Private Pilot (ASEL) Ground School Course

Lesson 23 | Electronic and Visual Navigation

Lesson Overview

Lesson Objectives:

- Develop knowledge and operational understanding of GPS.
- Develop an understanding of pilotage and dead reckoning.

Lesson Completion Standards:

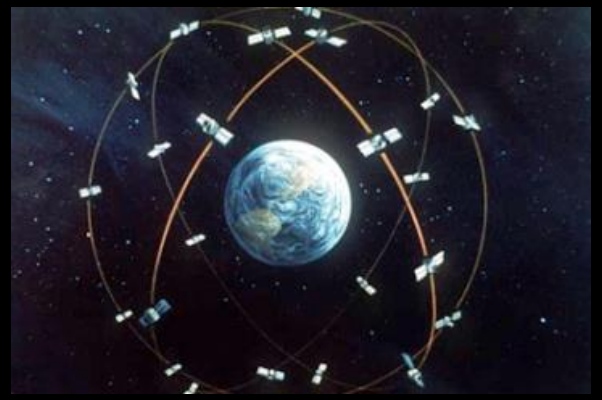
- •Student demonstrates satisfactory knowledge of electronic and visual navigation by answering questions and actively participating in classroom discussions.
- Students can describe how to recover from being lost while navigating through a classroom discussion.

Global Positioning System (GPS)

Electronic and Visual Navigation

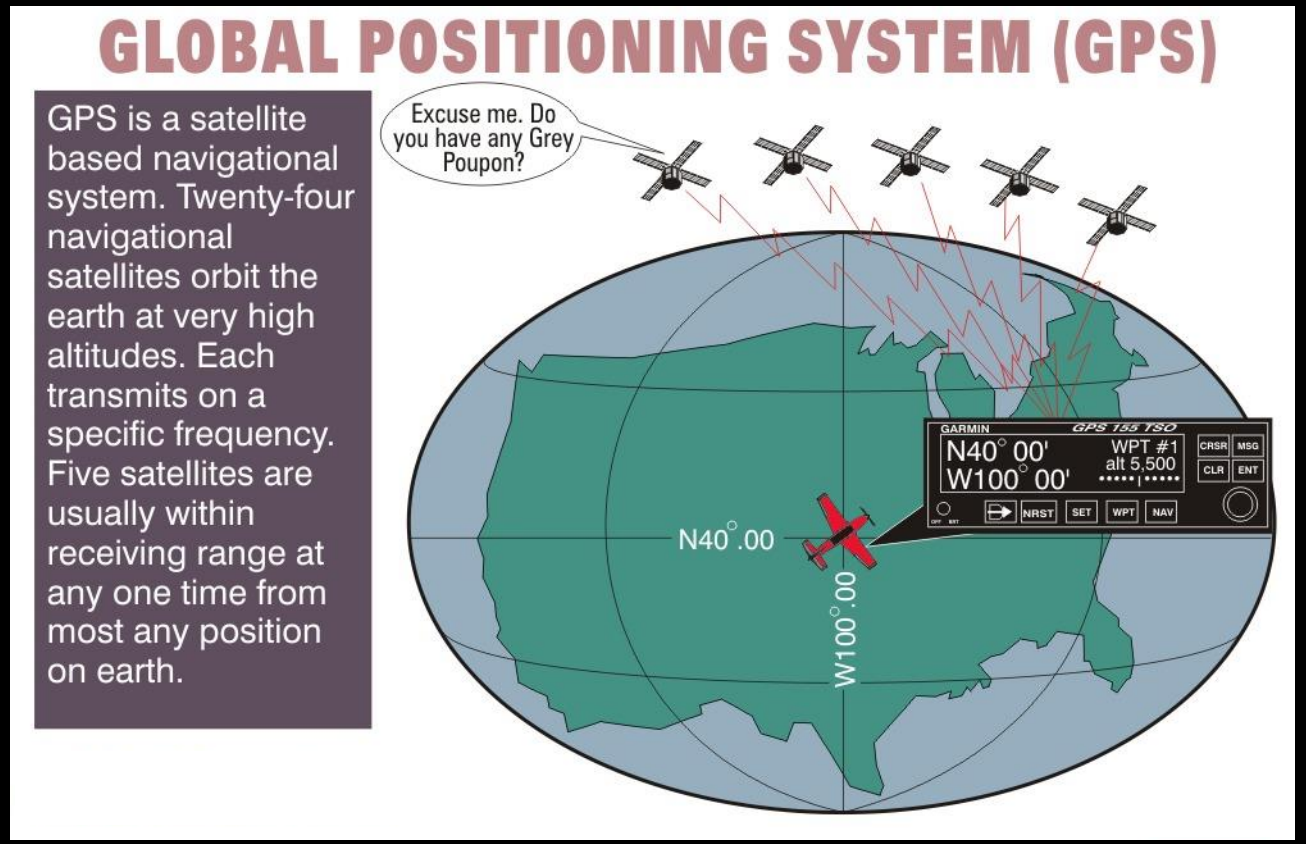
GPS Satellites

- GPS is a satellite-based radio navigational, positioning, and time transfer system
- Consists of 32 satellites revolving around the earth in six orbital planes
- GPS receivers allow you to determine your location in terms of latitude and longitude anywhere on earth
- It allows you to travel from one waypoint, as defined by the coordinates of latitude and longitude, to another



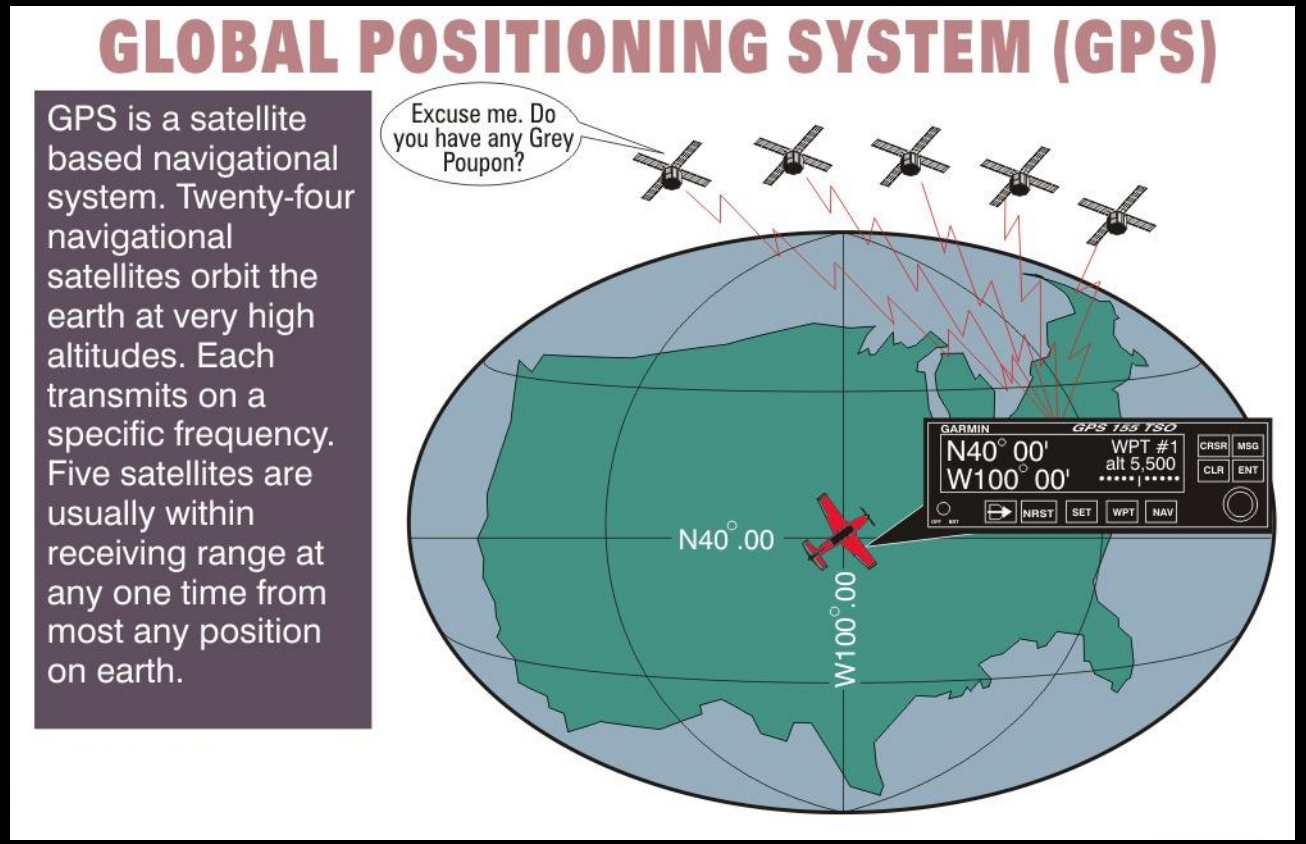
Global Positioning System

- Receiver locks onto signals from several satellites all at once
- It knows the exact location of each satellite and precisely matching timing with its onboard atomic clock
- GPS receiver can determine where it is with an accuracy of less than 3 meters horizontally



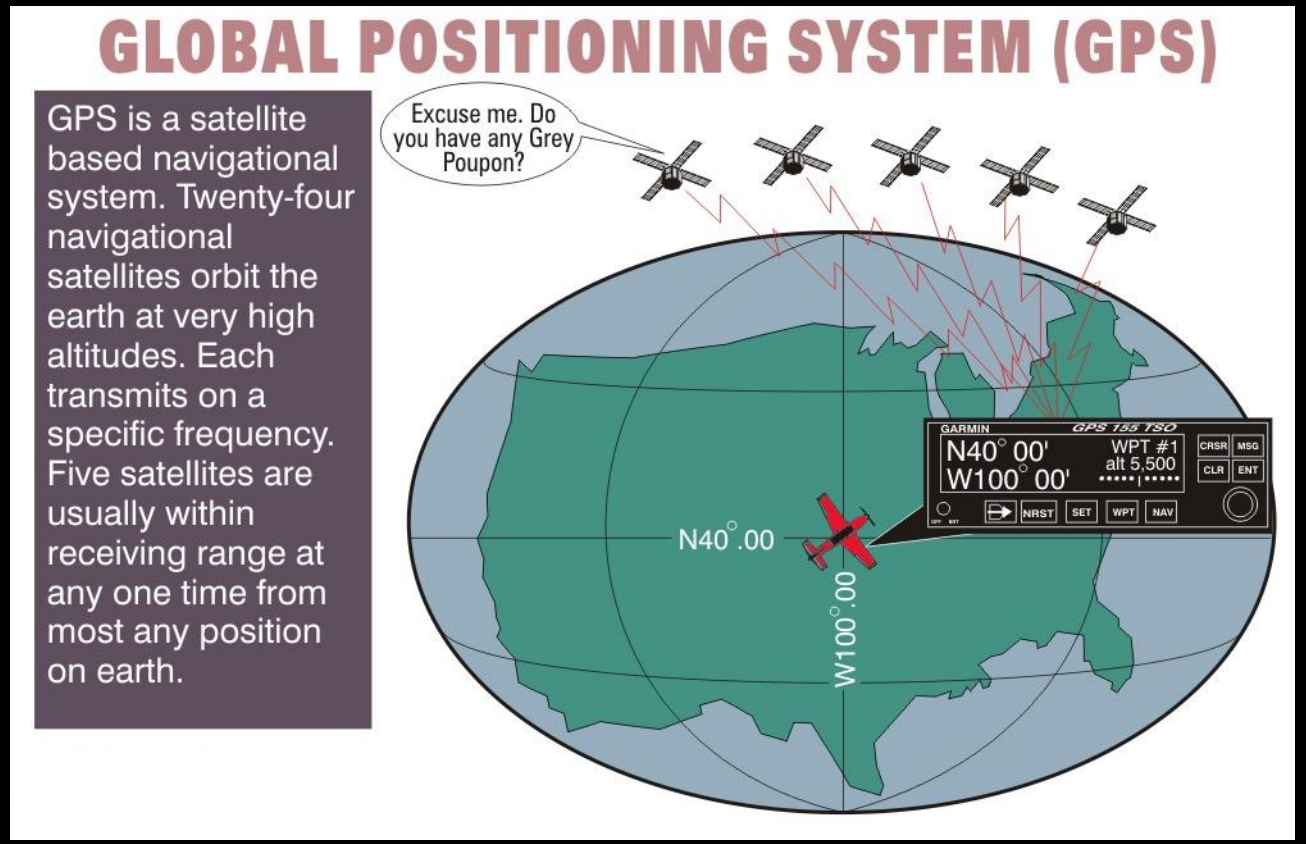
Global Positioning System

- At least 4 satellites must be in view for the GPS receiver to determine a three-dimensional fix (latitude, longitude, and altitude)
- A minimum of five satellites are usually in view by a user anywhere on earth



Global Positioning System

- GPS allows you to navigate to and from points in space known as waypoints
- Waypoints are defined by both latitude and longitude coordinates



GPS Receiver

- You can input Lat/Long coordinates directly into the GPS receiver
- Receiver has preprogrammed coordinates for these locations
- Can also input the letter/number identifiers of an airport or intersection

GPS Receiver

GPS Receiver

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GPS Receiver

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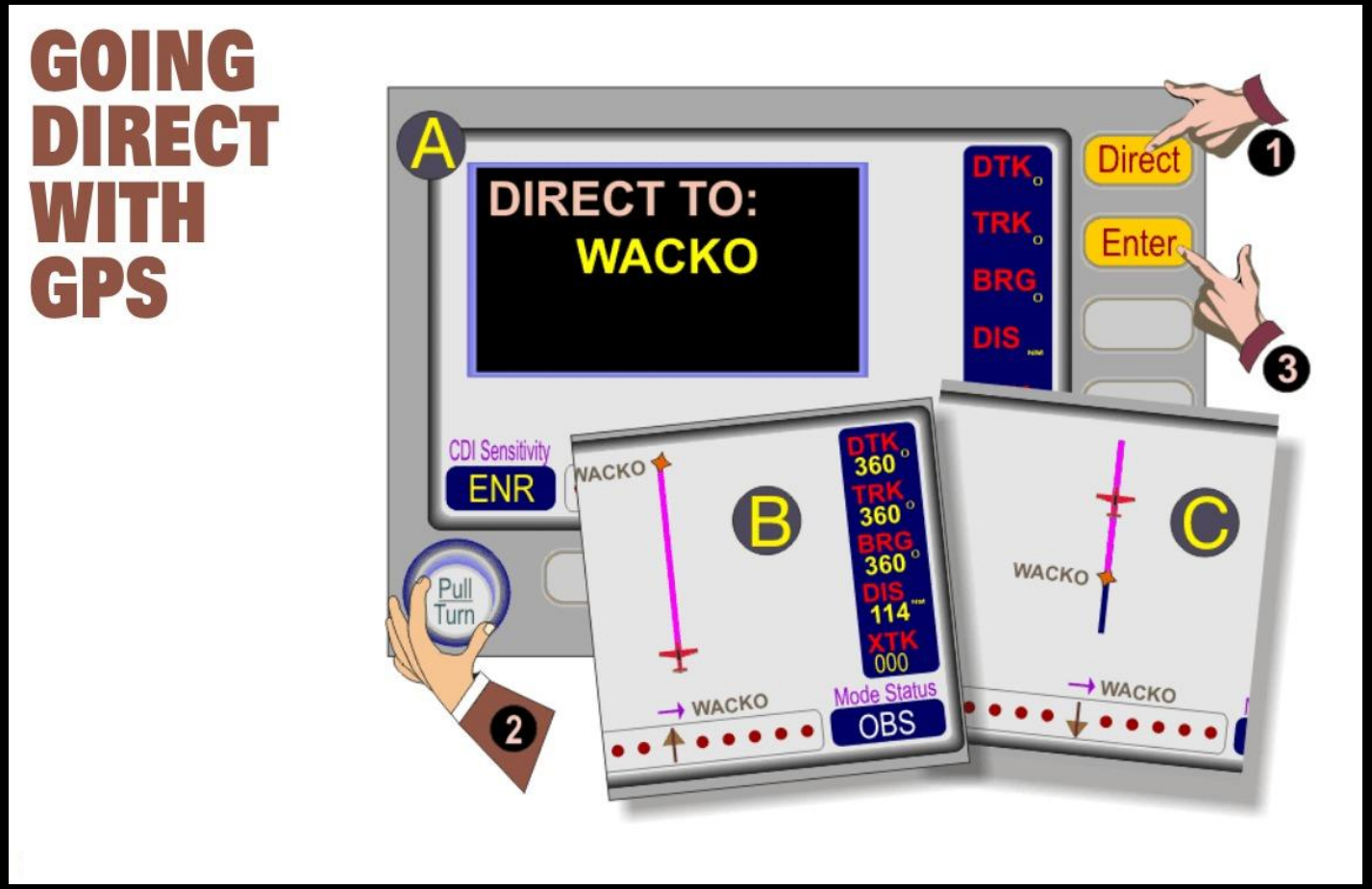
GPS Receiver

- Always knows its current lat and long
- By telling the GPS you want to go from your present position to a distant waypoint, it electronically knows what direction to get there
- GPS shows the bearing to that waypoint
- Also drives a course deviation indicator on a display like that of a VOR

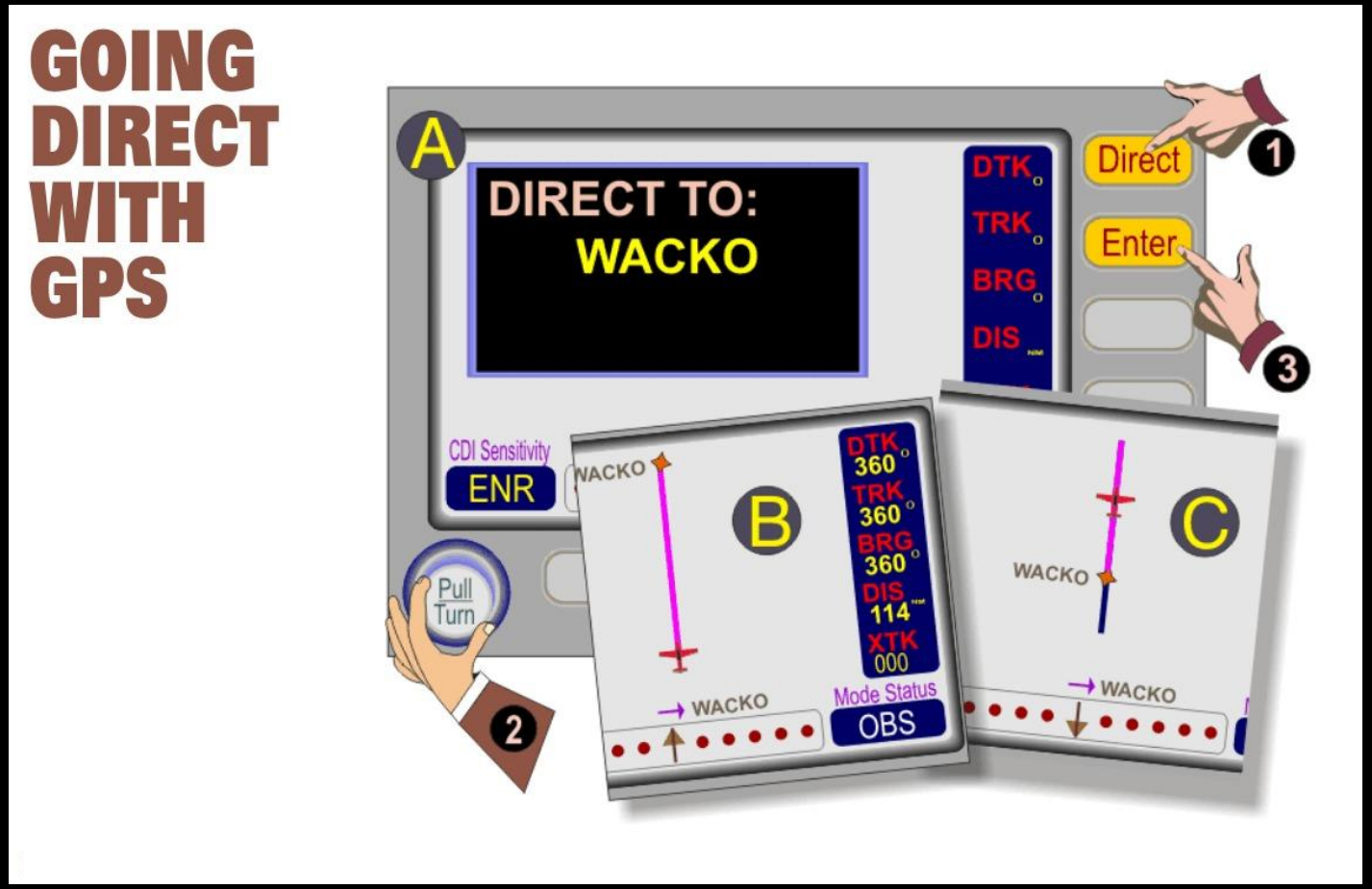
Direct With GPS

- GPS units have databases with the lat/long information for nearly all airports, intersections, and navigation aids
- Just input the name or letter/number identifier of any airport, intersection, or navaid in the GPS

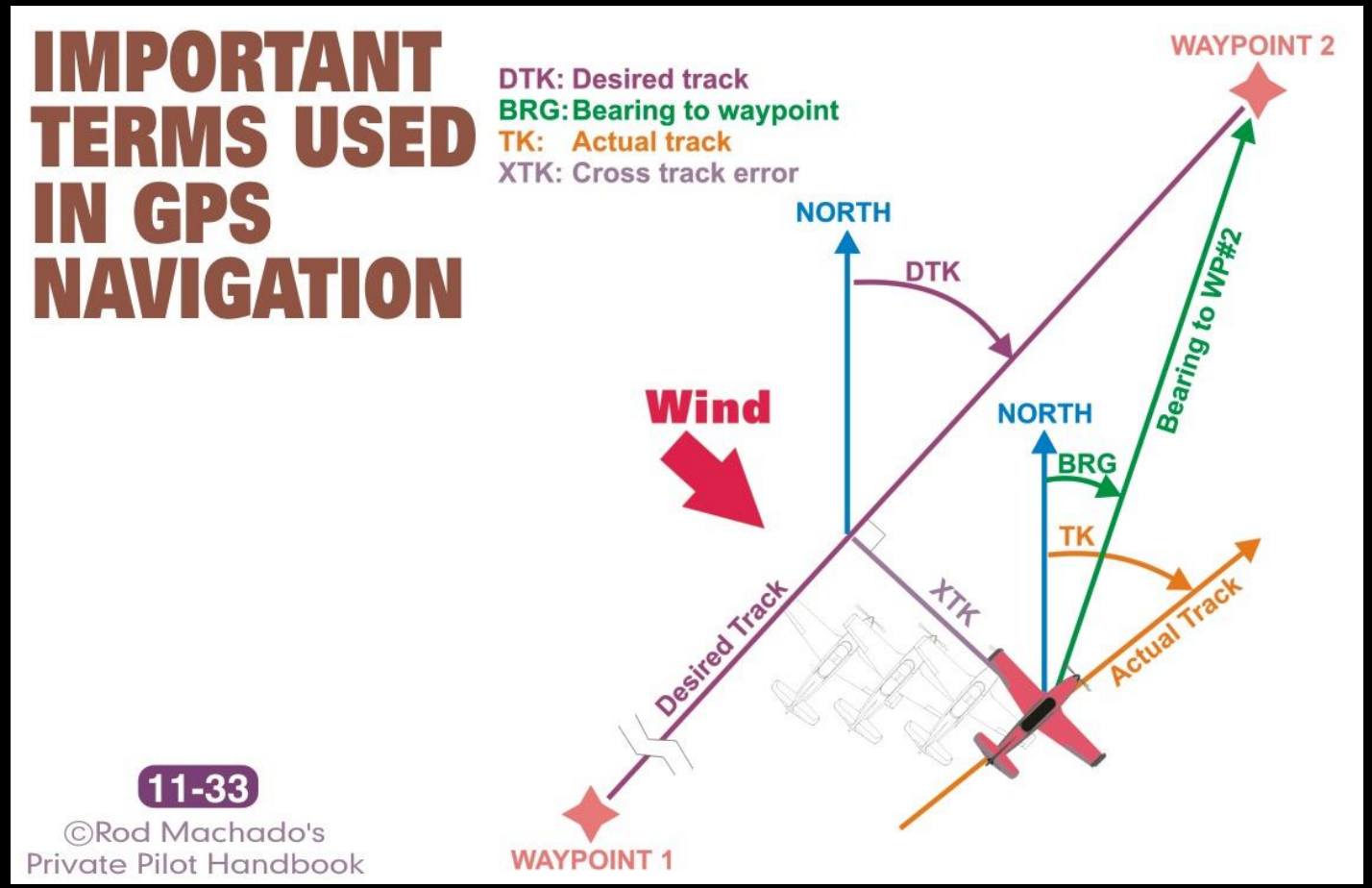


Direct With GPS

- To go to direct WACKO intersection, select the letters WACKO in the GPS's window, and push the appropriate buttons
- With a moving map display, GPS shows the track to WACKO
- Also displays information such as groundspeed, track, and crosstrack error



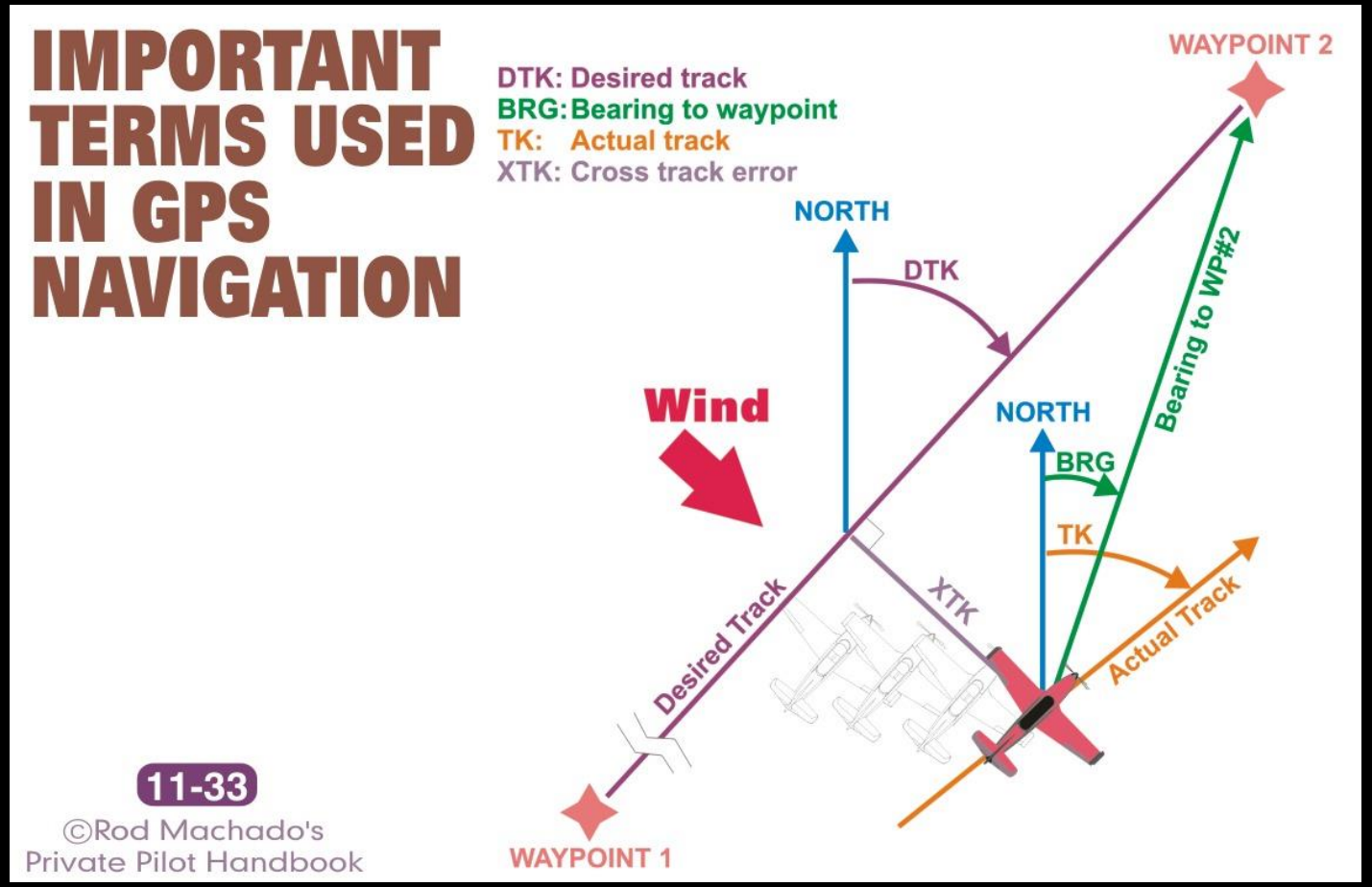
GPS NAV Terms



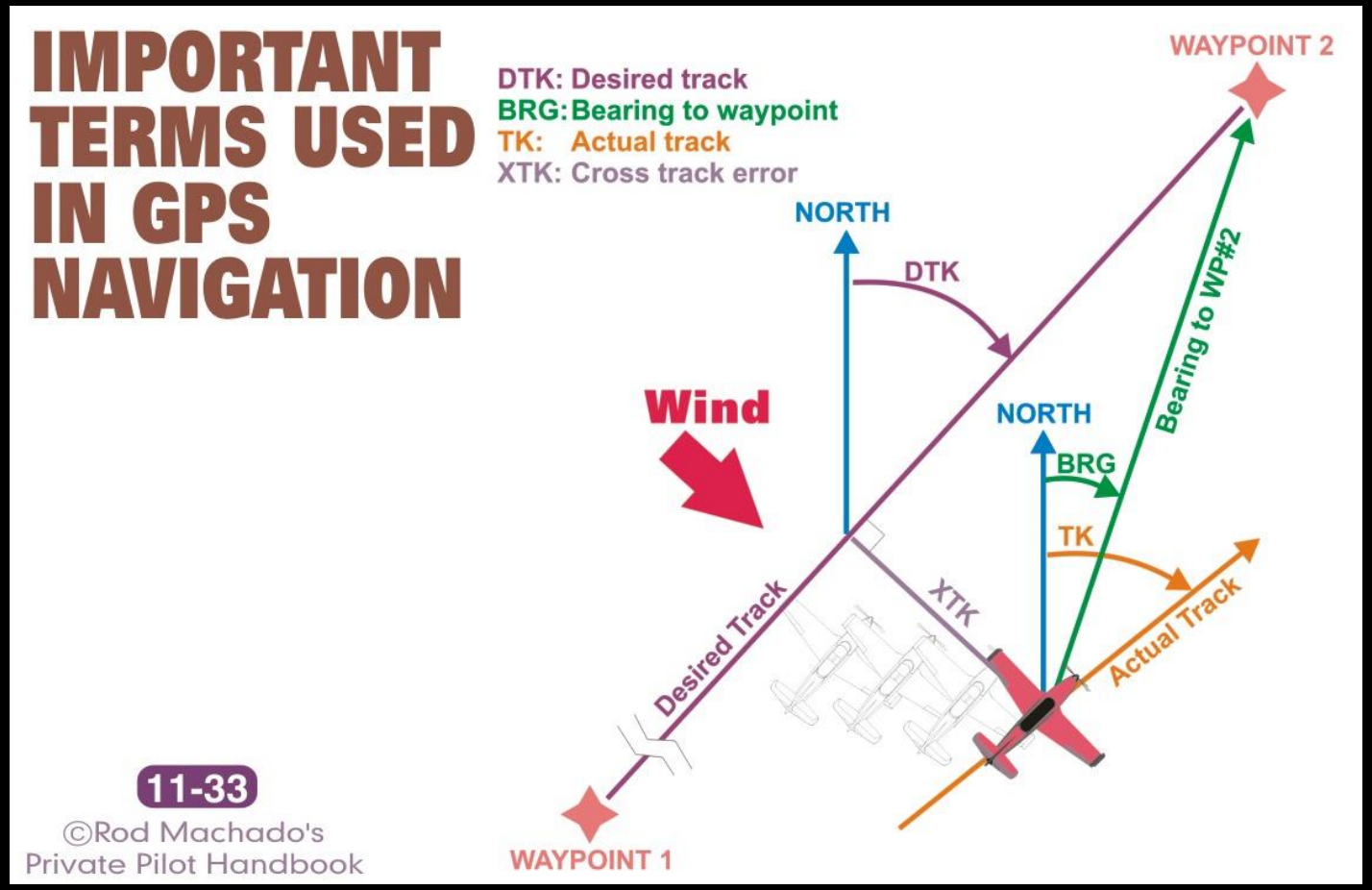
- Assume the GPS is programmed to a destination airport (Waypoint 2)
- GPS knows the lat/long of the starting point, so it assumes this is the departure waypoint (Waypoint 1)
- Line between these two points is the desired track
- Under a no-wind condition you'd fly the desired track (DTK) heading and eventually arrive at your destination

GPS NAV Terms

- Because of wind, the airplane is blown away from the DTK
- The airplane's actual track (TK) has now diverged from the DTK
- If the actual track TK differs from the desired track (DTK), then the GPS will show the discrepancy in terms the cross track error (XTK)



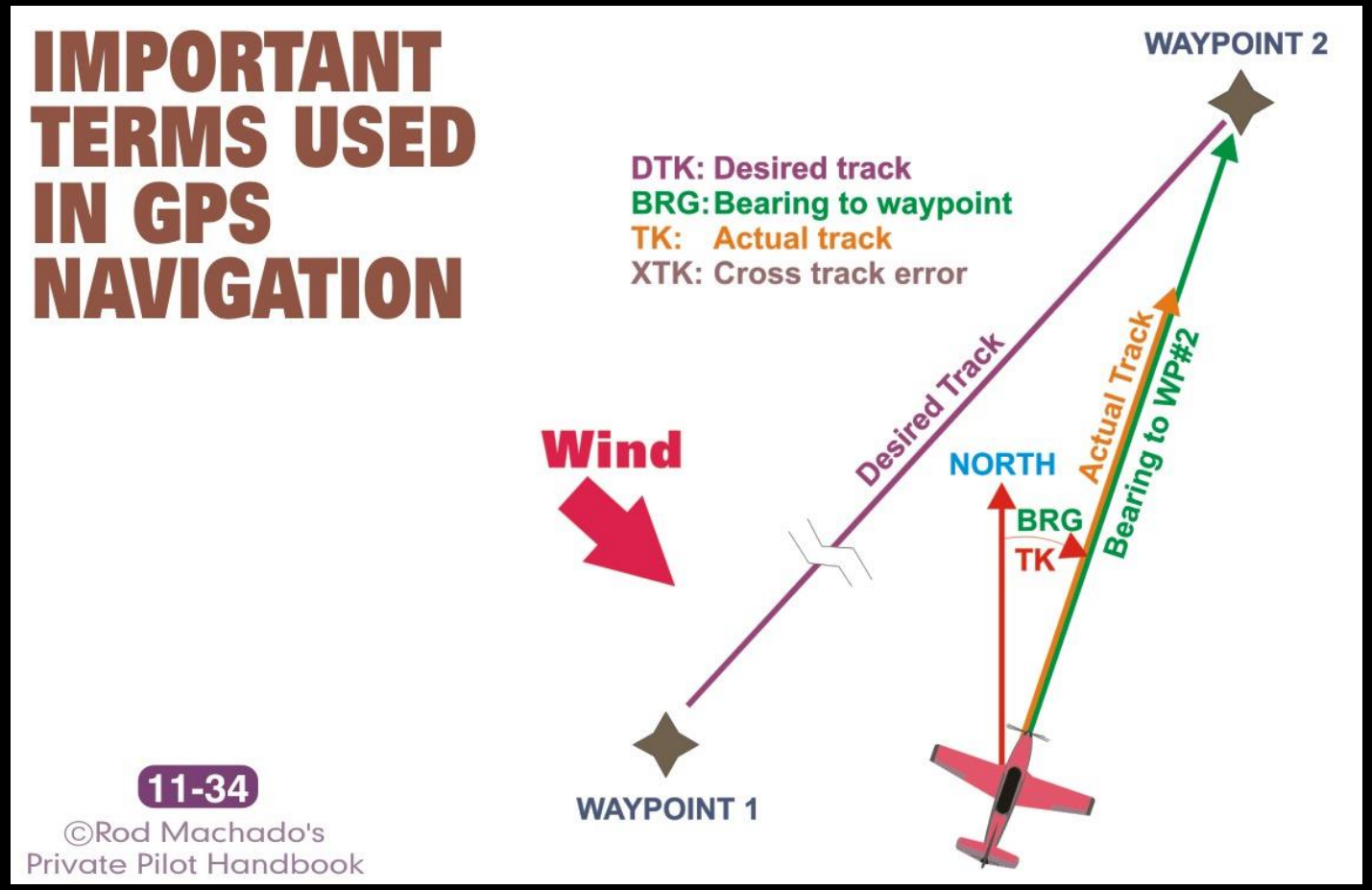
GPS NAV Terms



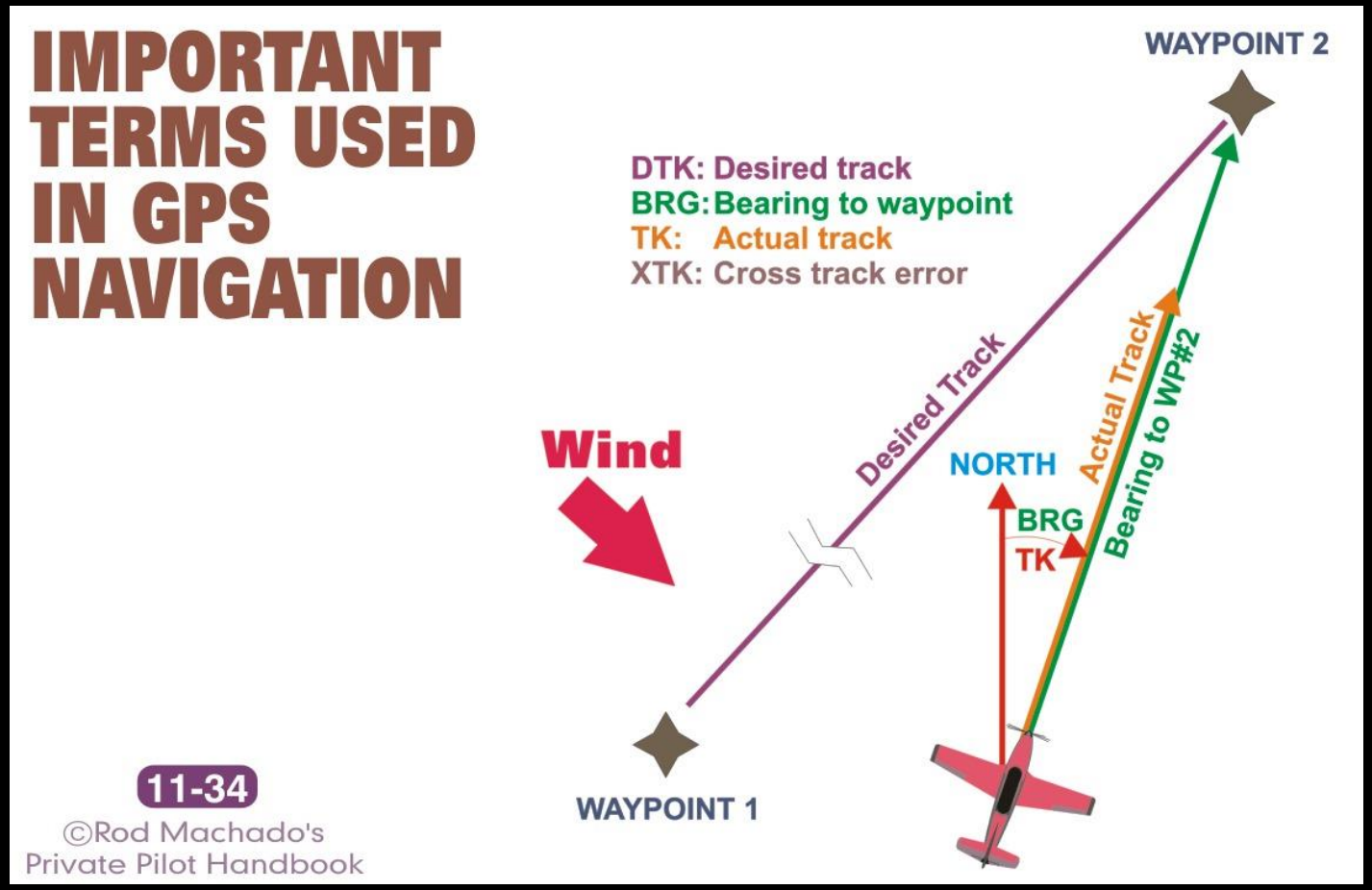
- The airplane is off course to the right
- You have the option of going directly from your current spot to Waypoint 2, instead of re-intercepting the original DTK
- Select the GPS Direct button and establish a new desired track (DTK) to Waypoint 2

GPS NAV Terms

- The BRG is the heading you must fly to get to your next waypoint in a no wind condition
- BRG and the actual track (TK) should be the same
- If these two values begin to differ, then wind is blowing the airplane off course



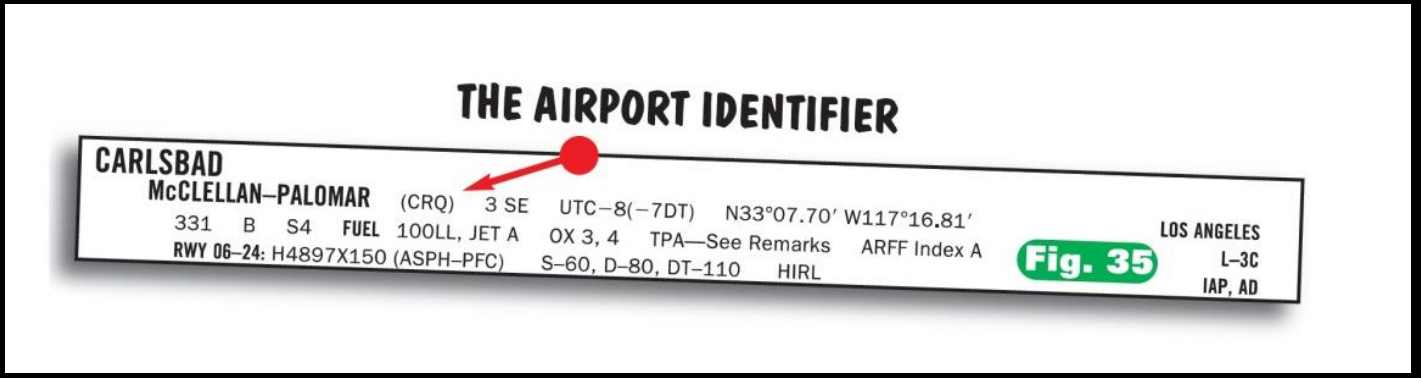
GPS NAV Terms



- Apply a wind correction
- Wind correction is sufficient when the bearing to the station (BRG) remains the same as the airplane's actual track (TK)
- Now you're on your way directly to Waypoint 2

Airport Identifiers

- Next to the airport's name is its identifier (CRQ) in parentheses
- To manually enter the airport letter by letter add a "K" in front (KCRQ)
- If an airport identifier contains numbers (e.g., L66, Q49, S52), place these identifiers directly into the GPS without the K prefix
- K identifies an airport in the continental United States

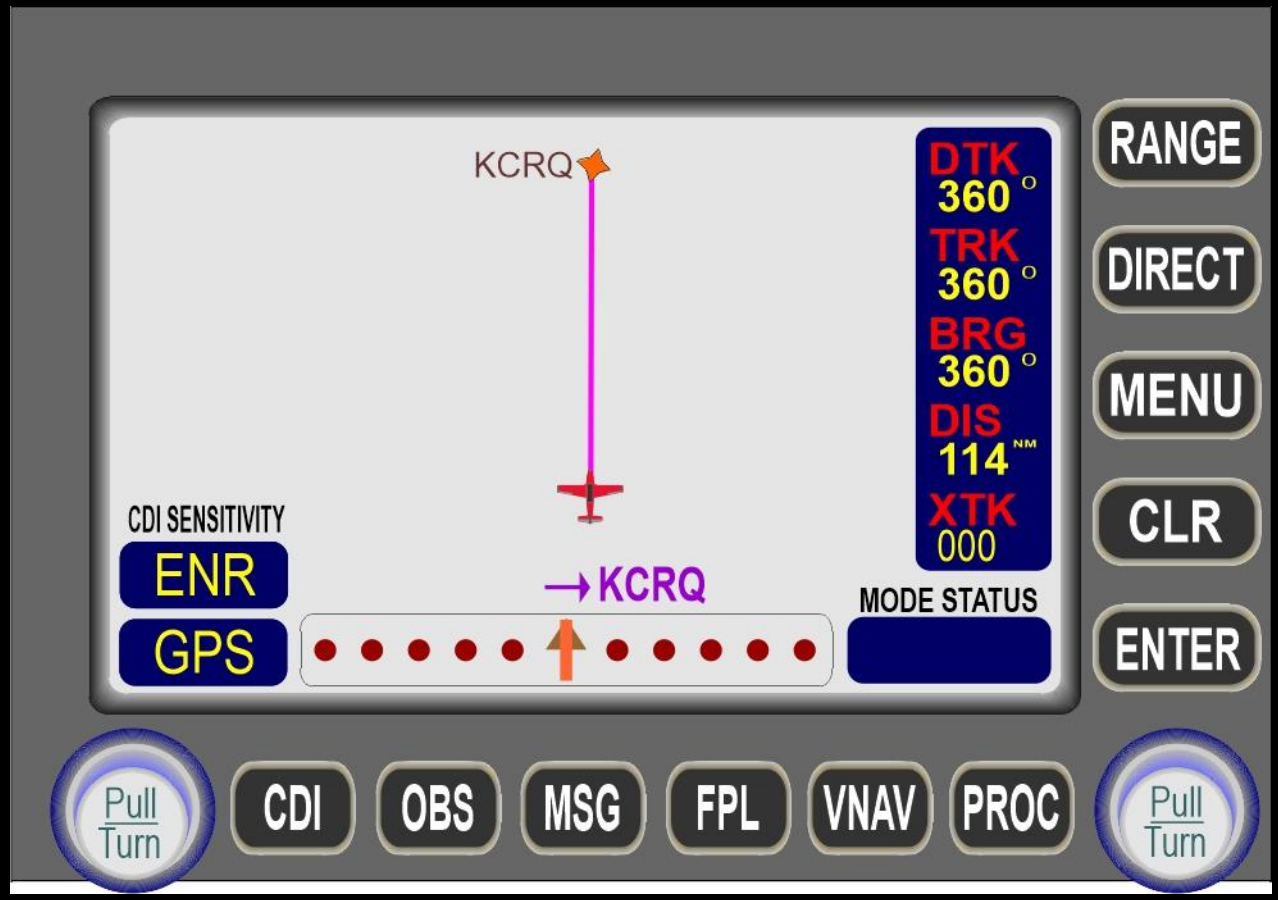


GPS Direct to KCRQ

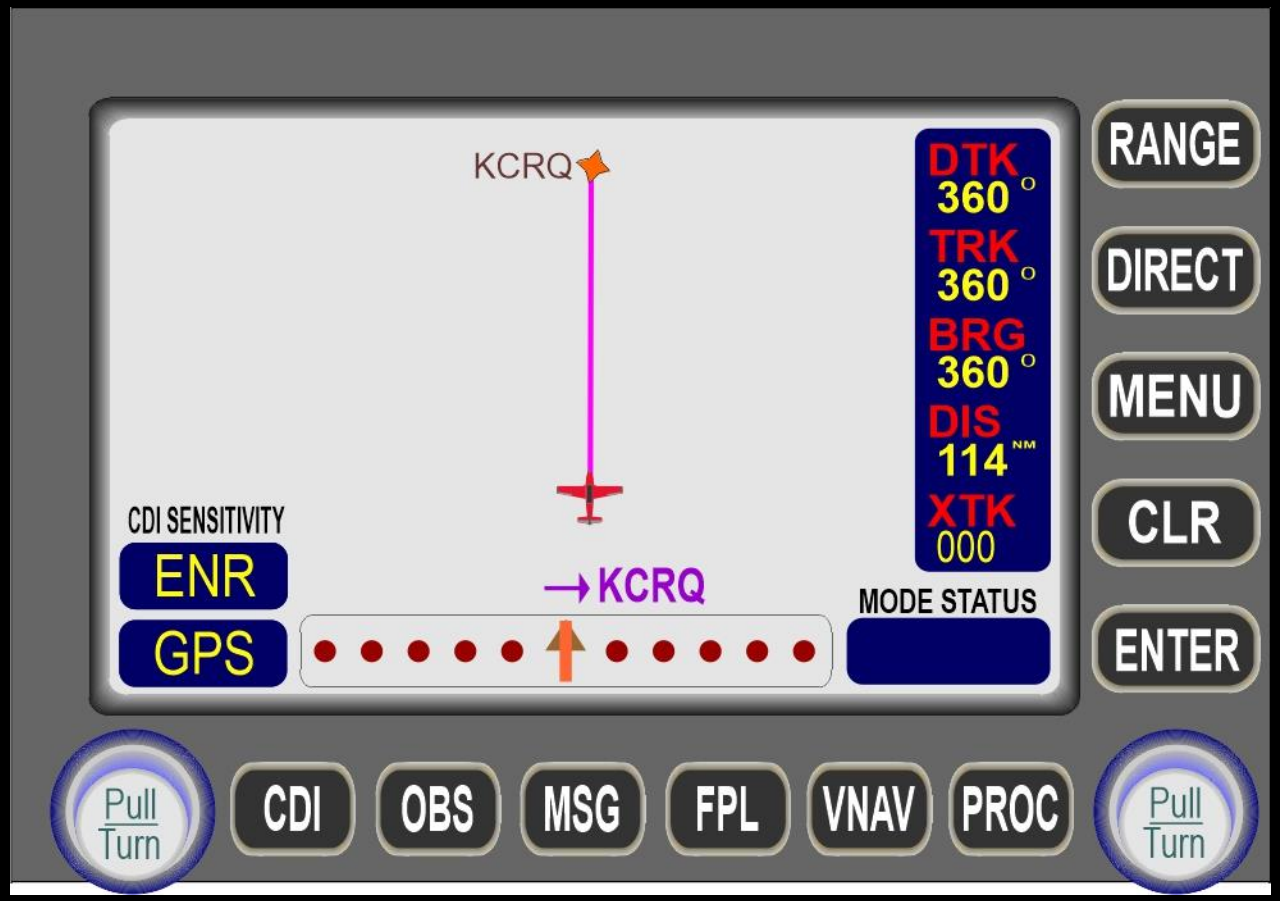
- *To fly direct from our present position to KCRQ:*
- Push the Direct button to activate a direct-to menu
- Use knobs to select the letters KCRQ in the menu
- Press Enter to make the airport the active waypoint

GPS Direct to KCRQ

- DTK, TRK, and BRG to KCRQ are 360° and distance is 114 NM
- The CDI built into the GPS shows an up arrow with a centered needle
- This means we're going TO the active waypoint
- The active waypoint (the one to which you're presently navigating) is shown above the CDI and right of the horizontal arrow



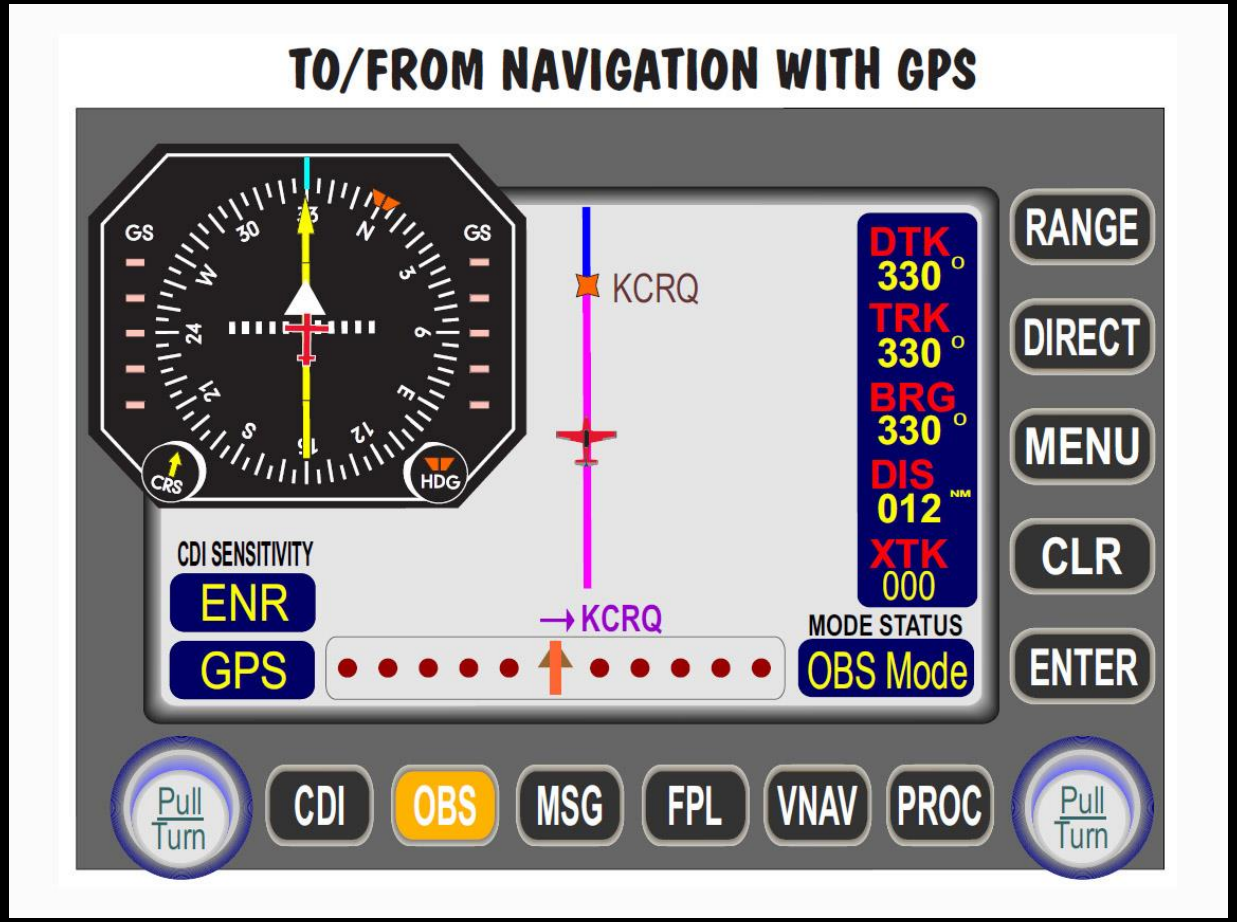
GPS Direct to KCRQ



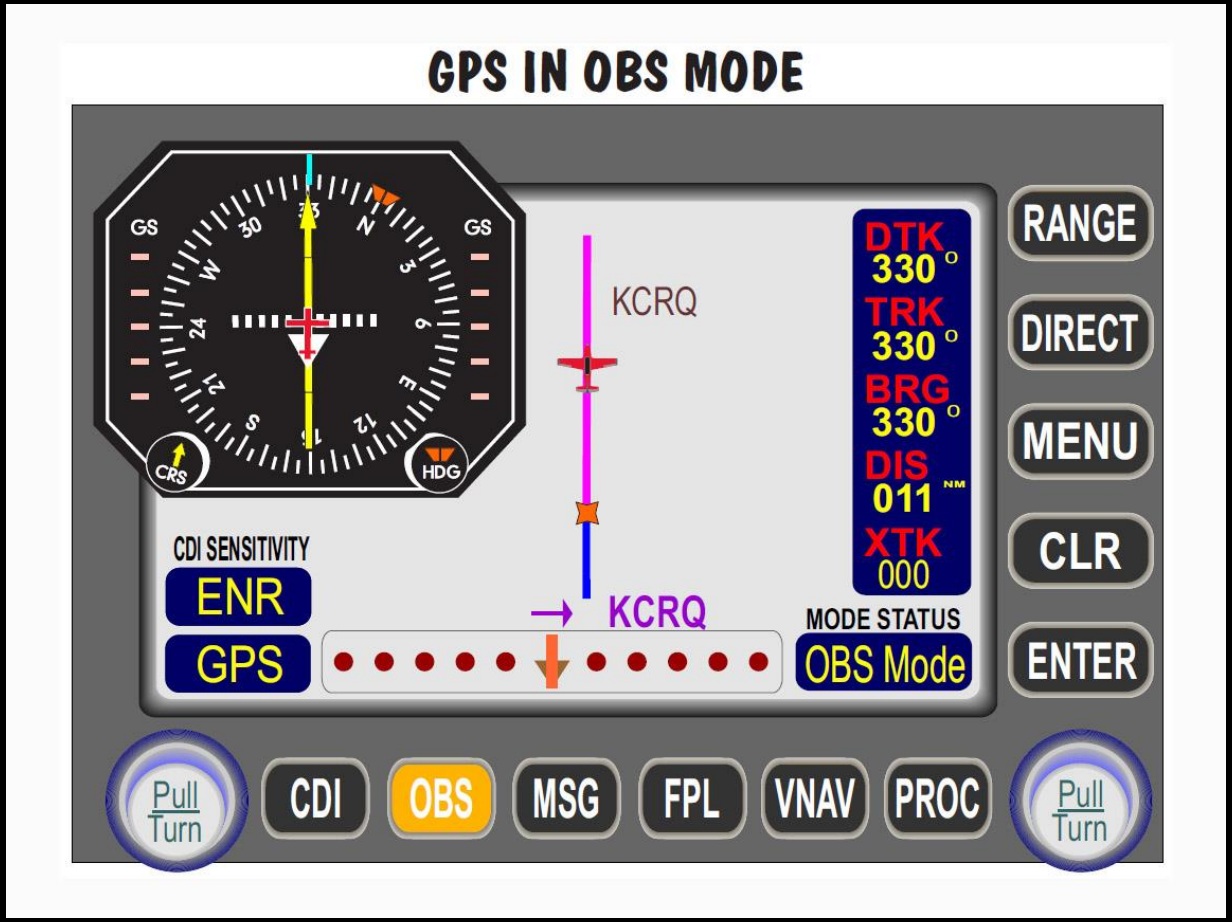
- Enroute (ENR) is shown as the current flight mode
- CDI is operating with enroute sensitivity
- Each dot on the built-in CDI scale represents distance in NM off course
- Full scale is either 2NM (WAAS) or 5NM (Non-WAAS)

GPS Direct to KCRQ

- Map shows difference in color between course to active waypoint, and the one beyond this waypoint
- Intercepting the 330 course, the HSI needle centers with a TO indication to KCRQ
- Map displays track up on its display
- Once tracking the course, it is shown vertically on the map

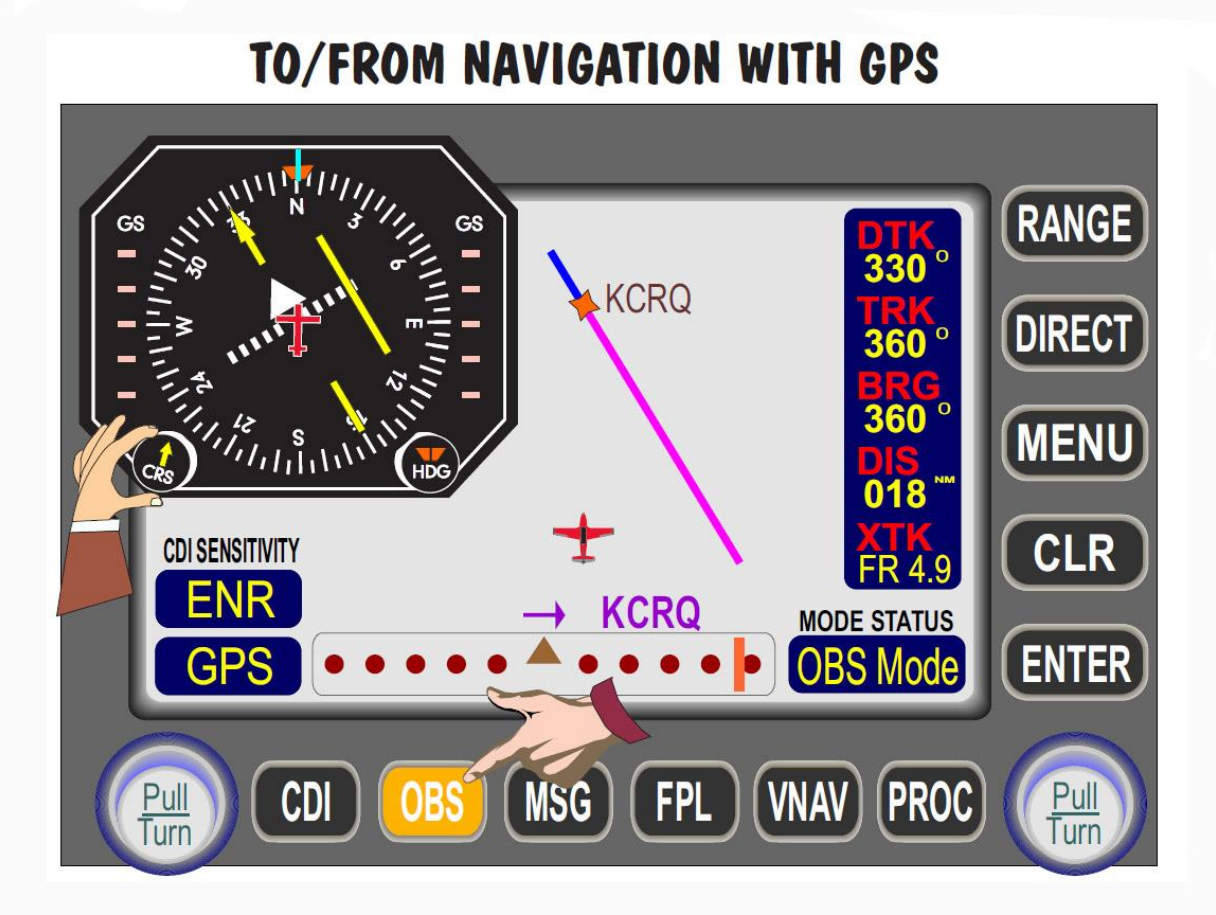


Fly Beyond KCRQ



- TO/FROM triangle flips downward (like a VOR) indicating you've flown beyond the chosen waypoint
- Called to/from navigation known as the OBS Mode

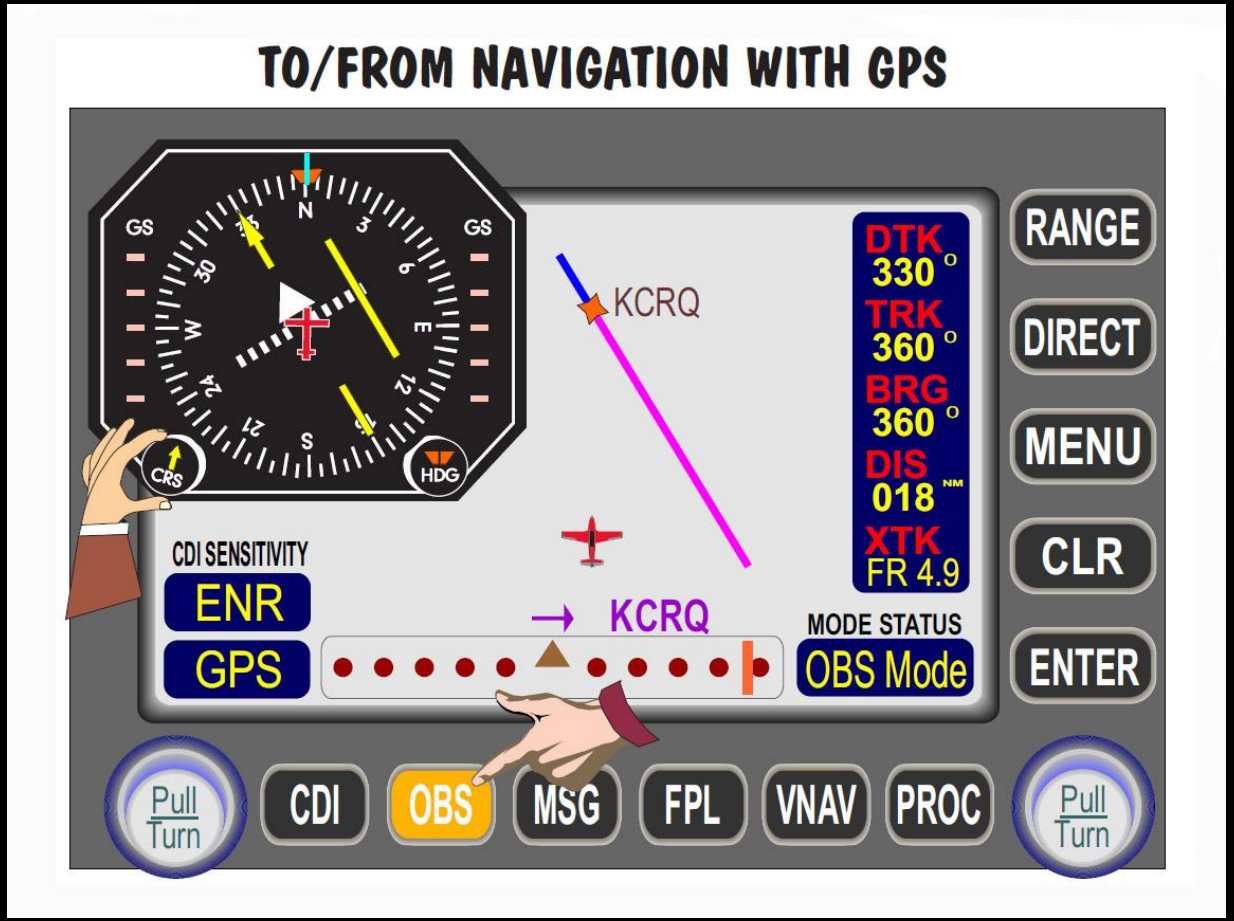
OBS Mode



- GPS not only takes you direct to any waypoint, it also lets you select any course you want to that waypoint
- Selection of a particular course to the active waypoint shown on the moving map is dependent on what is selected with the HSI's OBS
- GPS unit is now is now tracking to KCRQ as if this waypoint were a VOR station

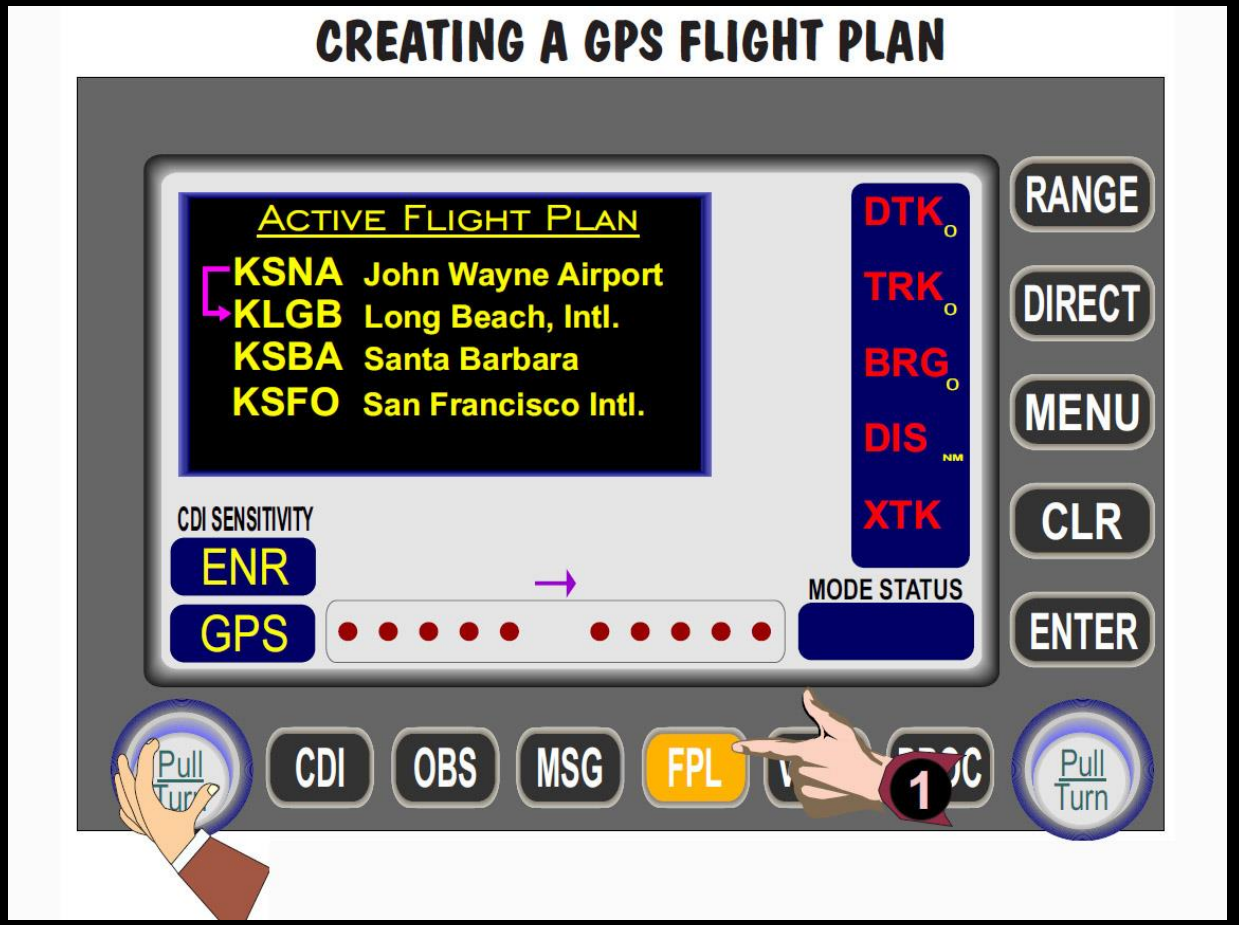
OBS Mode

- Any of 360 individual courses to or from this waypoint can be selected
- To intercept and track the 330° course to this waypoint instead of flying direct to KCRQ
- Push the OBS button and rotate the HSI's OBS to 330°



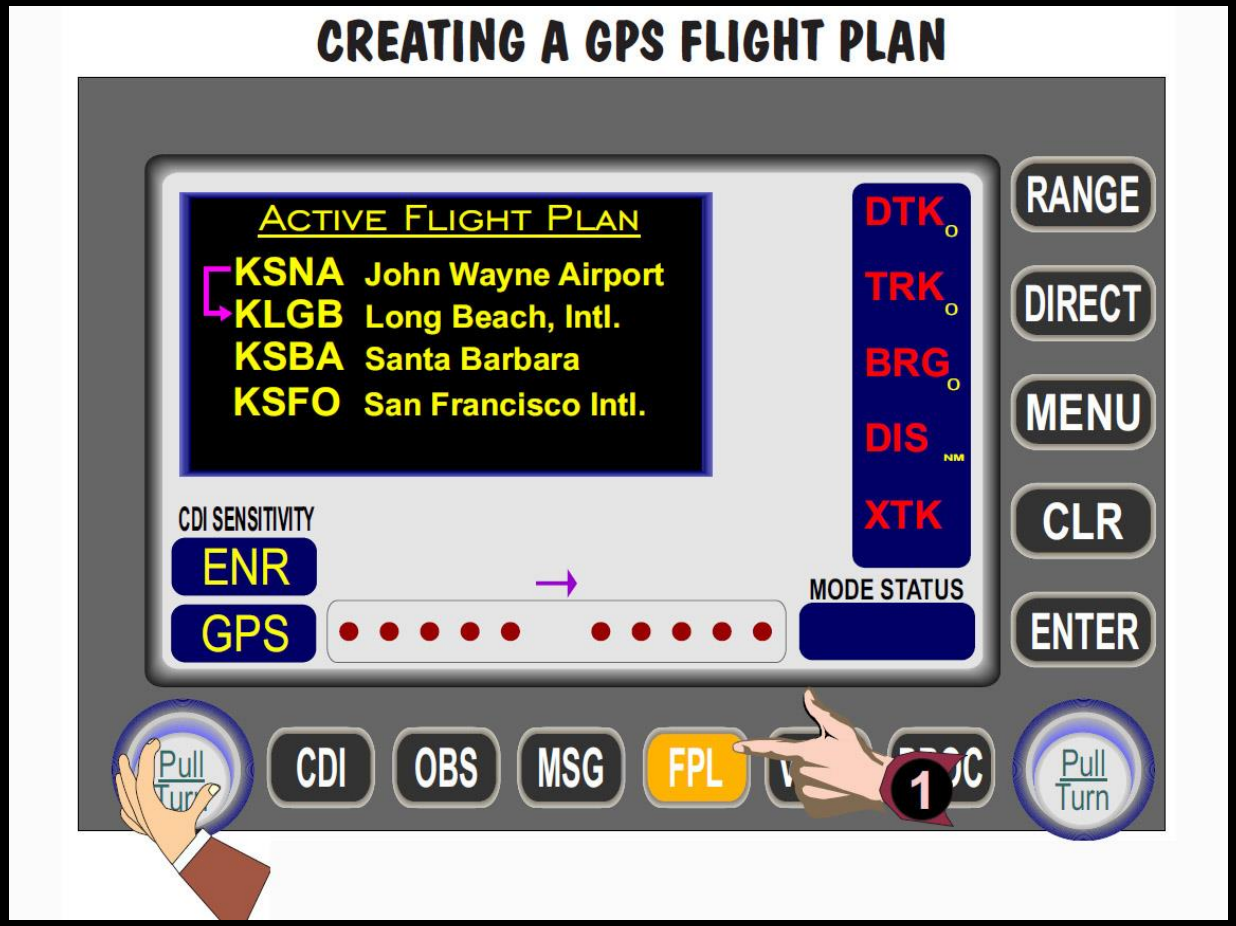
Flight Plan To/To (Leg Mode) Navigation

- You fly from one waypoint to another in a sequence
- Flight plan consists of several segments
- With to/to navigation, the GPS arrow references only the waypoint ahead of you

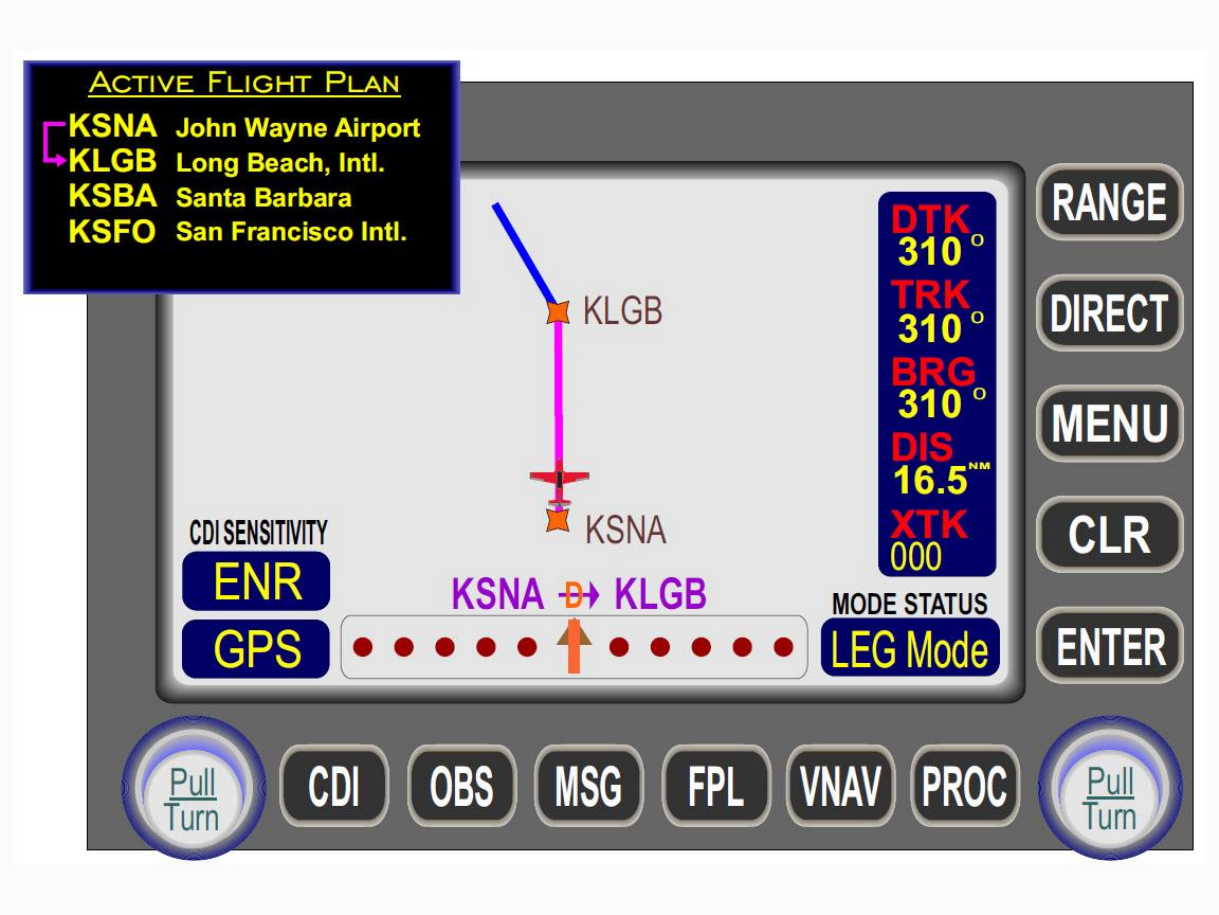


Flight Plan To/To (Leg Mode) Navigation

- Enter flight plan by pressing the FPL button
- Input waypoints that make up a route sequentially
- Waypoints can be made up of airports, VORs, NDBs, intersections, and/or latitude and longitude coordinates
- GPS automatically creates direct legs between the individual waypoints in your flight plan



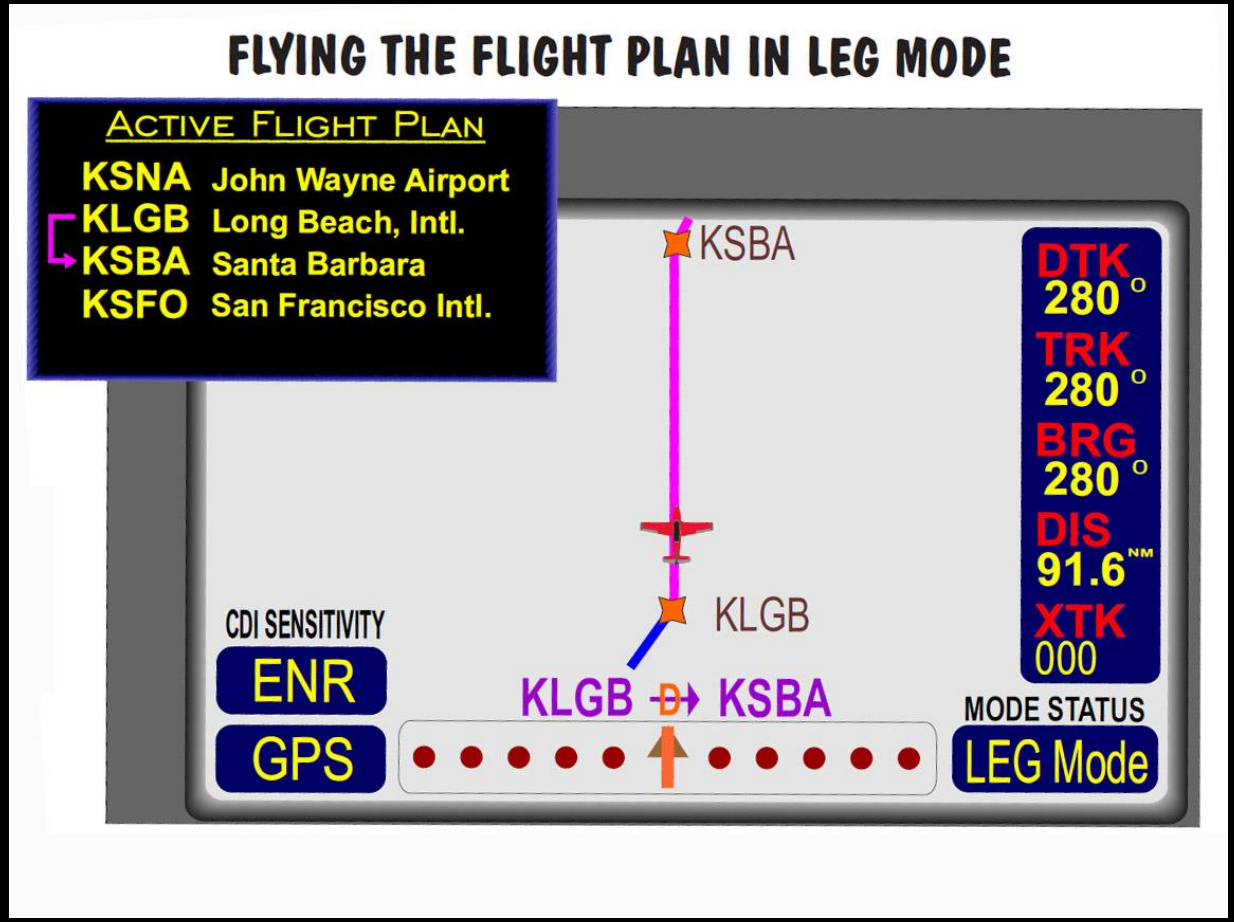
Flight Plan Leg Mode



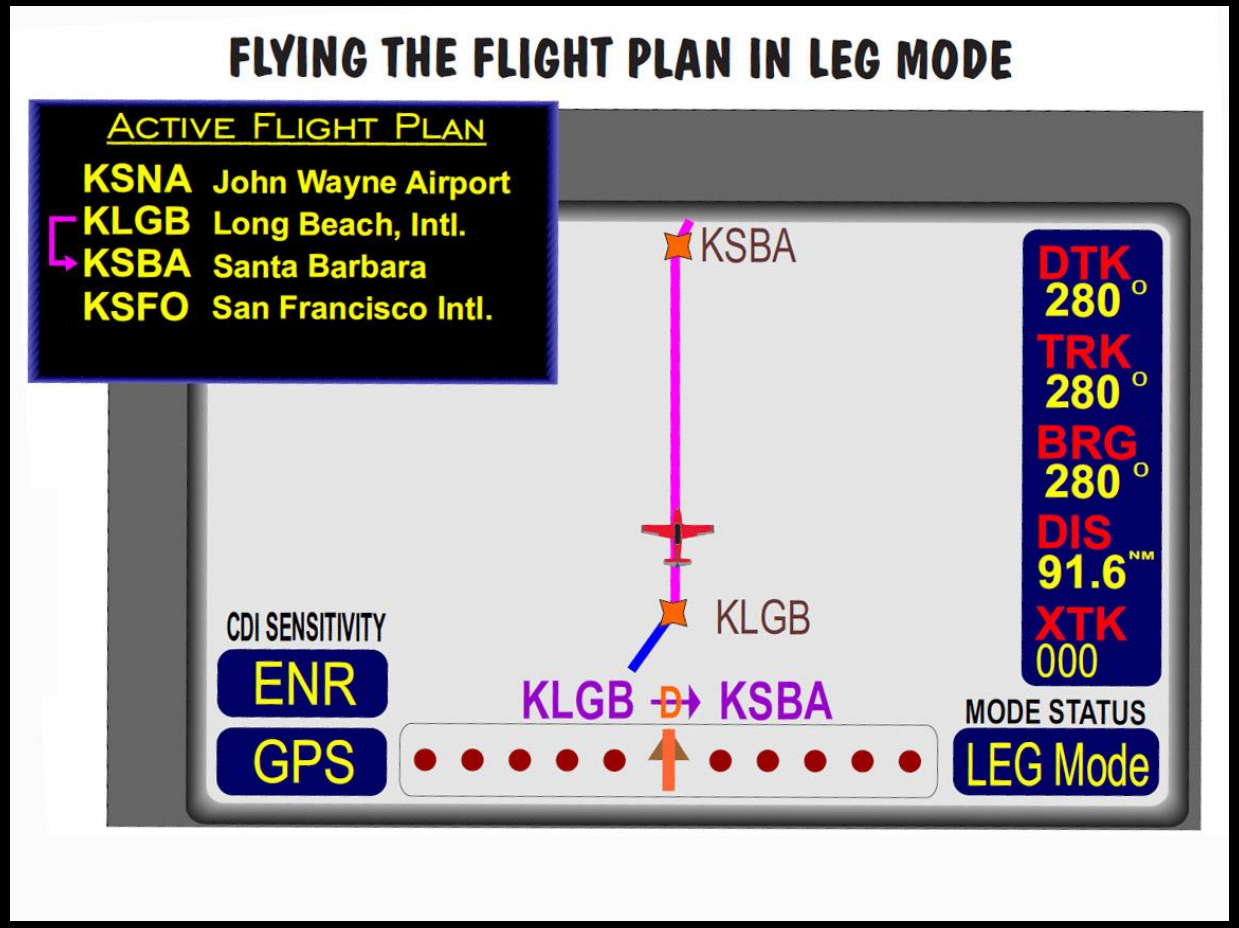
- Mode status Indicator depicts Leg Mode
- Waypoint identifiers KSNA and KLGB (above internal CDI) show the leg you're flying
- Active flight plan window shows the same leg with the arrow indicating that the current leg of the flight is from KSNA to KLGB
- DTK, TRK, BRG, DIS, XTK are shown for the active leg

Flight Plan Leg Mode

- When KLGB is crossed CDI shows TO KSBA
- Referencing to the next waypoint in the flight plan is called auto-sequencing
- When crossing over a waypoint in your flight plan, the GPS puts that behind you and automatically sequences to the next waypoint in the flight plan



Flight Plan Leg Mode



- Moving map always shows your relationship TO the waypoint ahead of you
- TO/FROM triangle in the CDI scale points up (TO indication)
- Continues to point up as the GPS references the next waypoint in the route

Suspending Leg Mode

- You can suspend Leg Mode at any time by pushing the OBS button
- This suspends the GPS's auto-sequencing between waypoints in the active flight plan

Suspending Leg Mode

- OBS Mode can select a different course to avoid a Restricted Area or TFR
- You can manually choose the specific route to fly to any specific waypoint
- After avoiding the flight restriction, pushing the OBS button returns the GPS to Leg Mode
- This resumes auto-sequencing and continues the flight planned route

RAIM

- Receiver Autonomous Integrity Monitoring
- Predicts the reliability (integrity) of the GPS unit for navigation
- If you don't have RAIM capability or if RAIM is lost during flight, GPS-displayed position may conflict with information from other navigational sources
- Pilot has no assurance of the accuracy of the GPS position

Fig. 46

RAIM

Fig. 46

- Four GPS satellites are required for navigation
- RAIM requires an additional satellite to be in view of the receiver (for a total of five satellites) to monitor navigational integrity
- If RAIM is not available, another type of navigation and approach system must be used

RAIM

- Required for Non-WAAS GPS receivers: TSO-C129
- A program built into the IFR GPS unit's software to warn you when there's a navigational accuracy or reliability problem
- RAIM is internal logic within your GPS unit that verifies two important items
  - First, it confirms that the signals received from the satellites aren't providing corrupted information
  - Second, it makes certain that a sufficient number of satellites are being received to check for any transmission errors (also referred to as adequate satellite geometry)

RAIM

- Good satellites can go bad and drop out of service
- These and other anomalies can cause an erroneous reading in the GPS
- To perform proper RAIM, your GPS unit must be able to spot at least one satellite in addition to the minimum of four required for normal nav
- You’d need six satellites in view to actually isolate a corrupt satellite from the navigational program

RAIM

- There are 32 GPS satellites circling the earth, but they are not in a geostationary orbit
- These satellites circle the earth about two times each day, so they are constantly changing their position relative to each other
- This creates situations where, at any given moment at a particular location, an insufficient number of satellites may be visible for RAIM
- Satellites have to be at least 7.5 degrees above the horizon to be received by a GPS unit
- A combination of these issues increases the chance of having inadequate satellite geometry, meaning that RAIM might not be available when needed

GPS Types

- *Non-WAAS: TSO-C129*

Previous Generation

- Lateral NAV only
- Accuracy: 40-50 meters

- *WAAS: TSO-C146*

- Latest
- Lateral + Vertical NAV
- Accuracy 1-2 meters

WAAS

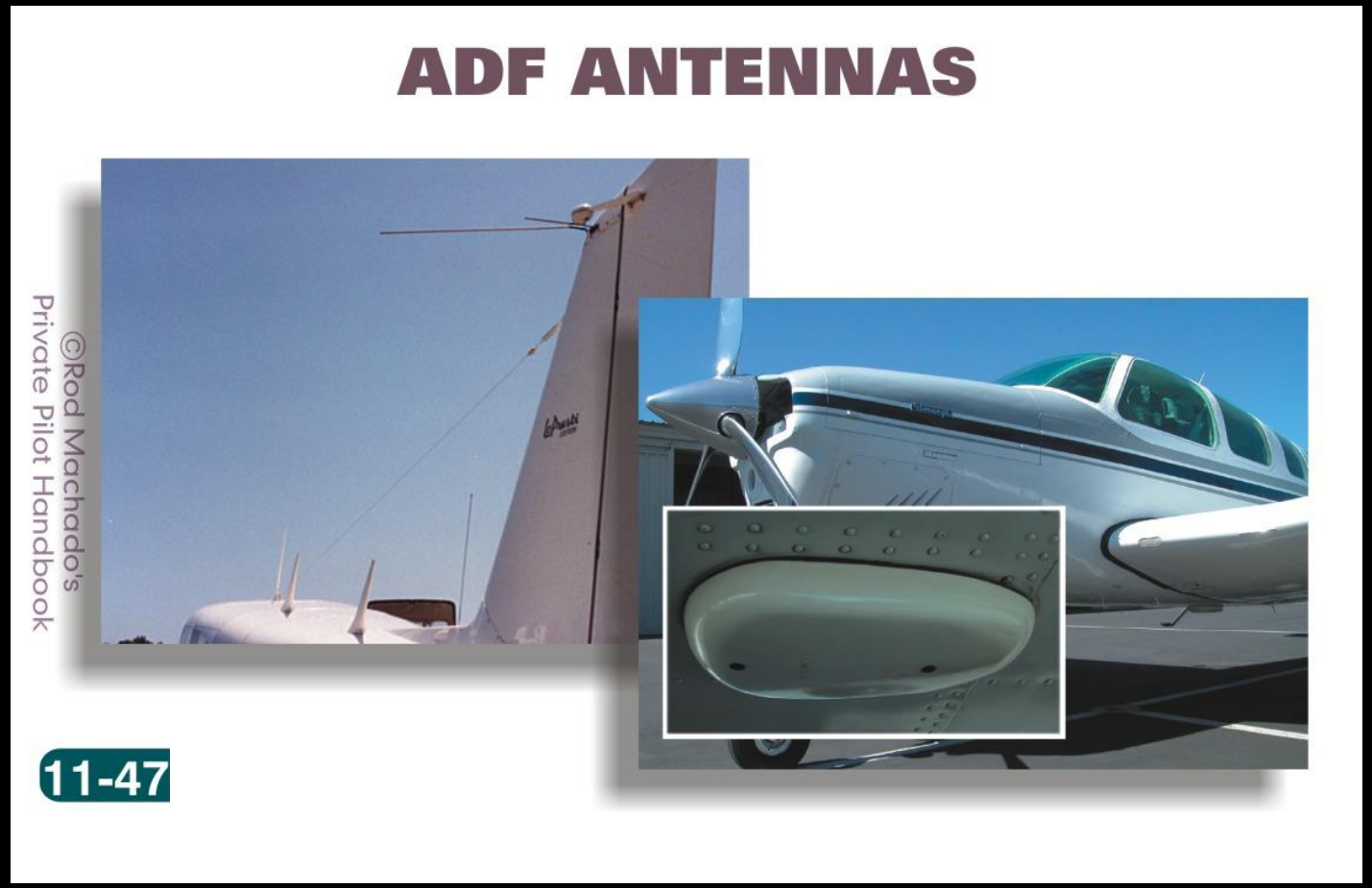
- Signals from the GPS satellites are monitored by WAAS ground-based stations to determine satellite clock and position corrections
- Two master stations collect data from the reference stations and create a GPS correction message
- The correction message is uplinked to a geostationary satellite
- The corrected differential message is broadcast through 1 of 2 geostationary satellites to the WAAS receiver

Navigating with GPS

- Lack of standardization between different of GPS receivers
- ***Must*** become thoroughly familiar with the specific GPS equipment installed in the airplane
- Review operation manual and the AFM or AFM supplement that covers the equipment installation
- Practice with a computer-based flight training device or avionics trainer to become familiar with its operation prior to flying
- Use the equipment in flight under VFR conditions ***before*** IFR operation

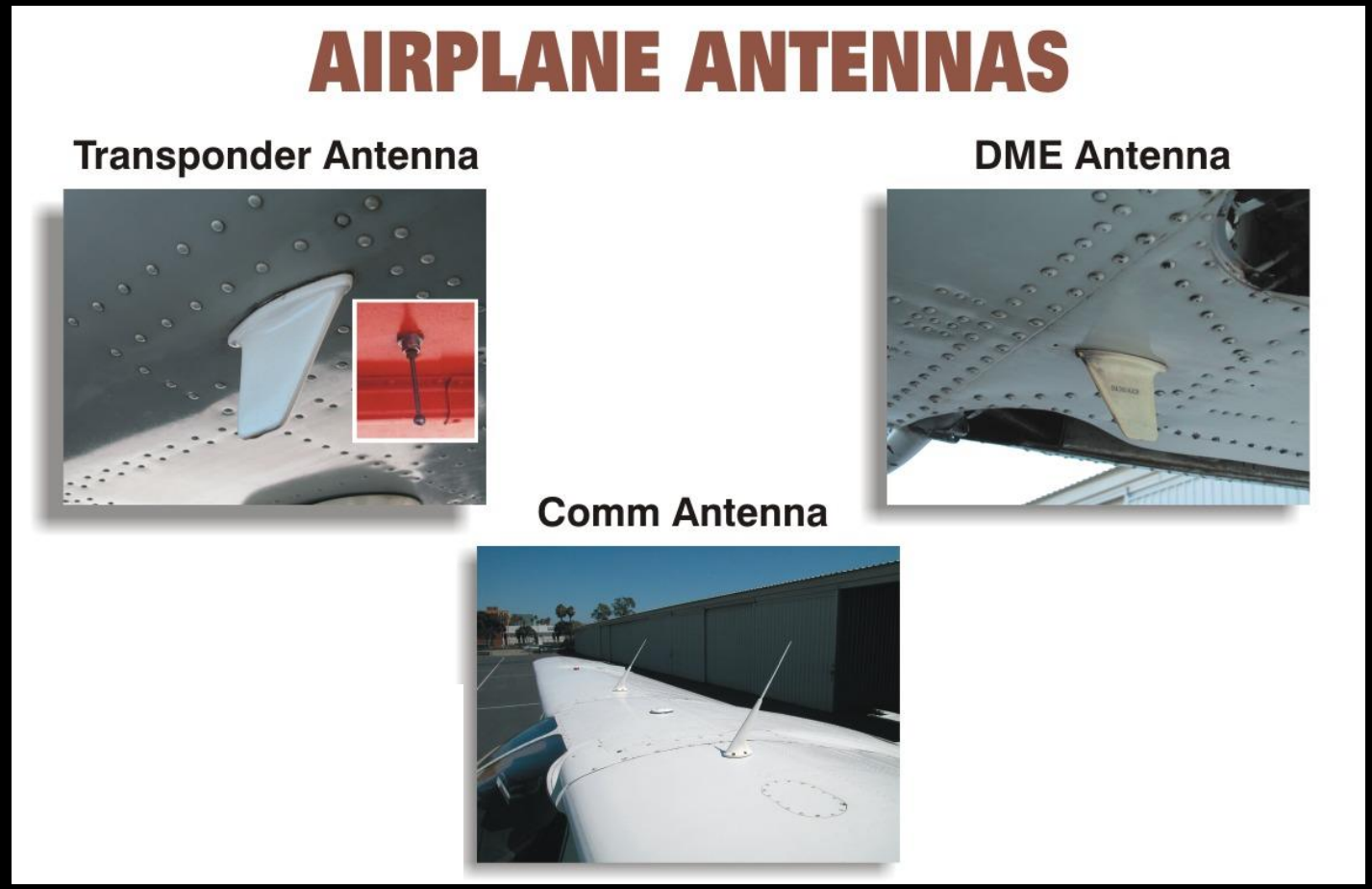
Aircraft Antennas

- ADF



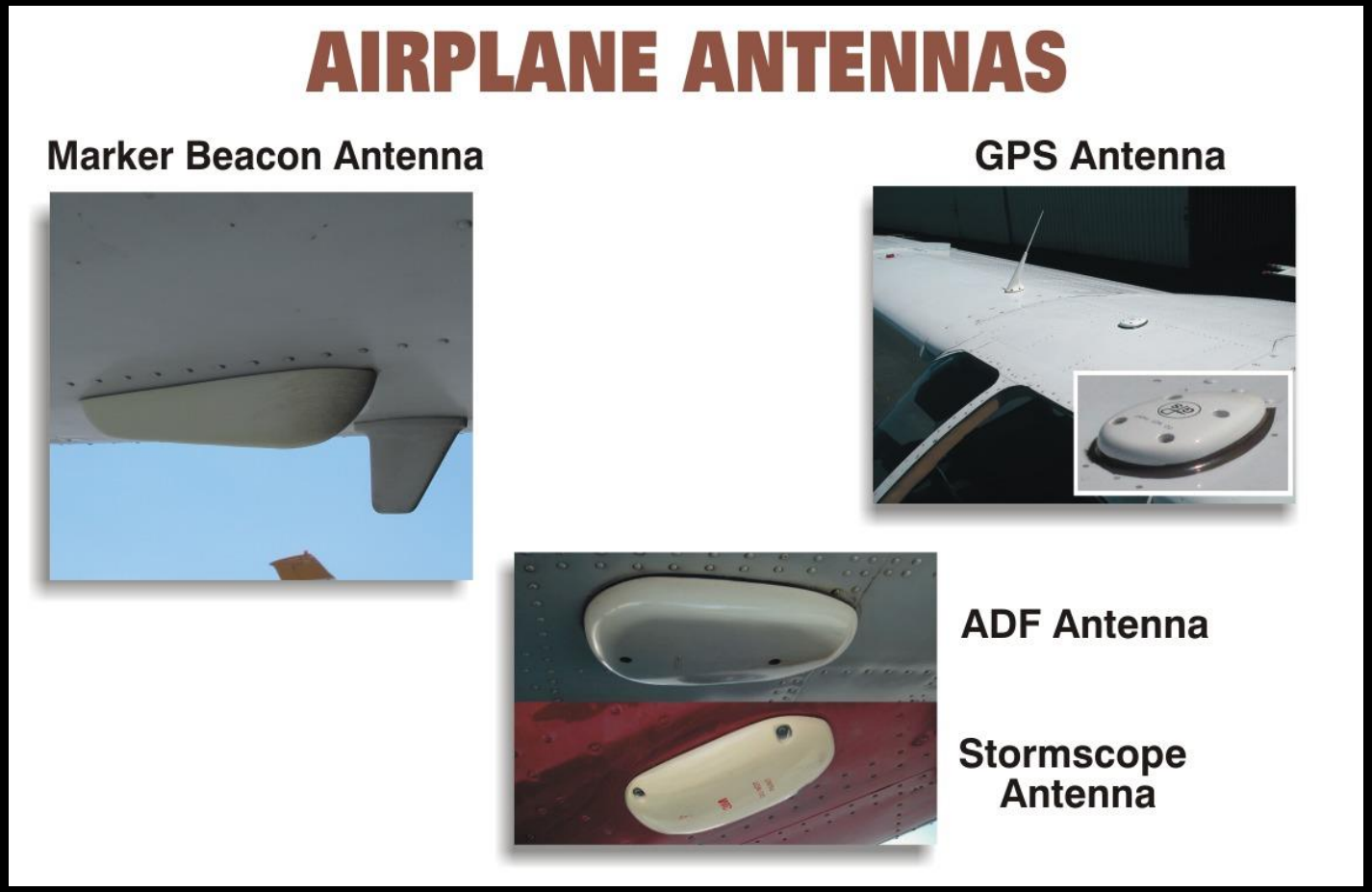
Aircraft Antennas

- Transponder
- DME
- VHF Comm



Aircraft Antennas

- Marker Beacon
- GPS
- ADF
- Stormscope



Pilotage

Electronic and Visual Navigation

Pilotage

- Pilotage is navigation by reference to landmarks or checkpoints.
- It is a method of navigation that can be used on any course that has adequate checkpoints, but it is more commonly used in conjunction with dead reckoning and VFR radio navigation.

Pilotage

- The checkpoints selected should be prominent features common to the area of the flight.
- Choose checkpoints that can be readily identified by other features, such as roads, rivers, railroad tracks, lakes, and power lines. If possible, select features that make useful boundaries or brackets on each side of the course, such as highways, rivers, railroads, and mountains.
- A pilot can keep from drifting too far off course by referring to and not crossing the selected brackets.

Pilotage – Good Checkpoints

- **Airports with Paved Runways:** The taxiways and runways of nearby airports are easy to spot due to large clearings. They also contrast with the grass around them.
- **Railroads:** Railroads are relatively easy to spot due to large clearings made for tracks.
- **Highways:** Multi-lane highways are easy to spot from the air.
- **Major Road Intersections:** Major road and highway intersections with multiple cloverleaf turnoffs are easily spotted.
- **Large Rivers:** Looks for rivers that are drawn with some level of open-water width. Small streams are simple lines, while rivers are drawn wider on your sectional chart.
- **Large Lakes with Definable Shapes:** If a lake has an easily definable shape, it'll be easy to spot from the air.
- **Towns with Prominent Features:** Does the town you're looking for have a major road, railway, or water tower
- **Wind Farms:** Wind farms situated in open clearings are a no-brainer.
- **Open-Pit Mines:** If you get lucky enough to find an open-pit mine along the way, use it as a checkpoint!
- **VOR Equipment:** When flying near a VOR, look for a clearing with a large white tower. New VORs may be harder to spot, with smaller white "pods" arranged in a circle. You can use a VOR's radial and distance to verify your location too.

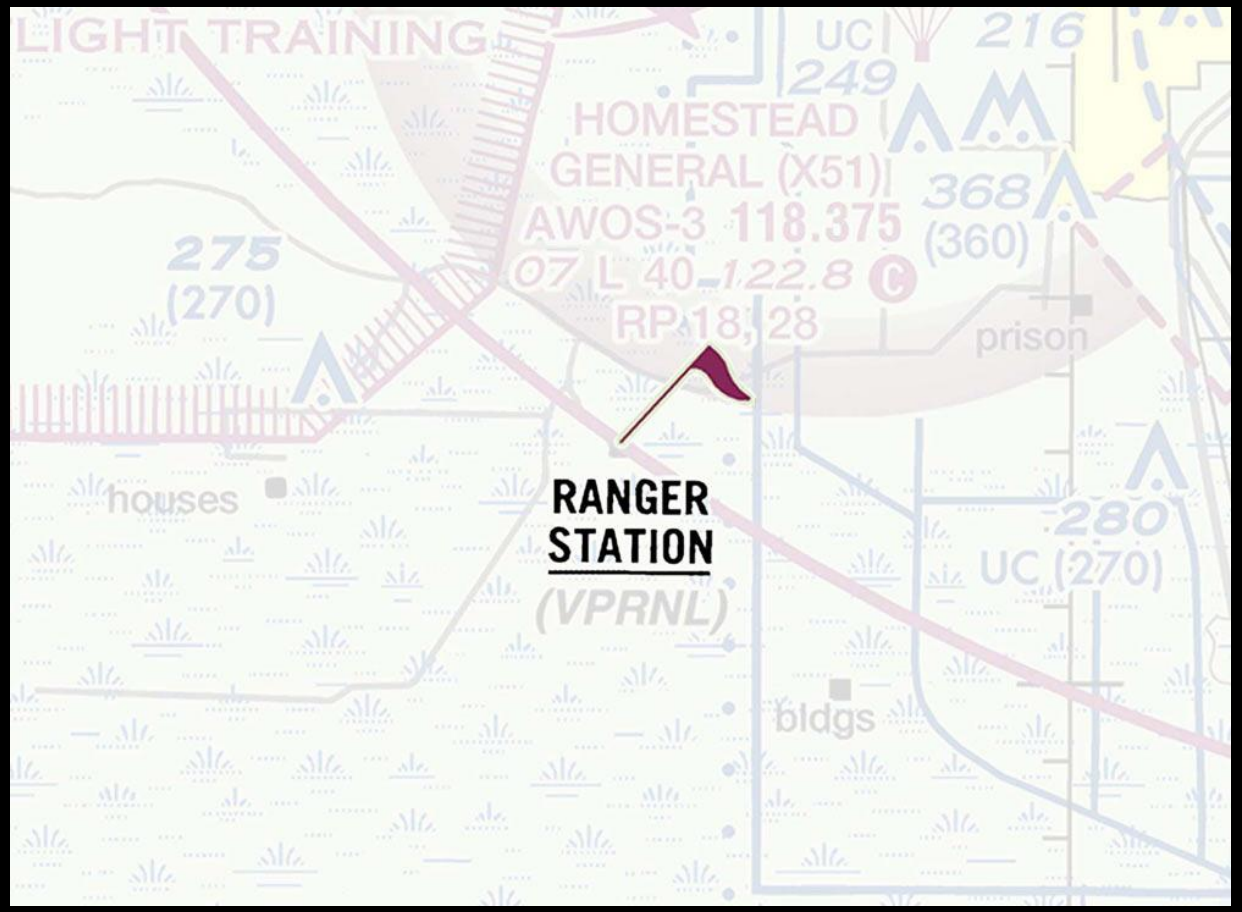
Pilotage

Pilotage

Pilotage

Pilotage

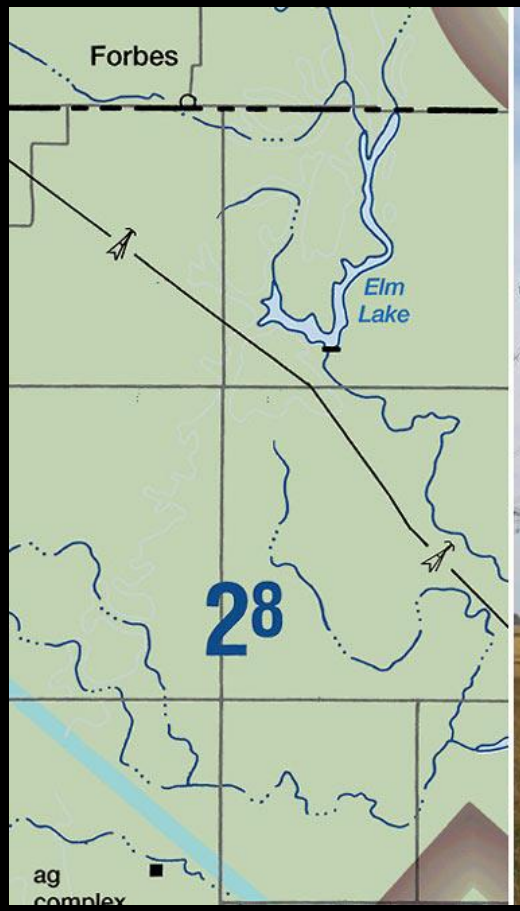
Pilotage – VFR Checkpoints



Pilotage – Bad Checkpoints

- **Powerlines:** Even large powerlines with towers are tough to spot from the air. At altitude, wires are extremely tough to spot.
- **Private Airports:** Private airports, even those with paved runways, are usually small and often tucked away near trees.
- **Grass Runways:** Spotting a grass runway from the air is not easy.
- **Small Streams:** While a stream or small river might be marked on a sectional, that doesn't mean it'll be easy to spot, especially if trees are covering much of it.
- **Small Lakes:** Small lakes aren't a good choice either. They usually don't have well-defined shapes for positive identification.
- **Dry Rivers, Lakes, and Streams:** Be careful not to pick lakes, rivers, or streams that have dried up.
- **Small Towns:** Just because a town is marked on a map doesn't mean it's a good checkpoint. It may be a cluster of just a few buildings. You'll need to find one with other identifiable features.
- **Individual Mountains:** Unless you're extremely familiar with a mountain range, from the air, mountains blend together. Using a single mountain as a waypoint is tough.
- **Towers:** Like powerlines, towers have a tendency to blend into nearby terrain and vegetation.
- **Road Intersections:** Unless you're looking at a major highway, avoid using common road intersections.
- **Areas of Unique Vegetation:** Have you ever seen marshland marked on a map? Identifying unique vegetation is a challenge from the air.

Pilotage



Dead Reckoning

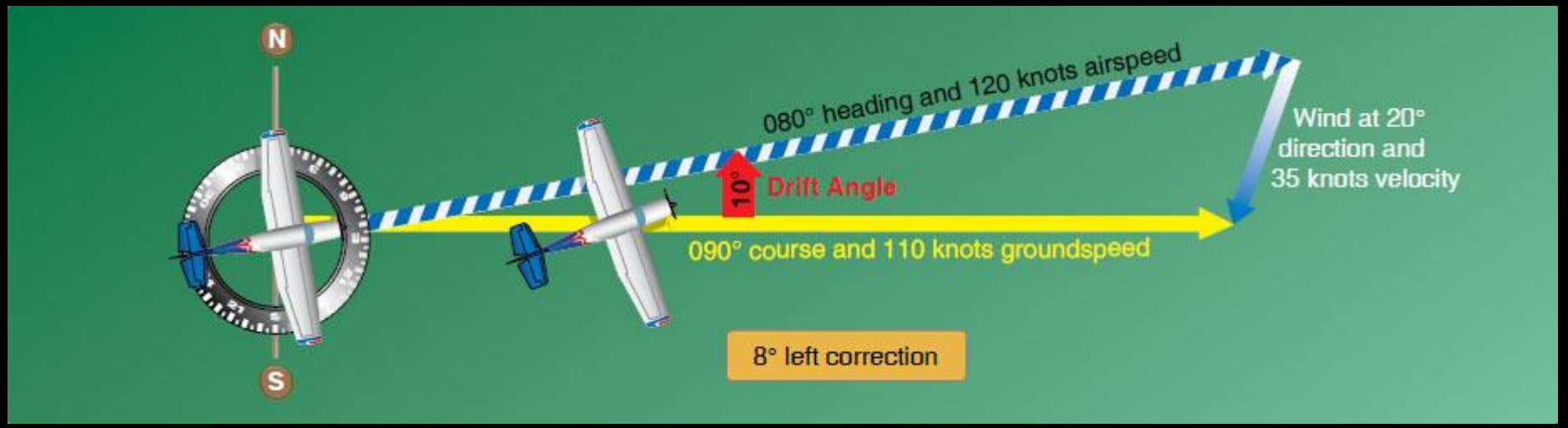
Electronic and Visual Navigation

Dead Reckoning

- Dead reckoning is navigation solely by means of computations based on time, airspeed, distance, and direction.
- The products derived from these variables, when adjusted by wind speed and velocity, are heading and GS. The predicted heading takes the aircraft along the intended path and the GS establishes the time to arrive at each checkpoint and the destination.
- Except for flights over water, dead reckoning is usually used with pilotage for cross-country flying. The heading and GS, as calculated, is constantly monitored and corrected by pilotage as observed from checkpoints.

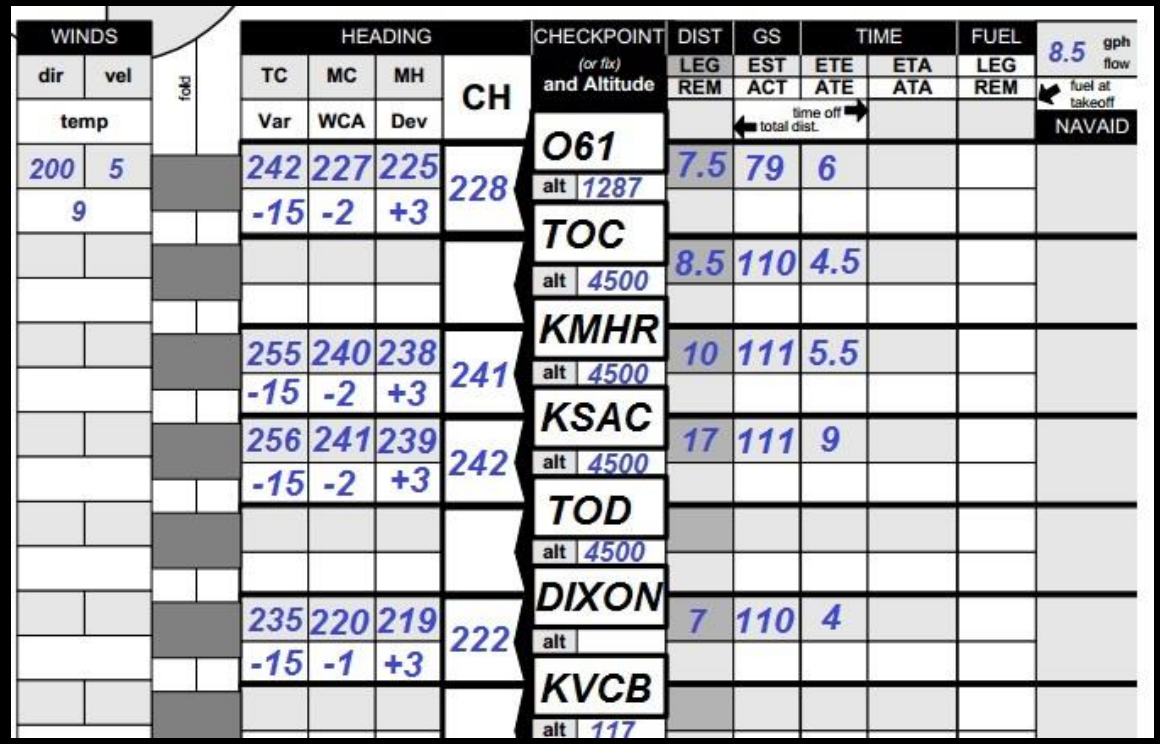
Dead Reckoning

- A series of calculations can be made to determine wind correction based on winds aloft and aircraft true airspeed



NavLog

- A navigation log can be used to keep track of all of the calculations. More detail will be spent calculation in the Cross-Country Lesson.



WINDS dir	WINDS vel	HEADING TC	HEADING MC	HEADING MH	CH	CHECKPOINT (or fix) and Altitude	DIST LEG REM	GS EST ACT	TIME ETE ATE	TIME ETA ATA	FUEL LEG REM	8.5 gph flow / fuel at takeoff / NAVAID
temp		Var	WCA	Dev				time off ← total dist. →				
200	5	242	227	225	228	O61	7.5	79	6			
9		-15	-2	+3		alt 1287						
						TOC	8.5	110	4.5			
						alt 4500						
		255	240	238	241	KMHR	10	111	5.5			
		-15	-2	+3		alt 4500						
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Dead Reckoning

- Dead reckoning is used in combination with pilotage to make it from one point to another.
- Think of dead reckoning as the detailed plan that will work in the absence of pilotage.
- In reality we will use both pilotage and dead reckoning

Knowledge Check

Which of the following is a good VFR checkpoint?

A. Grass runway
B. Open-Pit mine
C. Towers
D. Pipeline

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Knowledge Check

Dead reckoning relies on which on the following?

A. NavLog calculations from checkpoint to checkpoint
B. Visual checkpoints
C. VOR radials
D. None of the above

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