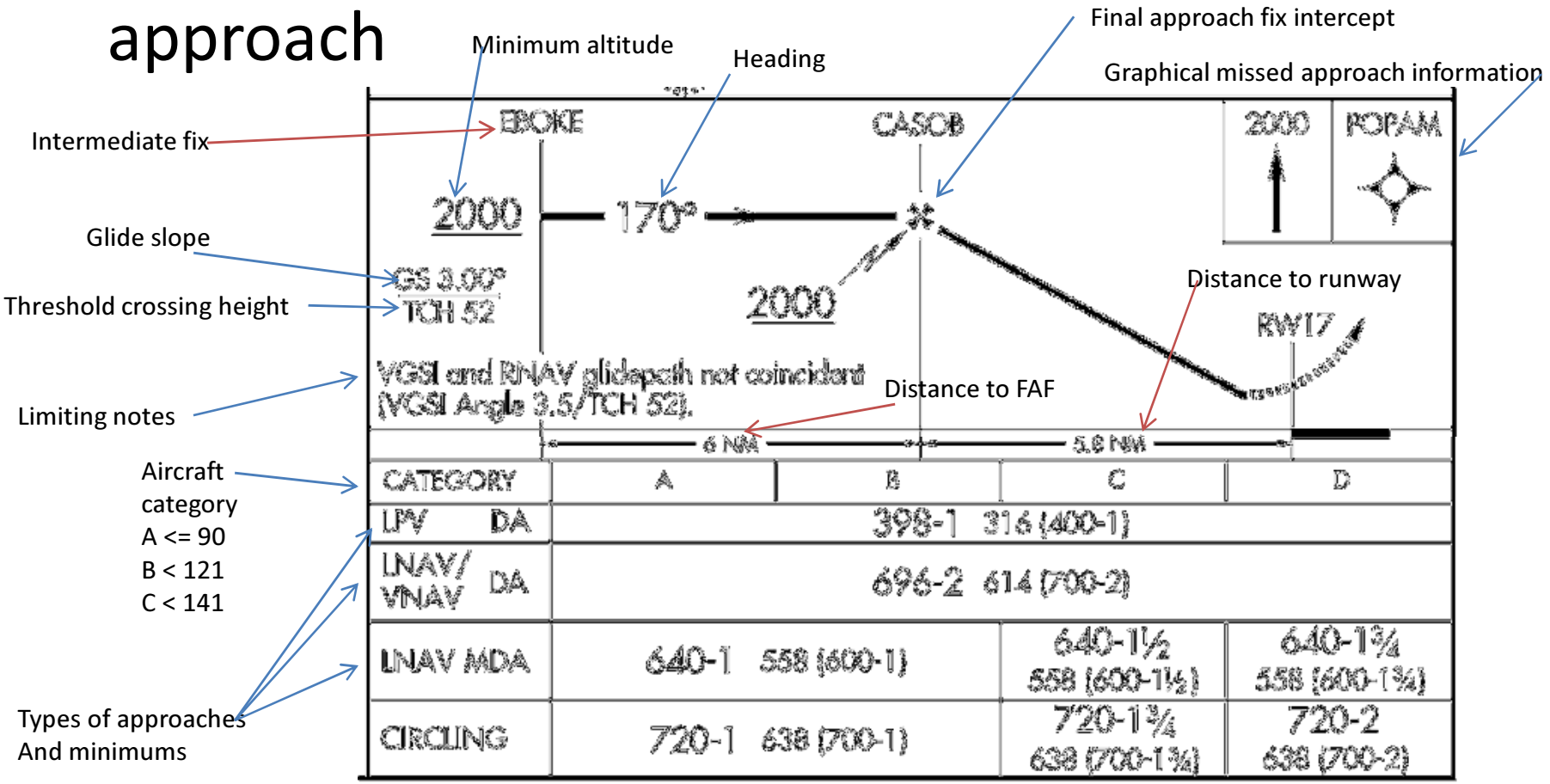
Initial Segment - Briefing

- Plan view – mentally run through the approach

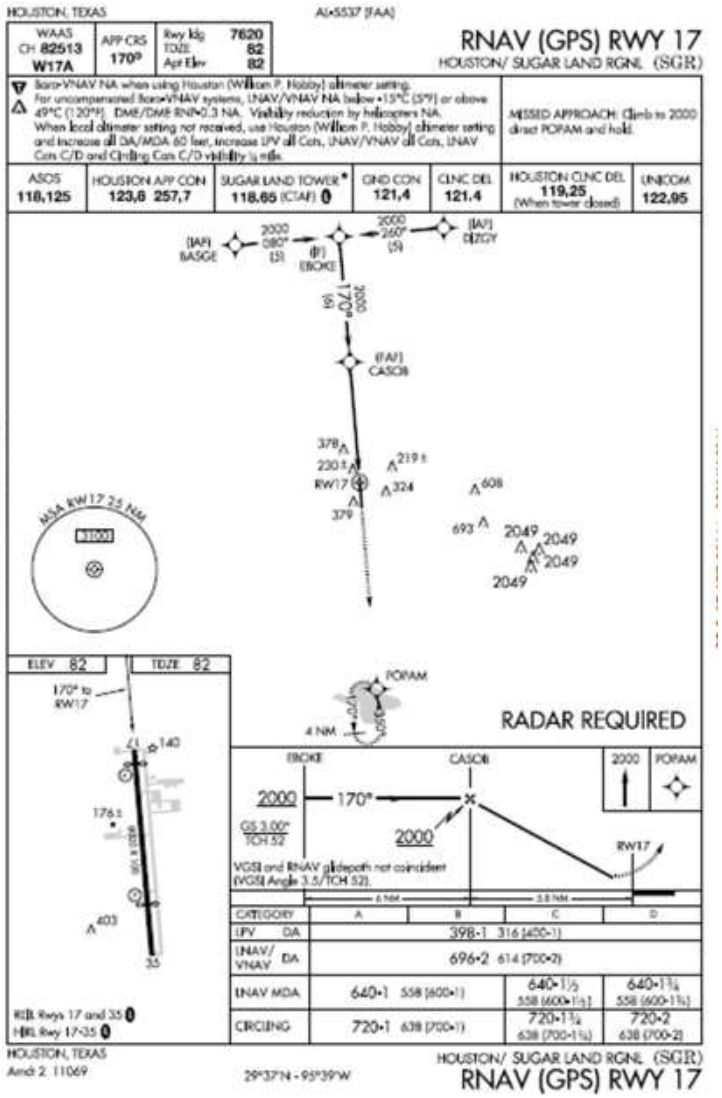


Initial Segment - Briefing

- Profile view – mentally run through the approach

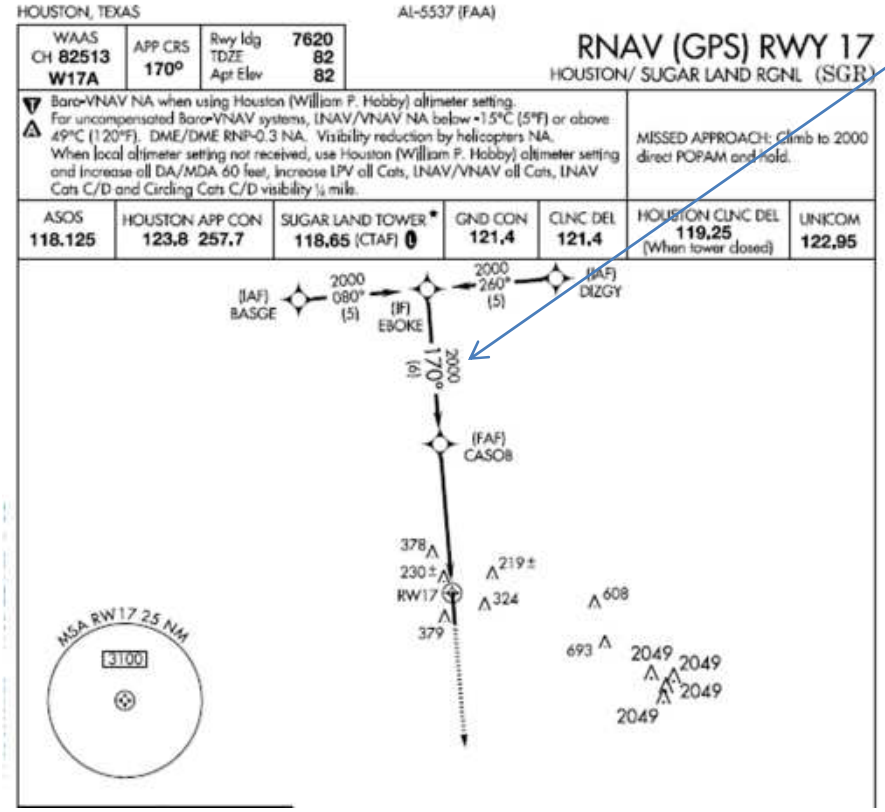


Let's Fly – The Initial Segment



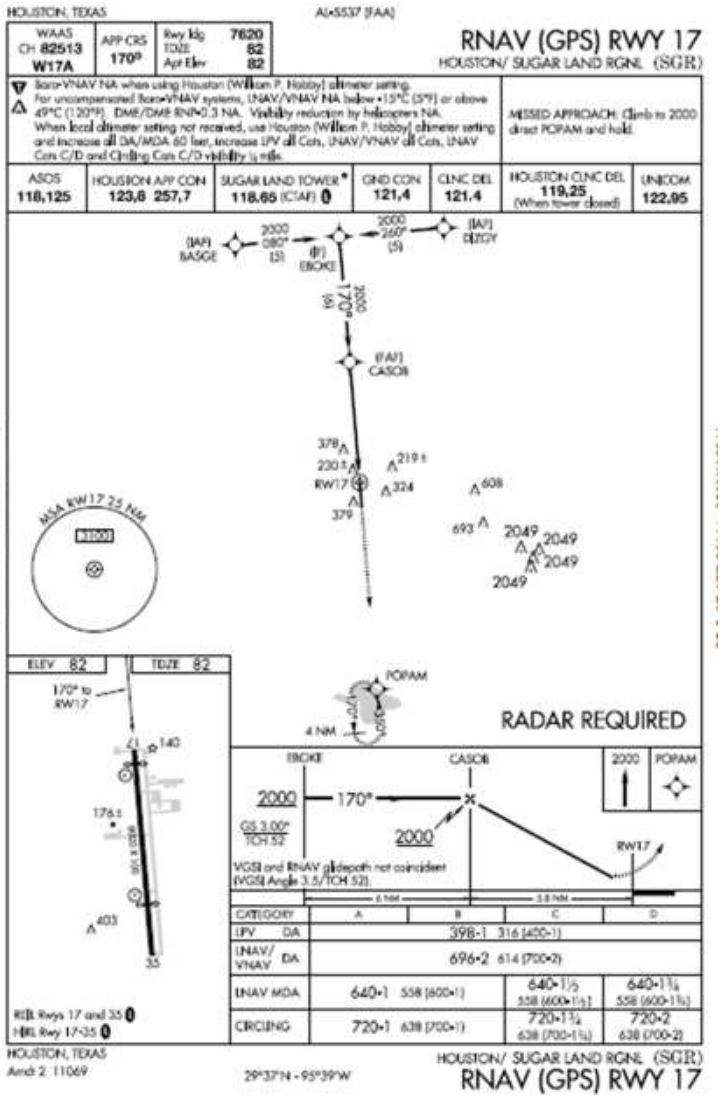
- GPS loaded and activated – Note you can review the approach in the GPS (Garmin press FPL key)
  - If approach is not activated before 2 nm of MAWP, approach mode will not become active timely
- Radios tuned to Approach / Tower
- Confirm CDI is set for GPS (not VLOC)!
- Reduce power to approach setting
- Cross over IAF at 2,000 feet – segment should turn magenta
- Turn to track towards IF either (80 / 260 degrees)
- Be sure to turn the OBS ring with each directional change to match the course as a reminder, although it won't impact the CDI indication
- Before IF begin turn inbound on 170° based on turn anticipation
- Intermediate segment should become active - magenta.

Flying the Approach



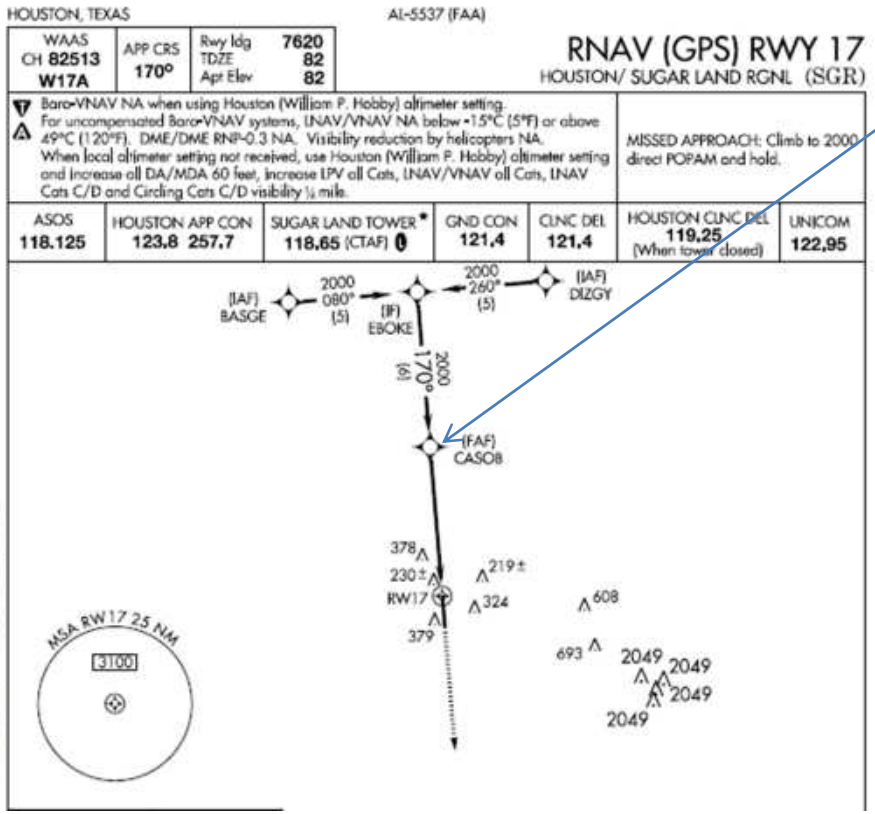
- Intermediate Segment
  - Intermediate segment positions the aircraft for the final descent to the airport
  - normally aligned within 30° of the final approach course
  - Segment begins when
    - you are proceeding inbound to the FAF,
    - are properly aligned with the final approach course
  - May not be charted on some non TAA approaches (TAA)
    - Approach with a procedure turn is the most common example of an uncharted IF
      - intermediate segment begins when you intercept the inbound course after completing the procedure turn
  - Ends at final approach fix

Let's Fly – The Intermediate Segment



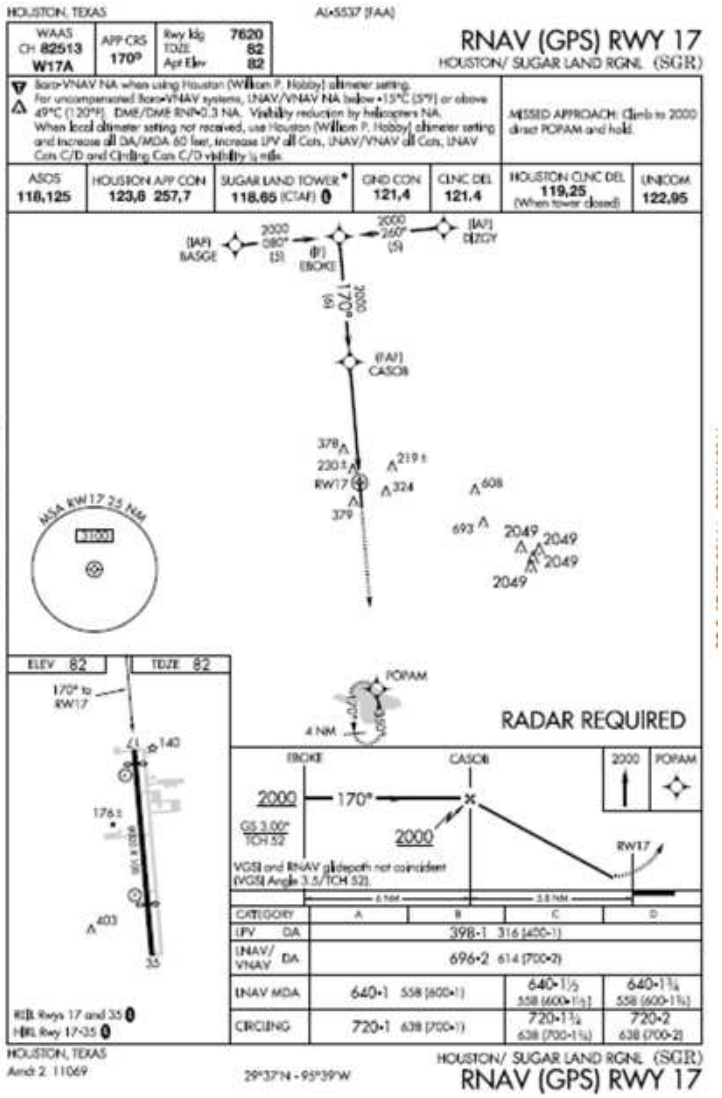
- Inbound on 170°
- Verify power settings for the approach and drop first notch of flaps
- Remain at 2000 feet
- Glide Slope needle should start to come down from the top of the CDI/HSI
- When the glide slope needle reaches the middle of the CDI/HSI, drop the gear (some wait to FAF)
- Likely to be told to switch to local / tower frequency
- Complete landing checklist (try to complete as much as possible before intermediate segment)
- You are now at the final segment!

Flying the Approach



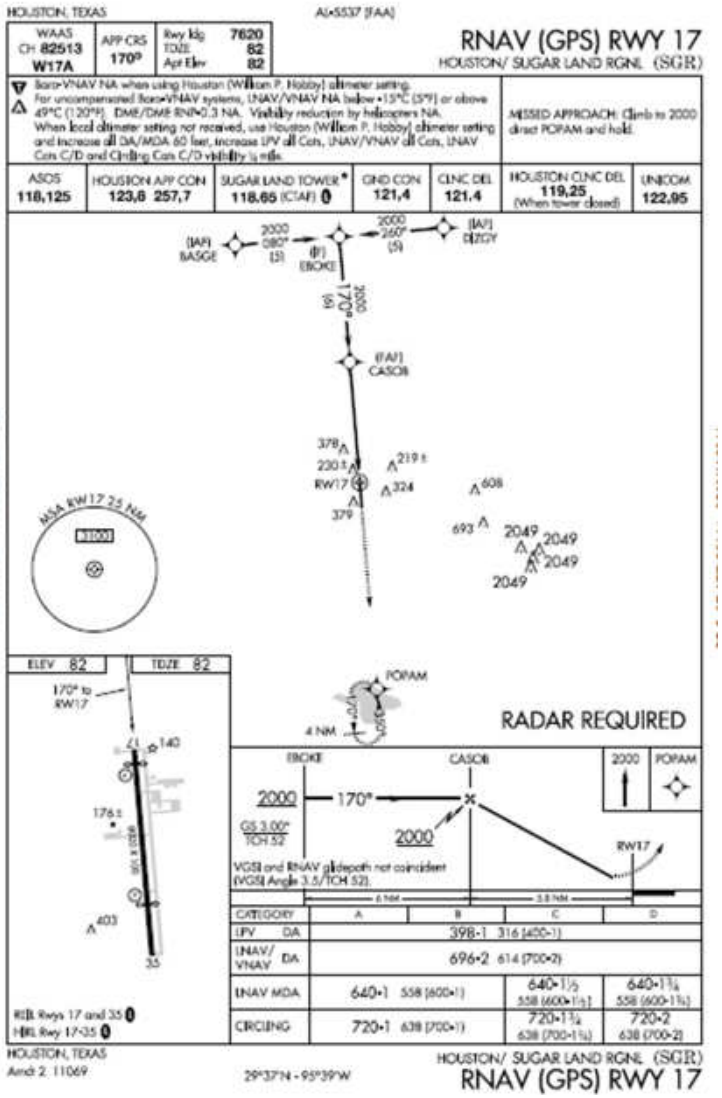
- Final Approach Segment
  - Final approach segment begins at the final approach fix shown on the chart.
  - Ends at MAWP

Let's Fly – The Final Segment



- Confirm gear down
- Second notch flaps – Check in white arc
- Final speed reduction
- Glance out the window to look for the runway environment
- You reach the MAWP (Should be at DA 398' (DA is MSL – DH is AGL) MAP not DA is guide to missed approach)
  - If you now have an identifiable segment of the approach environment unmistakably visible and identifiable you may continue the approach if:
    - Visibility is above the minimums for approach category
    - You are in a position to make a normal descent to the intended runway using normal maneuvers
    - FAR 91.175

Let's Fly – The Final Segment

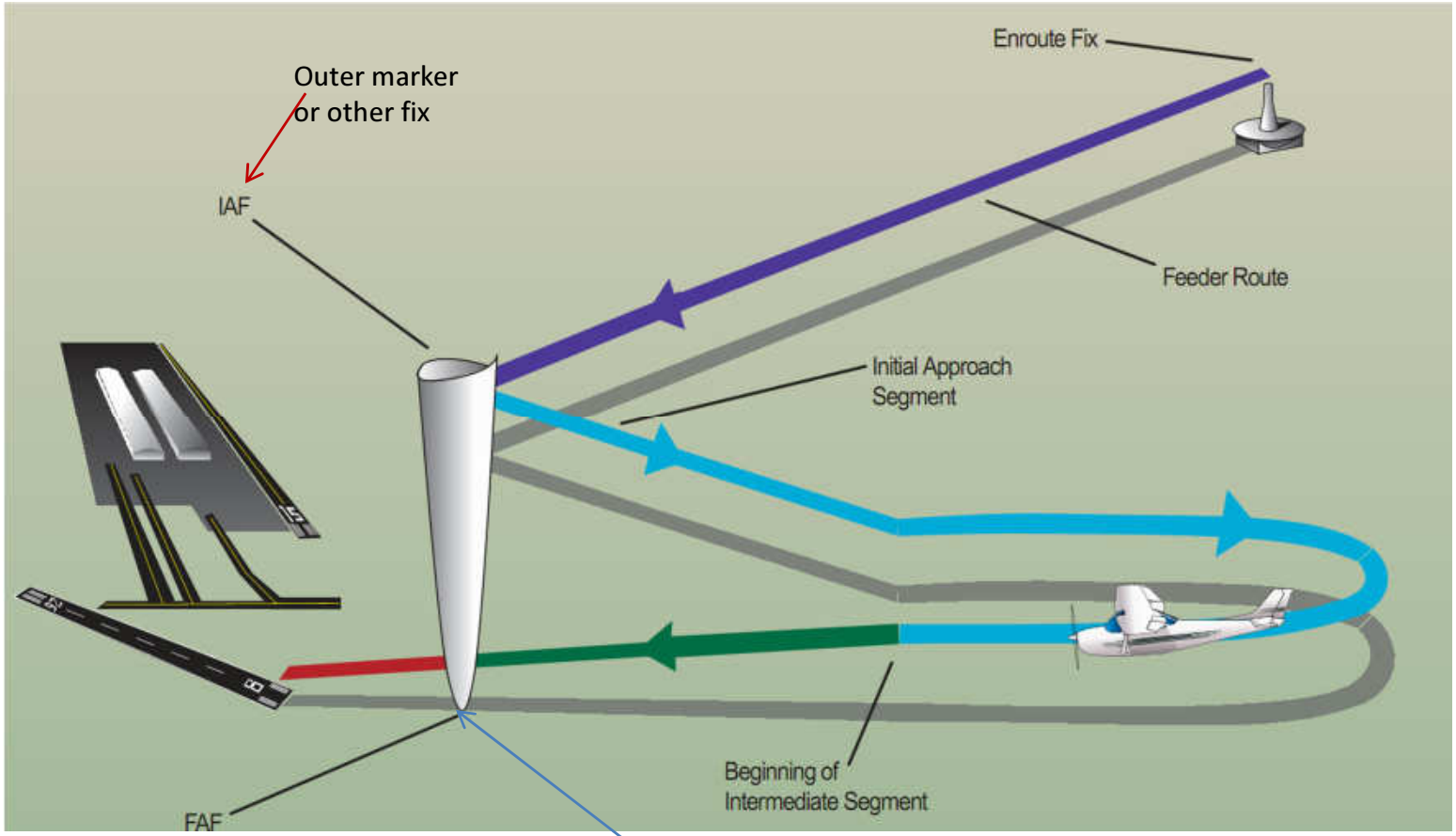


  - If not, commence missed approach turn - do not turn out early (e.g. if full needle deflection)
  - Don't level off and look for the runway environment
- Drop full flaps and land
- If using circling approach level off at 720' and continue to MAWP
  - At MAWP:
    - Runway environment in sight
    - Visibility above minimums
    - Able to make a normal descent to intended runway

Overlay Approach

- Generally more complicated than a stand alone approach
- GPS provides course guidance for each segment up to the MAWP
- Procedure turns are generally stored as a leg of the approach – However, some GPS' require the pilot to enter the susp / obs mode. GPS may give you a message to start proc turn.
  - Often no guidance is provided within the procedure turn – guidance only for entry and exit points
- Select and load the approach as with stand-alone approaches – then activate when ready
- Be sure you know where you are in the approach as the same waypoint can appear more than once

Overlay Approach Segments



Overlay Approach Differences from Underlying Approach

- If no pronounceable 5 letter name is assigned to a waypoint or fix, it is given a database alphanumeric identifier – these points are in the database, but may not appear on the chart
- Procedures without a FAF (e.g., VOR or NDB on airport) will have a FAWP added to the database at least 4 nm prior to the MAWP to allow the GPS receiver to transition to approach mode
- May also have an added database point when the MAWP and the MAHWP are the same
- DME arcs and radial approaches may also have additional non-charted waypoints

Overlay Approach Differences from Underlying Approach

- A DME identified fix will not be in the waypoint sequence on the GPS receiver unless a name is assigned
- When a name is assigned to a DME fix, the along track distance may be zero rather than the DME listed on the approach plate – Be alert for this discrepancy

Visual Descent Point

- If a visual descent point (VDP) is published, it will not be included in the DB waypoints.
- Pilots are expected to use normal piloting techniques for beginning the visual descent, such as along track distance

Alternates

- A non-GPS approach procedure must exist at the alternate airport when one is required
- If the non-GPS approaches require DME or ADF, the aircraft must be equipped with DME or ADF avionics as appropriate – Can’t rely on GPS distances.

Missed Approach

- Must go missed at MAWP if:
  - you do not see the runway environment
    - Approach lighting system – not below 100’ AGL until you see red side lights or red terminating bar
    - Runway or runway markings or lights
    - Threshold, threshold markings or lighting
    - REILS
    - VASI
    - Touchdown zone or markings or lighting
  - Have visibility minimums
  - You are not in a position to make a normal descent to the runway

Missed Approach Point

- After crossing the MAWP most GPS receivers will give you a Susp message indicating that waypoint sequencing has been suspended
- A from indication will appear on the CDI
- Until the missed approach function is activated, the GPS will display an extension of the inbound final approach course and the distance will increase from the MAWP until it is manually sequenced after crossing the MAWP.

Missed Approach Actions

- A GPS missed approach requires pilot action to sequence the receiver past the MAWP to the missed approach portion of the procedure.
- Pilot must:
  - be thoroughly familiar with the activation procedure
  - initiate appropriate action **after** the MAWP
    - Activating the missed approach prior to the MAWP
      - will cause CDI sensitivity to immediately change to terminal (± 1 NM) sensitivity
      - will cause the GPS to continue to navigate to the MAWP.
      - The receiver will not sequence past the MAWP.
      - Turns should not begin prior to the MAWP.

Missed Approach

- If the receiver does not sequence into the approach mode or a RAIM failure/status annunciation occurs prior to the FAWP, the pilot should not descend to Minimum Descent Altitude (MDA), but should proceed to the missed approach waypoint
- GPS receiver will not automatically sequence past the MAP to the missed-approach segment without user intervention
- Take the GPS out of the OBS mode and putting it back into sequencing mode – in some cases you will have to manually alter the flight plan to go to the next waypoint.
- Low, slow, and busy is not a good time to be giving all of your attention to the GPS. Point yourself in the right direction, start climbing, clean it up, do anything else you need to do, and then worry about sequencing the GPS

Missed Approach Actions

- Missed approach routings in which the first track is via a course rather than direct to the next waypoint require the pilot to set the course.
- Being familiar with all of the inputs required is especially critical during this phase of flight.
- Overriding an automatically selected sensitivity during an approach will cancel the approach mode annunciation. The RAIM and CDI sensitivity will not ramp down, and the pilot should not descend to MDA, but fly to the MAWP and execute a missed approach

SID

- The GPS receiver must be set to terminal (± 1 NM) CDI sensitivity (should be automatic)
- The navigation routes must be contained in the data base in order to fly published IFR charted departures and DP's.
- Terminal RAIM, however, may not be available unless the waypoints are part of the active flight plan rather than proceeding direct to the first destination.
- Certain segments of a DP may require manual intervention, especially when radar vectored to a course or required to intercept a specific course to a waypoint.
- The data base may not contain all of the transitions or departures from all runways
- Some GPS receivers do not contain DP's in the data base.

Equipment Failure

- If GPS avionics become inoperative, the pilot should advise ATC and amend the equipment suffix.
- WAAS receivers do not “fail down” to lower levels of service once the approach has been activated.
  - If only the vertical off flag appears, the pilot may elect to use the LNAV
  - If the lateral integrity limit is exceeded, a missed approach must be executed since there is no way to reset the lateral alarm limit.

RAIM

- If, at any point during the approach, you lose RAIM then you can not descend to the MDA for the approach
- If you already have started down, you should execute a missed approach immediately. (overfly the MAWP to guarantee clearance with obstacles, but begin your climb immediately)
- Once the approach has begun the GPS receiver will go up to five minutes without the necessary satellites before giving an annunciation, to give itself the opportunity to reestablish communication – hence, if a warning pops up, you could already be considerably off course

RAIM

- Aircraft using GPS navigation equipment under IFR must be equipped with non-GPS alternate navigation equipment appropriate to the flight.
- Active monitoring of alternative navigation equipment is not required if the GPS receiver uses RAIM for integrity monitoring.
- Active monitoring of an alternate means of navigation is required when the RAIM capability of the GPS equipment is lost

RAIM

- Procedures must be established for use in the event that the loss of RAIM capability is predicted to occur. In situations where this is encountered, the flight must rely on other approved equipment, delay departure, or cancel the flight.

QUESTIONS