Radio Navigation

Uses of Radio Navigation Aids for VFR

- Supplement navigation by visual reference to ground
- Determine position by triangulating
- Answer questions on PPA written test

Types of Radio Navigation Aids

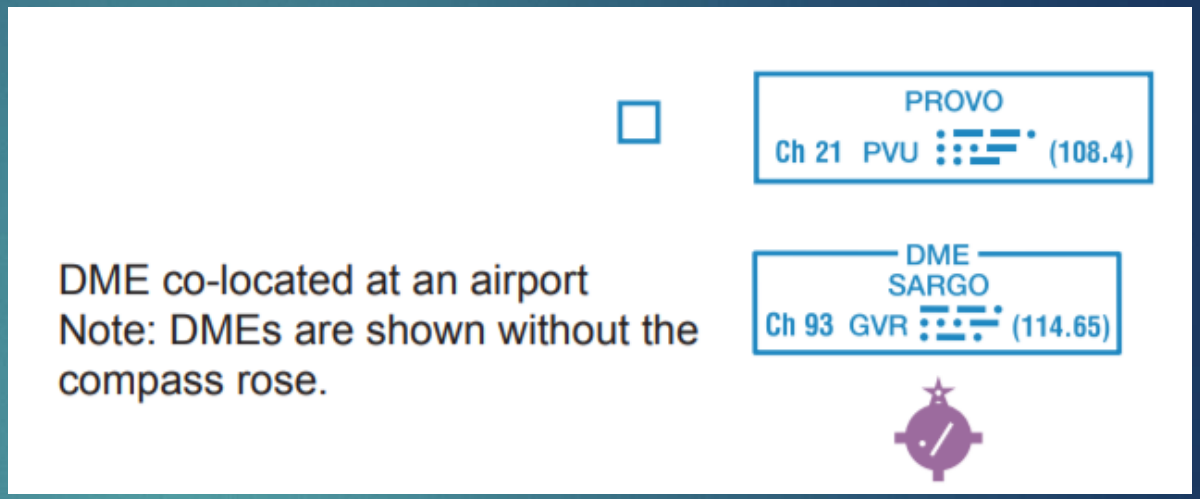
- NDB: Non-Directional Beacon
- DME: Distance Measuring Equipment
- TACAN: Tactical Air Navigation System (Military)
- VOR: VHF (Very High Frequency) Omnidirection Range
- VOR-DME: VOR + DME
- VORTAC: VOR + TACAN
- GPS

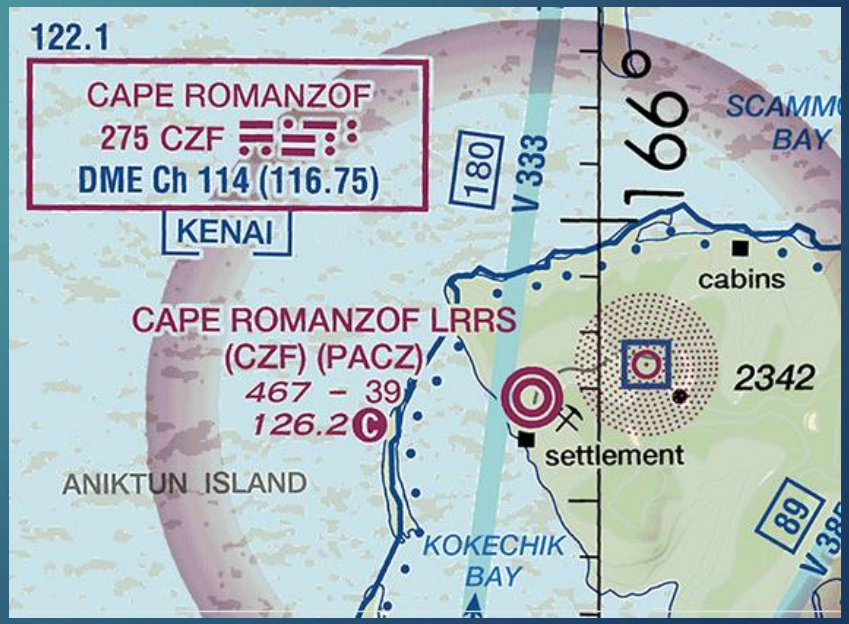
Non-Directional Beacon (NDB)

- Really just a radio antenna
- First NDBs in the US were AM radio stations
- Today they transmit just
- below the audio AM band (190-535 kH)

Automatic Direction Finder

DME: Distance Measuring Equipment

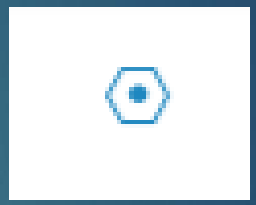




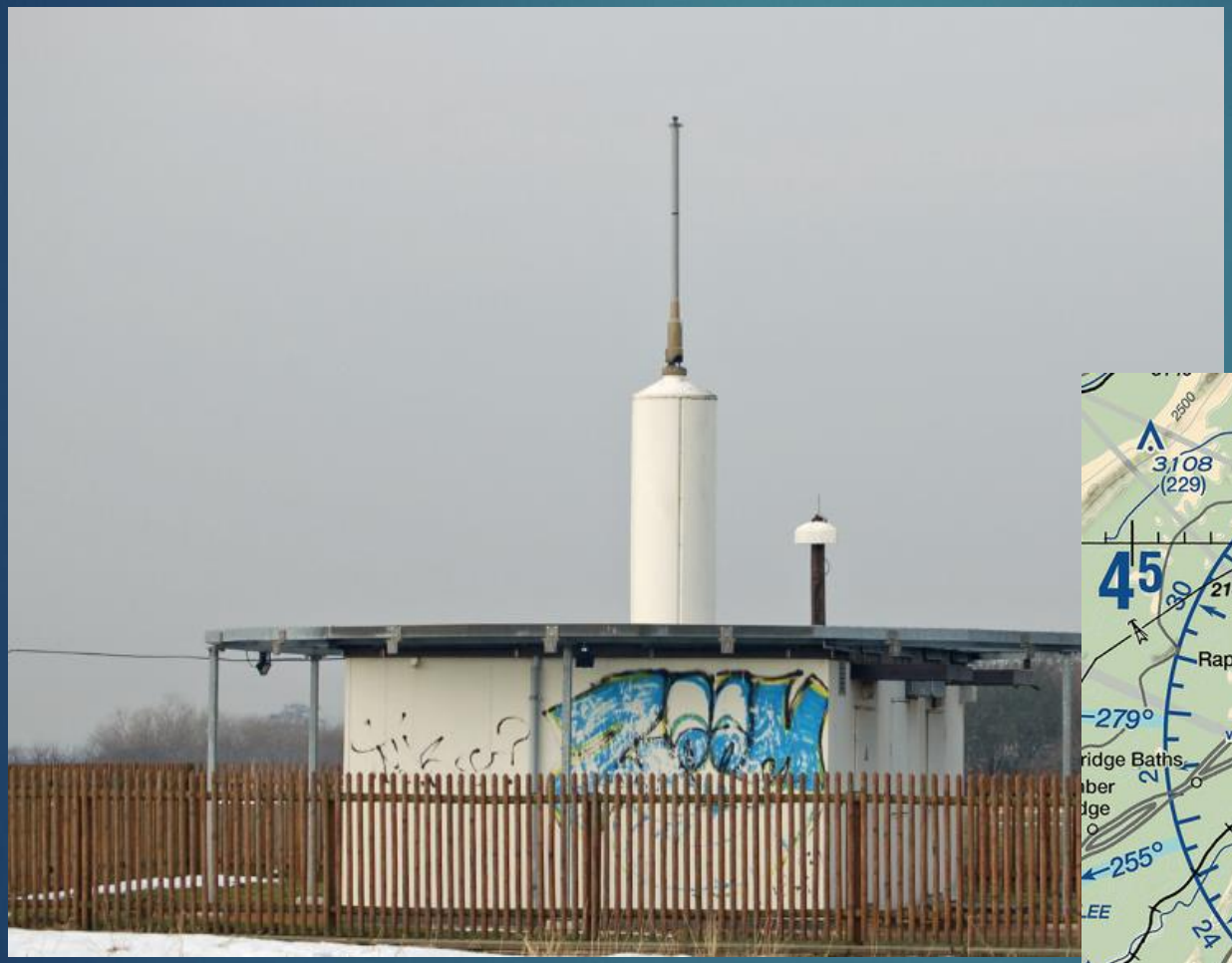
TACAN: Tactical Air Navigation System

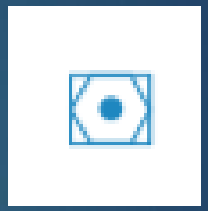
- Military use
- Not charted on civilian sectionals/TACs
- Small; may be mobile (as seen) or on ships
- Combines position and distance measuring
- Distance measuring element available for civilian use.

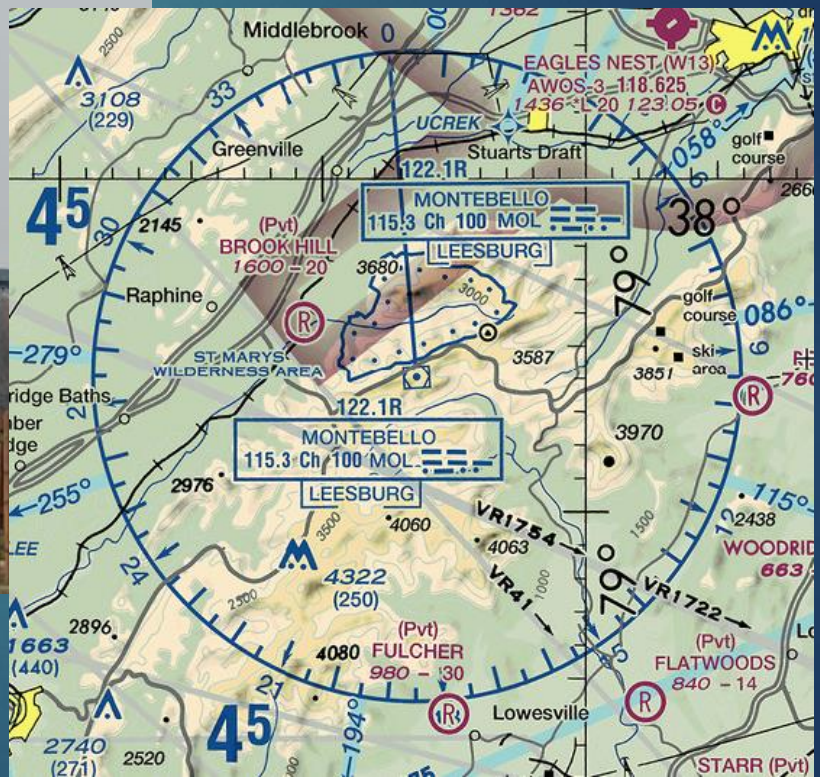
VOR: VHF Omnidirectional Range



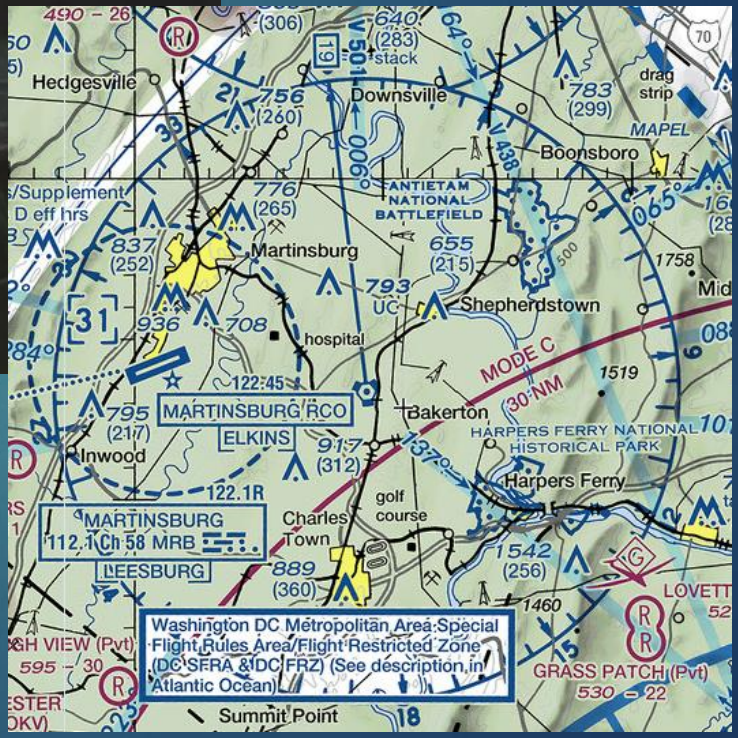
VOR-DME





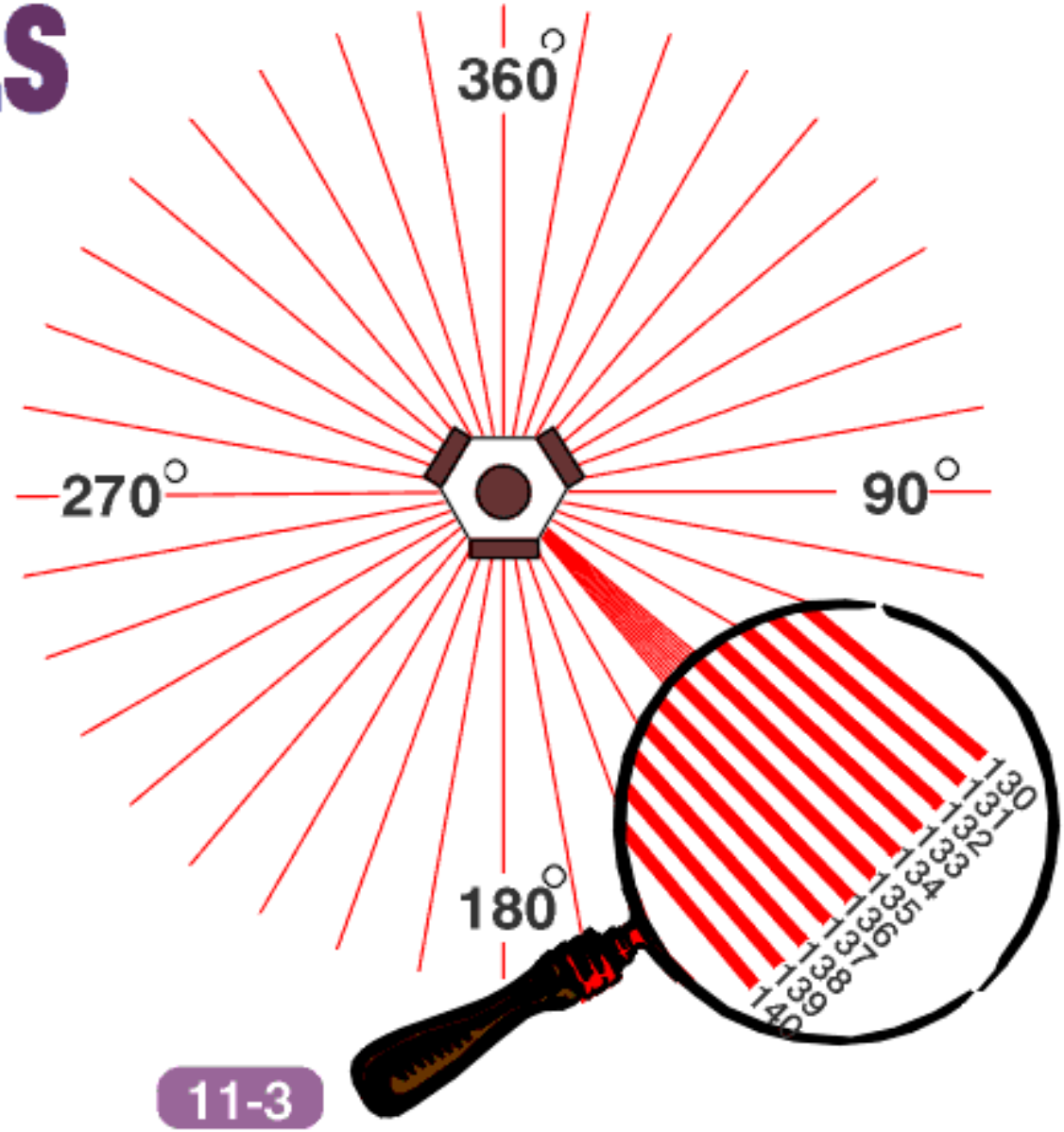

Middlebrook
EAGLES NEST (W13)
AWOS-3 118.625
UCREK
Greenville
Stuarts Draft
122.1R
MONTEBELLO
115.3 Ch 100 MOL
LEESBURG
(Pvt)
BROOK HILL
1600 – 20
Raphine
ST MARYS
WILDERNESS AREA
golf course
ski area
122.1R
MONTEBELLO
115.3 Ch 100 MOL
LEESBURG
VR1754
VR41
VR1722
(Pvt)
FULCHER
980 – 30
(Pvt)
FLATWOODS
840 – 14
Lowesville
STARR (Pvt)

VORTAC


Hedgesville
Downsville
Boonsboro
ANTIETAM NATIONAL BATTLEFIELD
Martinsburg
Shepherdstown
hospital
MODE C
30 NM
MARTINSBURG RCO
122.45
ELKINS
122.1R
MARTINSBURG
112.1 Ch 58 MRB
LEESBURG
Inwood
Bakerton
HARPERS FERRY NATIONAL HISTORICAL PARK
Harpers Ferry
golf course
Charles Town
Washington DC Metropolitan Area Special Flight Rules Area/Flight Restricted Zone (DC SFRA &DC FRZ) (See description in Atlantic Ocean)
GRASS PATCH (Pvt)
Summit Point
drag strip
MAPEL

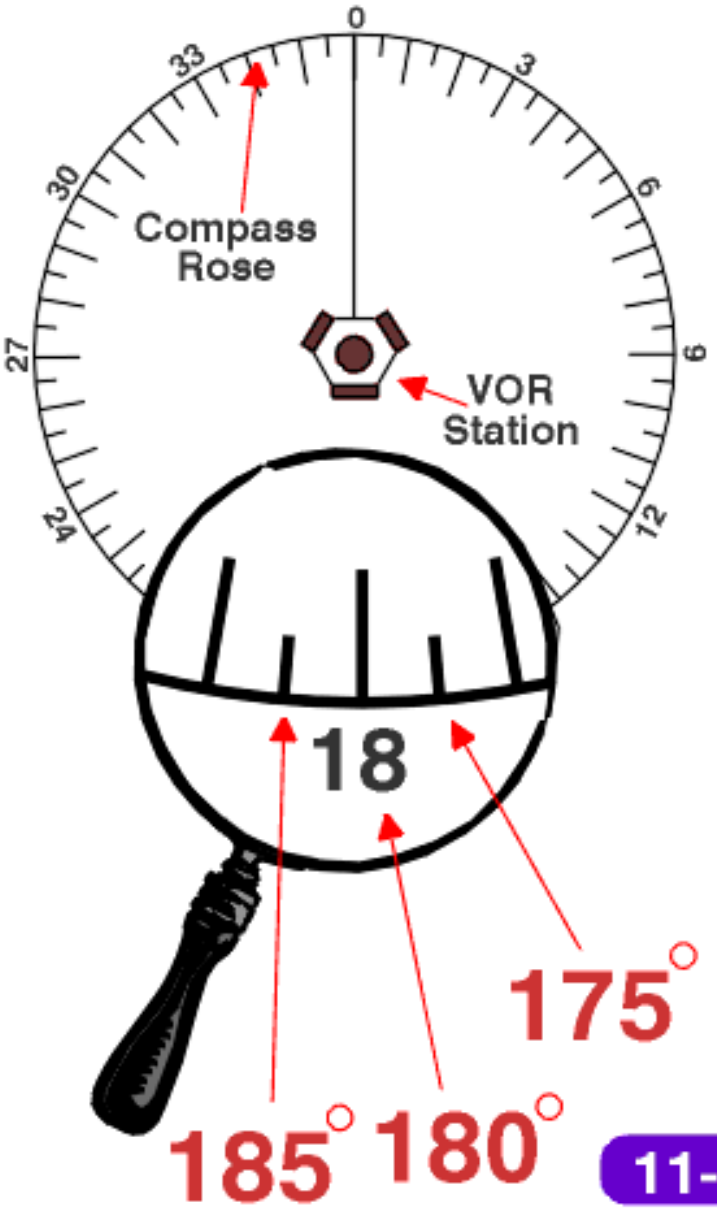
VOR RADIALS

Think of the VOR as a transmitter that radiates 360 individual radials from its center. These radials are oriented to the magnetic north pole. You may navigate to or from the station on any of these radials via your airborne VOR equipment.



VOR COMPASS ROSE

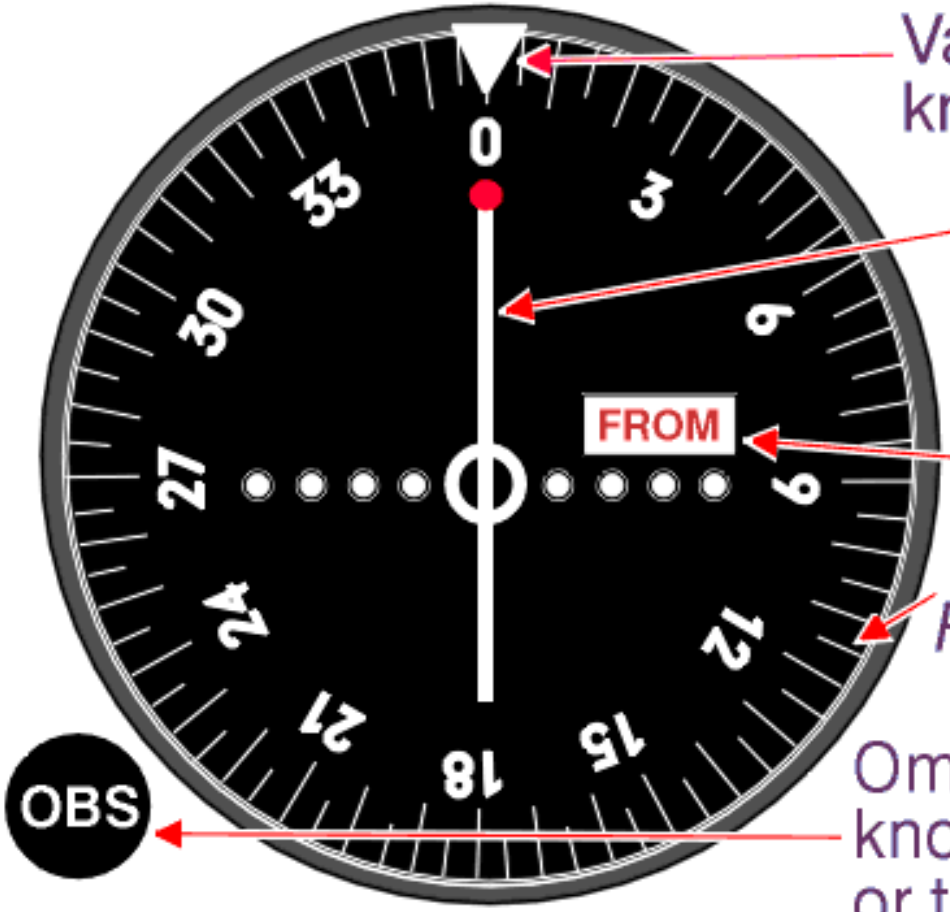
The VOR compass rose has markings every 5 degrees, with larger markings at 10 degree increments. Additionally, the compass rose is numbered at 30 degree increments.




Co-located with airport
Standalone VOR
SPEEDWAY
Pittsfield
COOPER (Pvt)
485 – 16
526
(240)
stack
Penacook
980
Contoocook
849
(300)
872
CONCORD MUNI (CON)
ASOS 132.325
342 °L 60 122.7
CONCORD
112.9 Ch 76 CON
BANGOR
652
(445)
stacks
EPSOM
216 CO
CTC BOSTON
20 NM ON 124
941
HOOKSETT
TOLLBOOTHS
1049
(366)
INTERVALE
425 – 21
122.8
610 – 20
V 188
Ansonia
(Pvt)
SIKORSKY (JSD)
CT - 133.6
1016
(496)
TRUMBULL
WEST HAVEN
MILFORD
stacks
511
358
(348)
stack
WESTPORT
BRIDGEPORT/
SIKORSKY (BDR)
CT - 120.9 ATIS 119.15
09 °L 47 123.0
RP 29
318
BRIDGEPORT
VOR-DME
BRIDGEPORT
108.8 Ch 25 BDR
BRIDGEPORT
CTC NEW YORK APP WITHIN
20 NM ON 120.05 343.75
BELTT
Caution
Student Training
Port

Dual NAV-COMM Stack

THE VOR INDICATOR



Value of OBS selection known as the *Index*

Course Deviation Indicator also known as the *CDI*

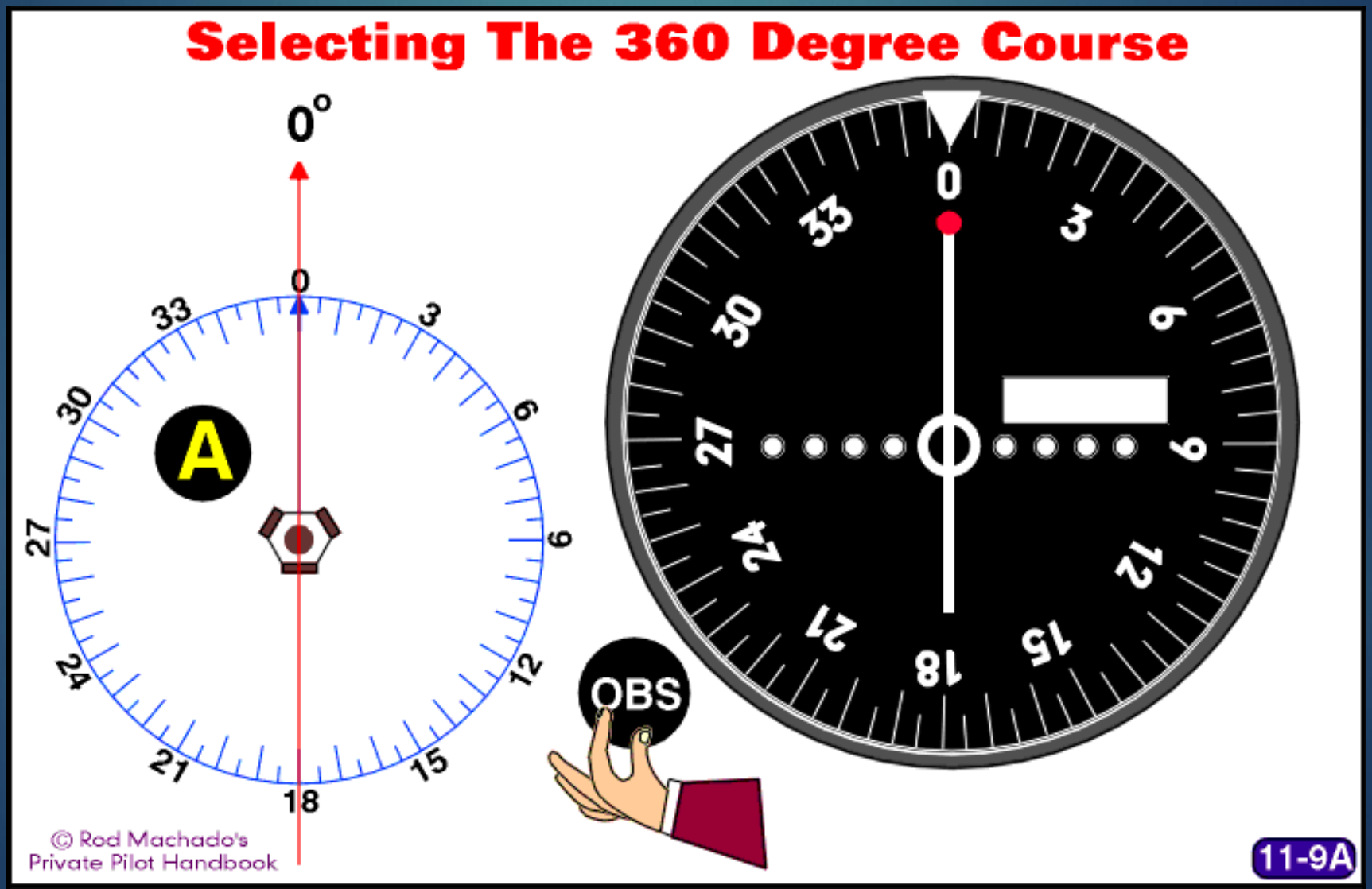
Ambiguity Indicator swings from TO/OFF/FROM

TO | OFF | FROM

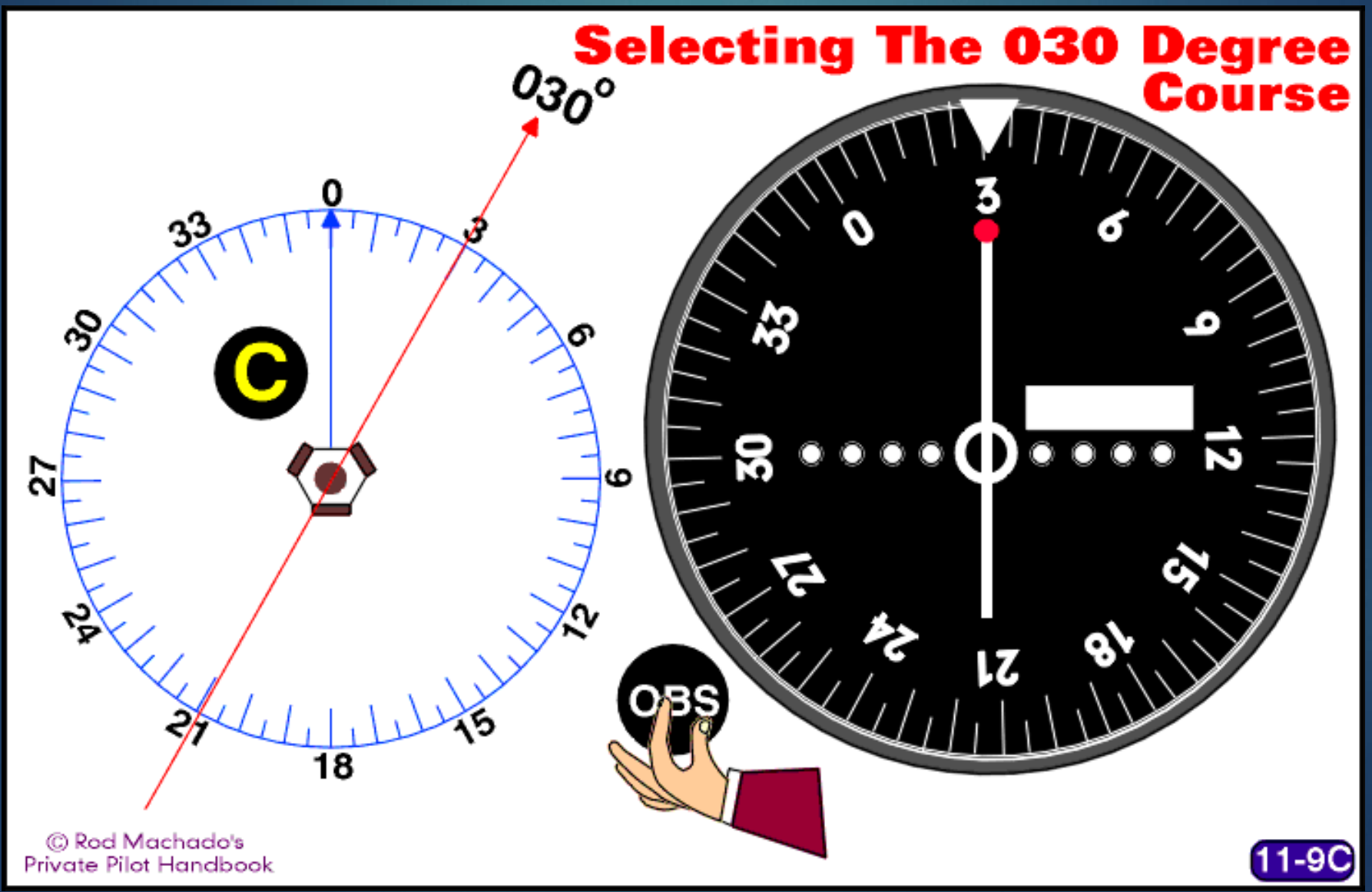
Rotatable Compass Card

Omni Bearing Selector also known as the *OBS* knob or the *Course Selector*

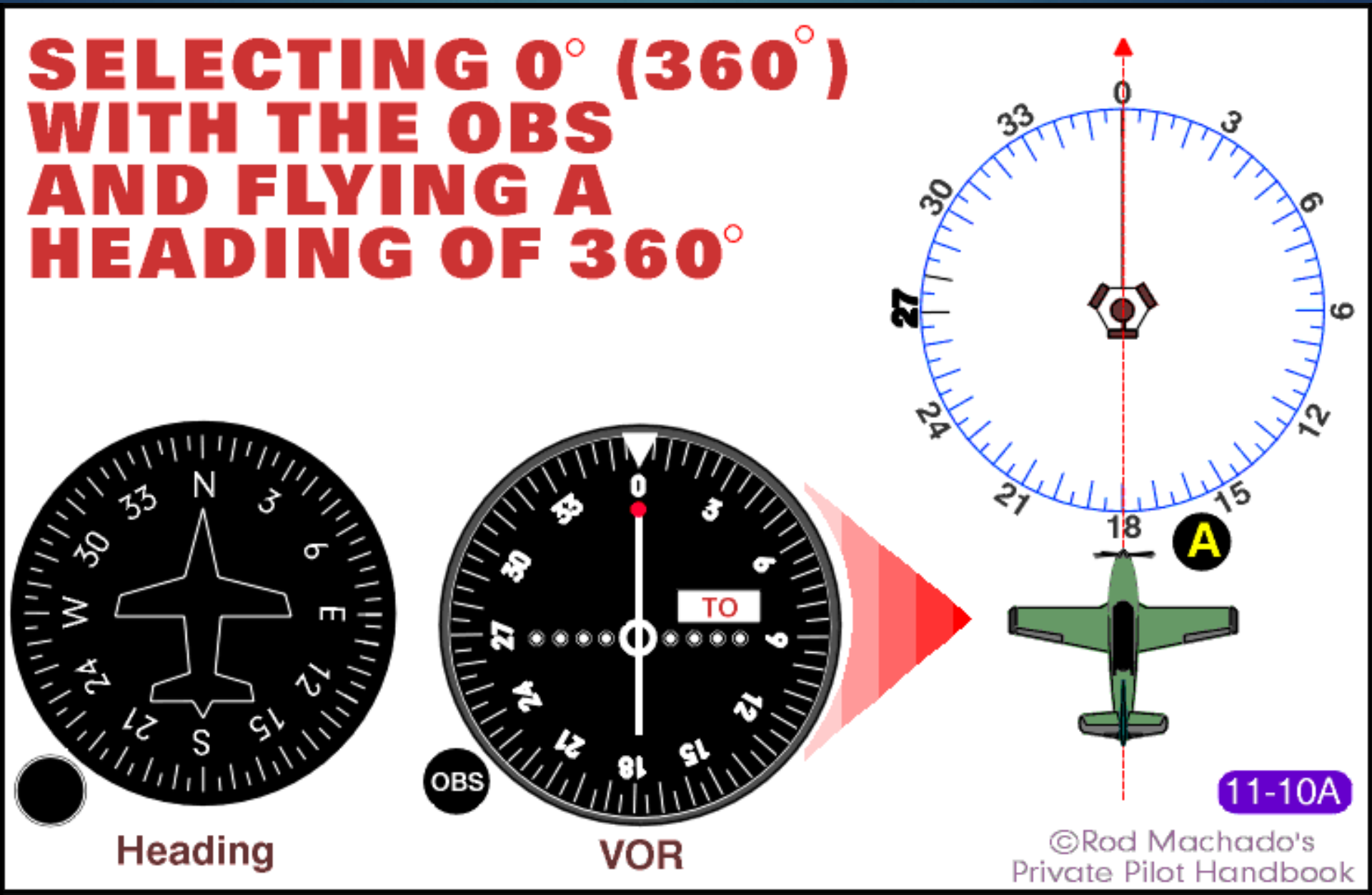
Rotate the “OBS” knob to orient the movable compass card, aligning the desired course with the index bug (0°/360°).



Rotate the “OBS” knob to orient the movable compass card, aligning the desired course with the index bug (030°).

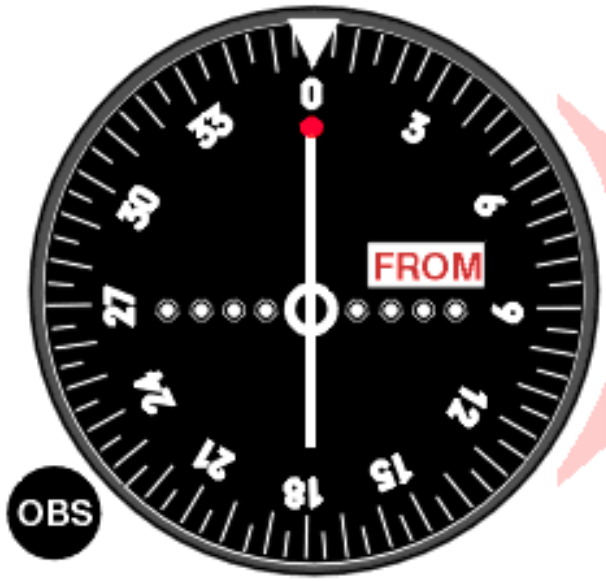


Flying Heading 0°/360° **TO** the VOR

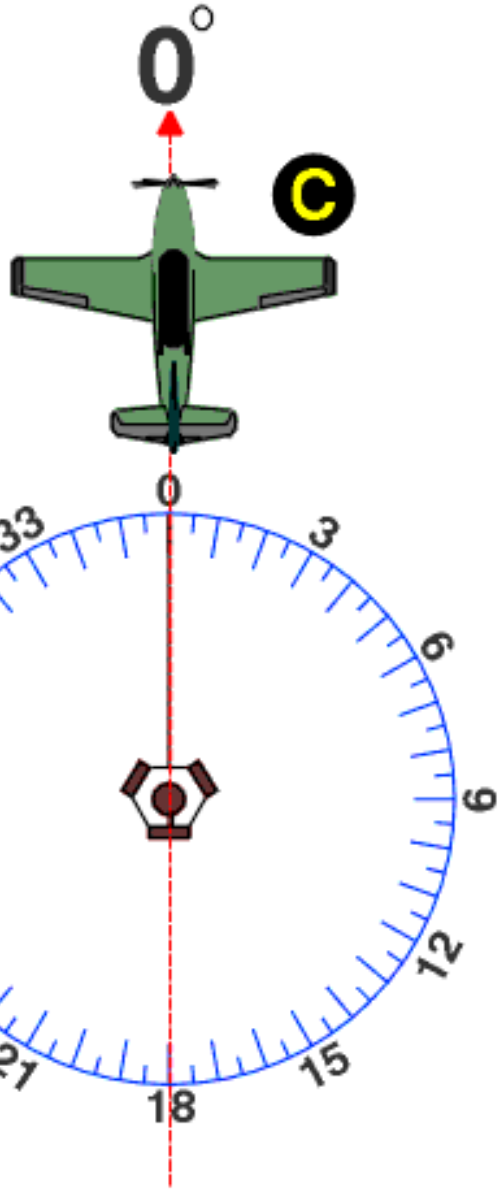


Flying Heading 360 **FROM** the VOR

Heading



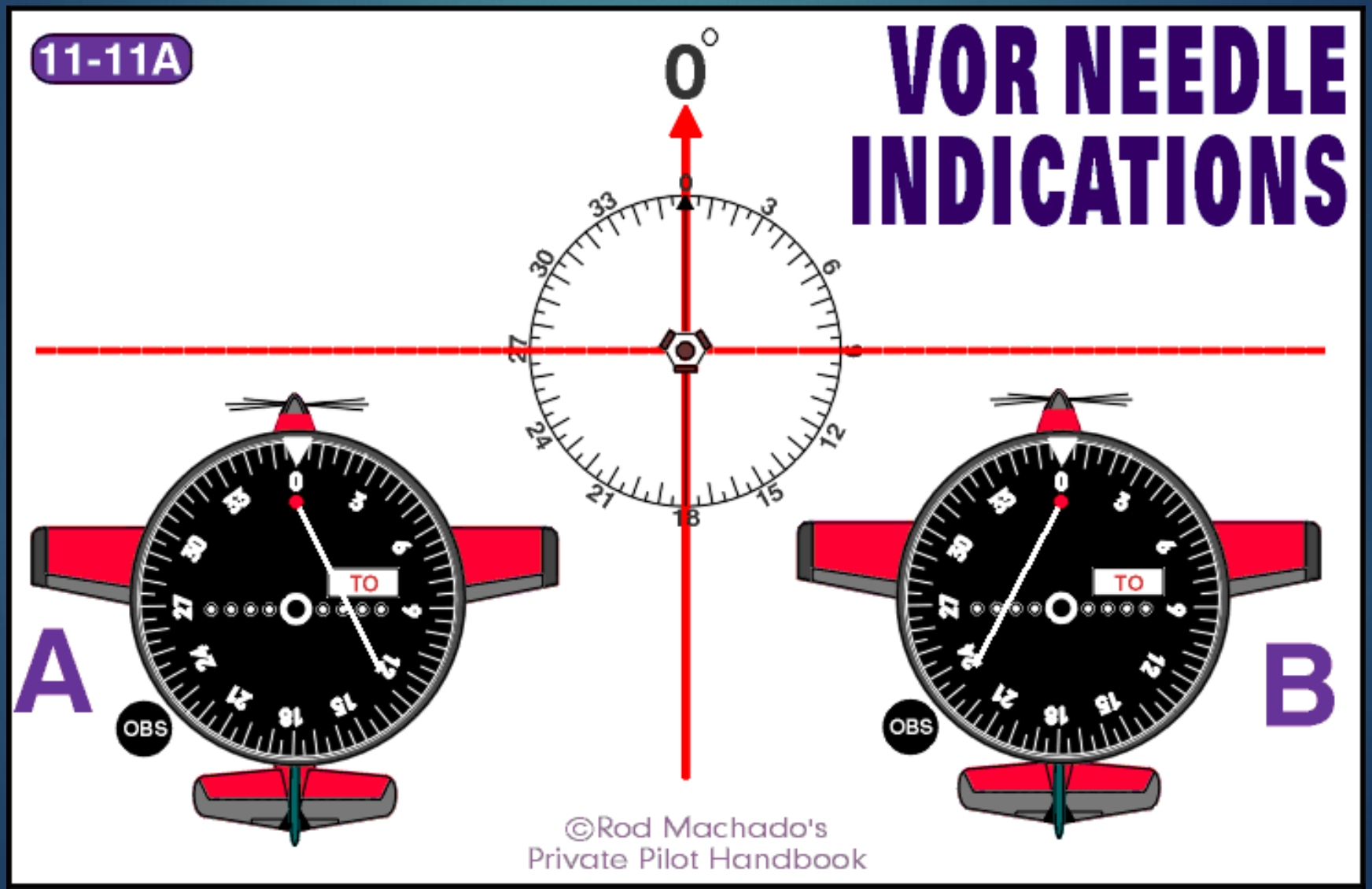
VOR



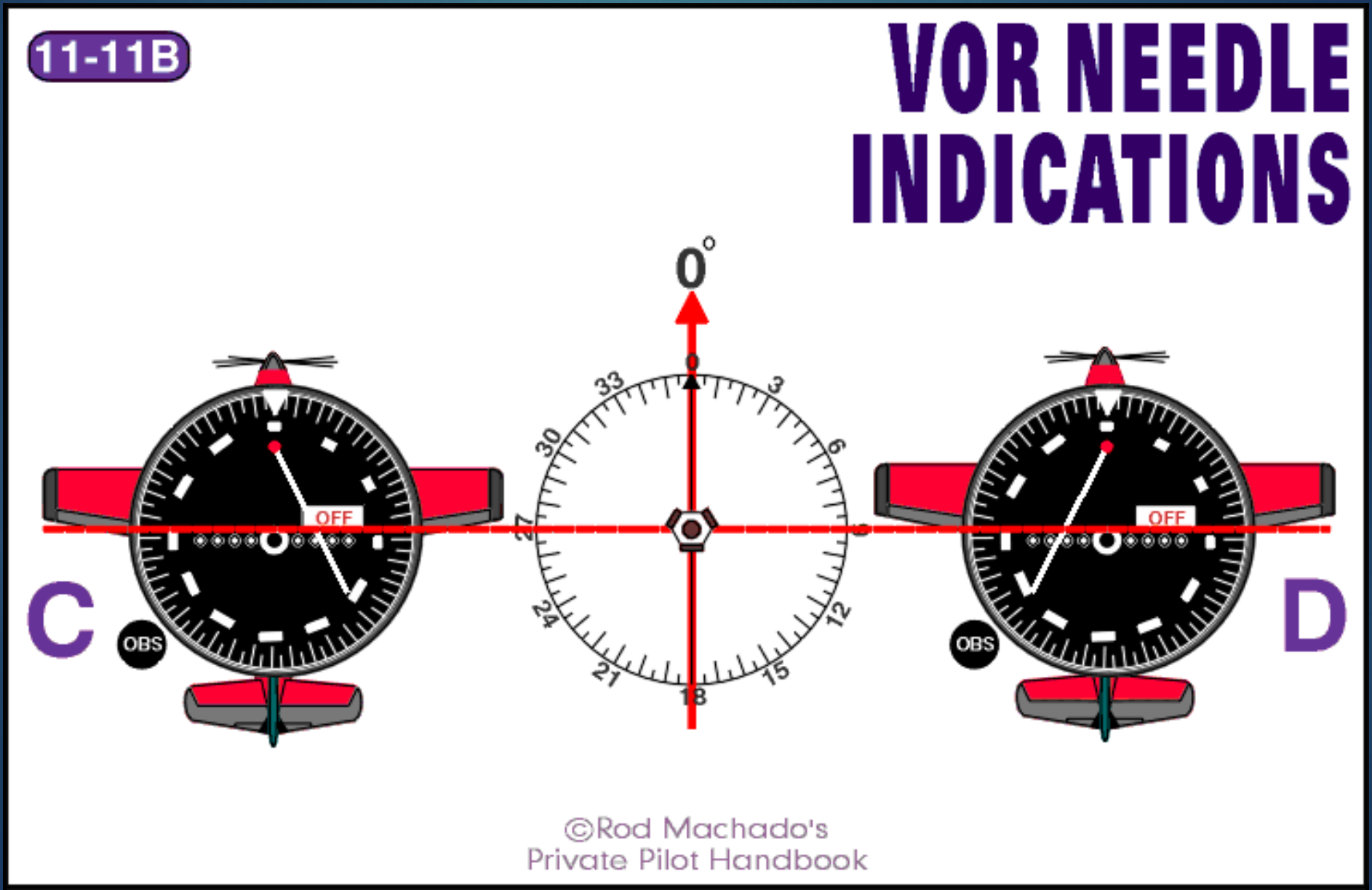
SELECTING 0° (360°) WITH THE OBS AND FLYING A HEADING OF 360°

11-10C

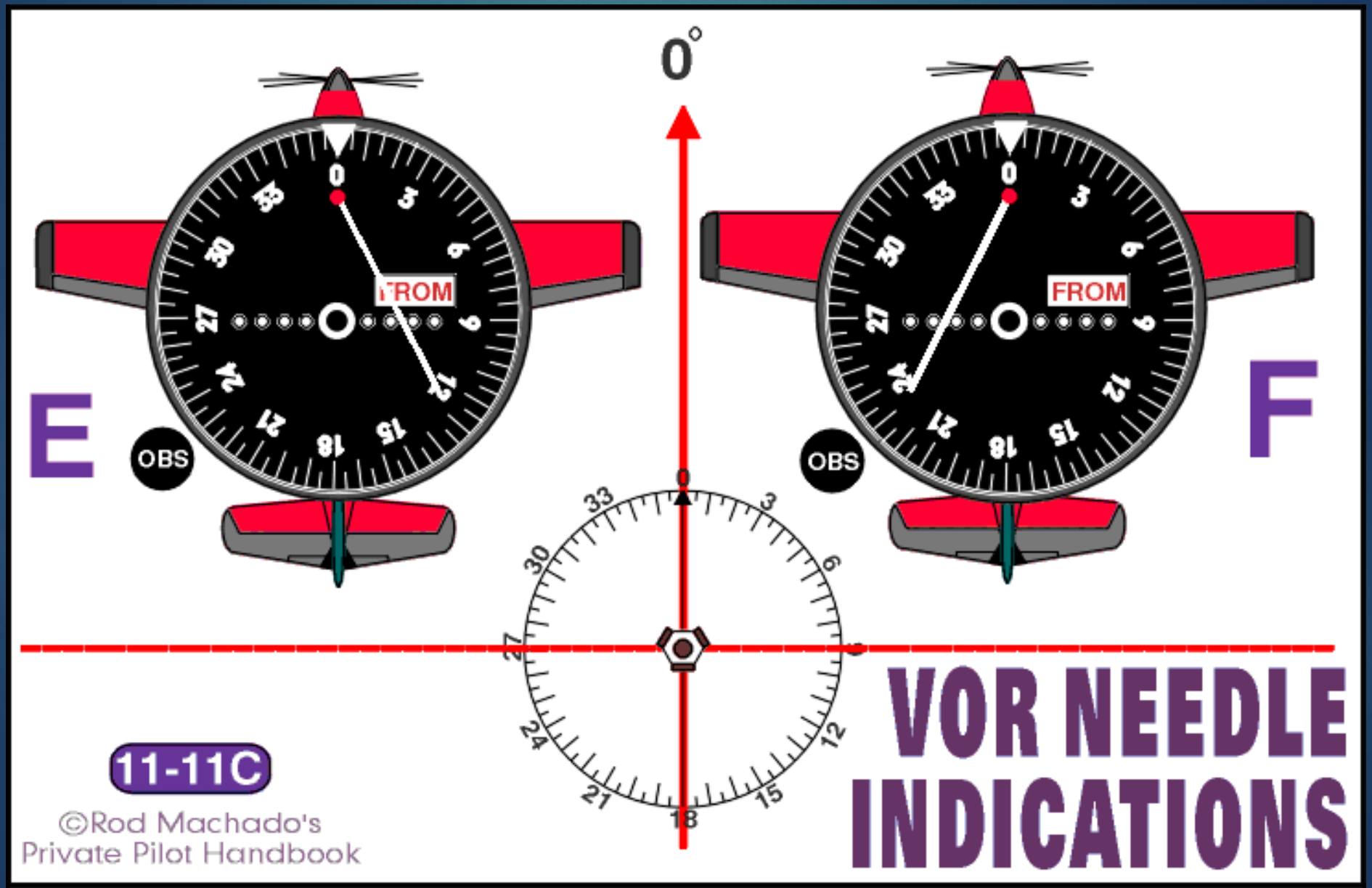
What happens if you are flying the right heading, but off course?



As you pass the VOR, the ambiguity indicator switches from **TO** to **OFF**

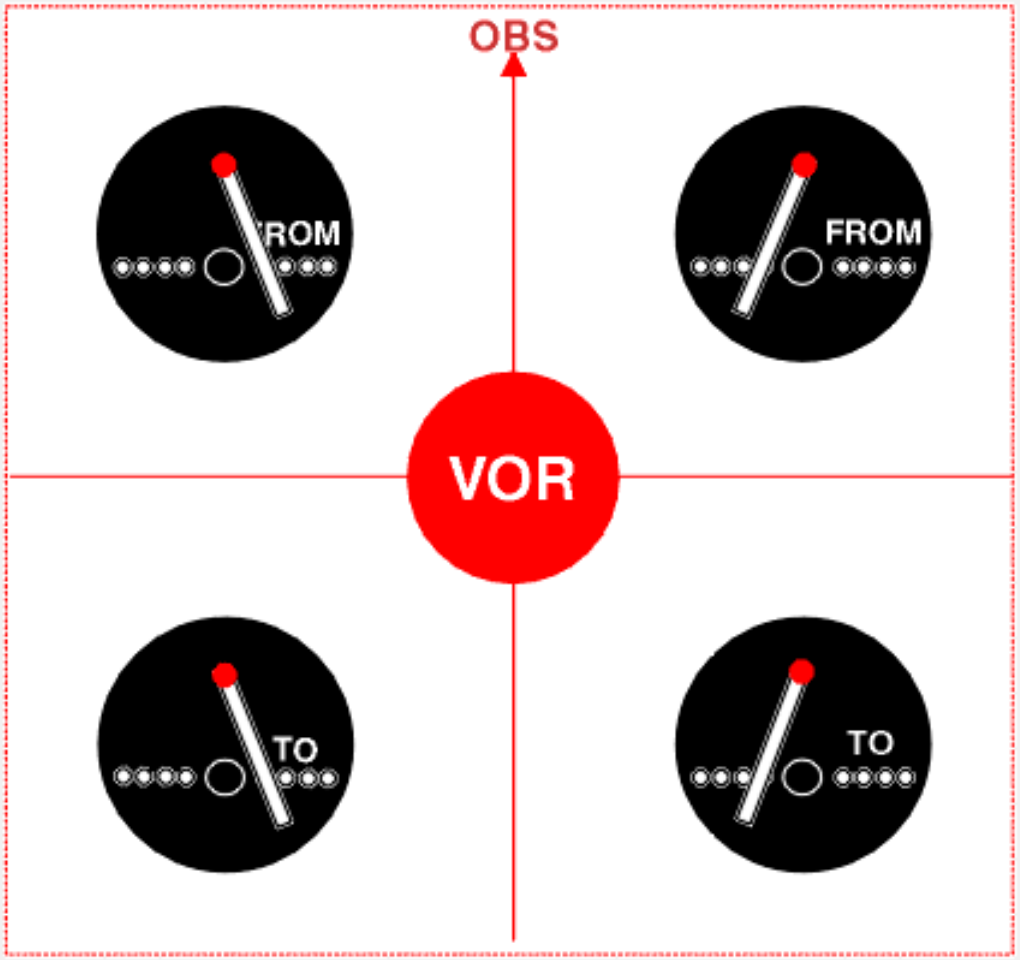


You are now flying away from the VOR; the indicator reads **FROM**

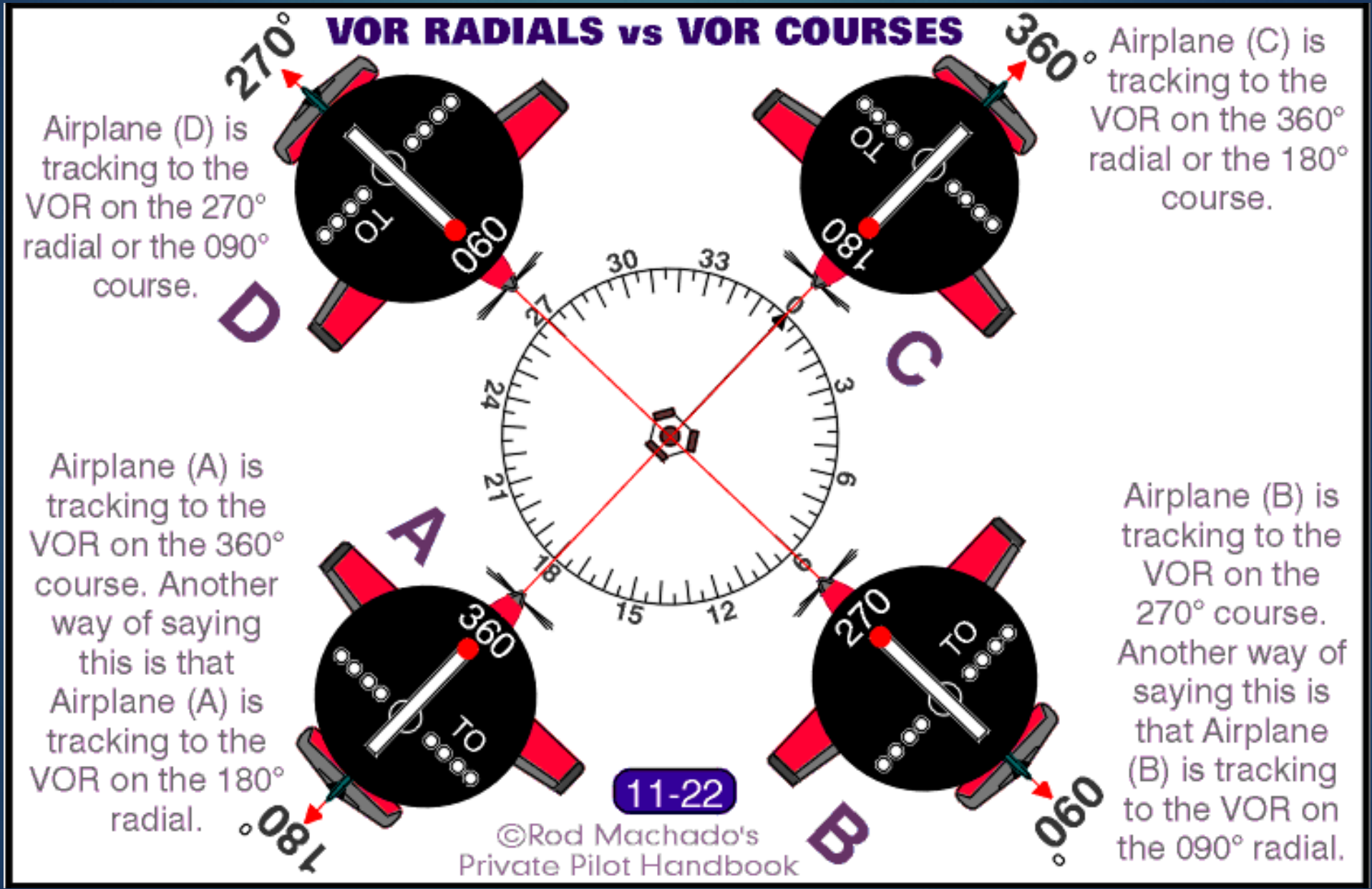


Knowing where you are in relation to the VOR

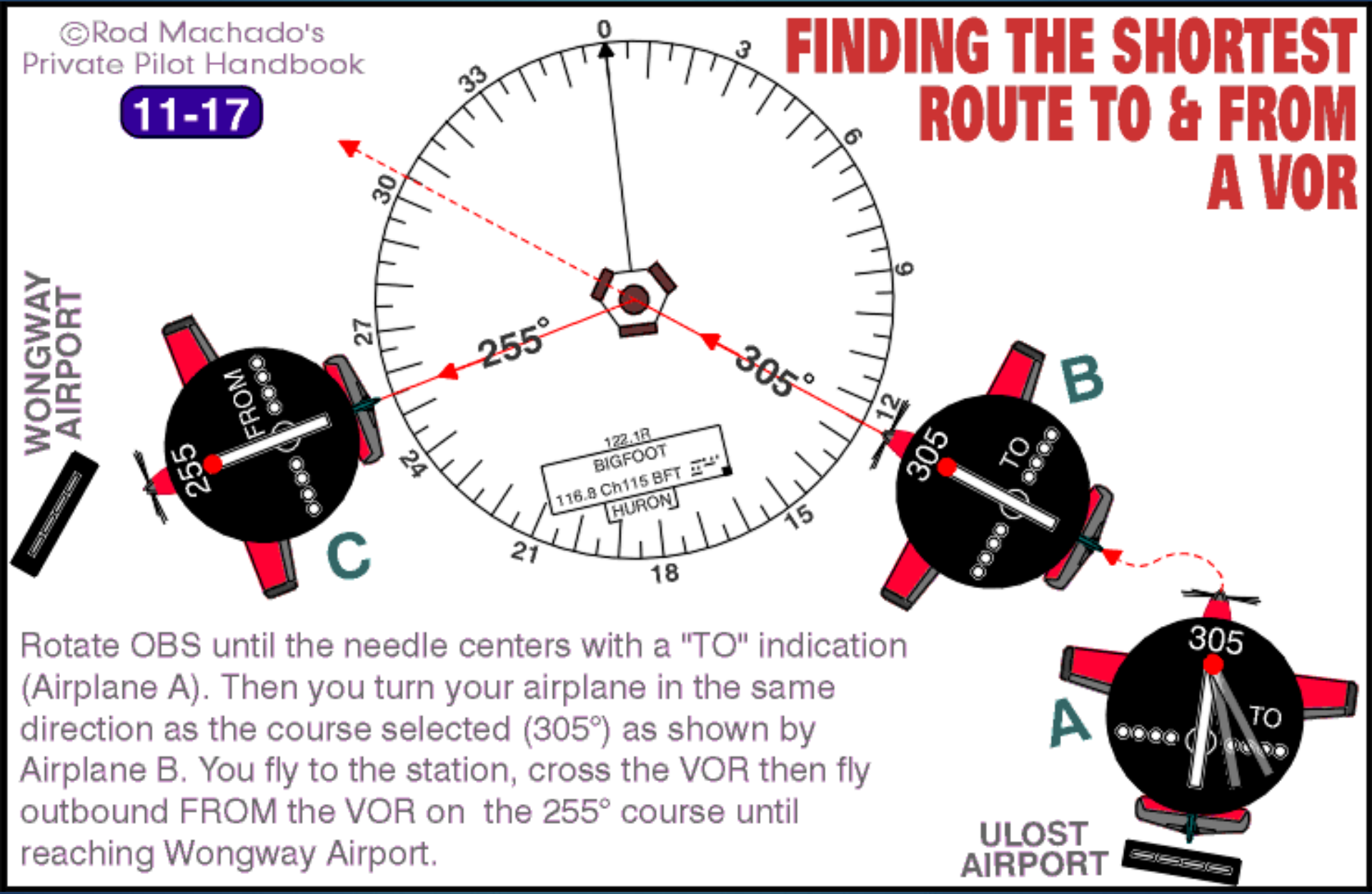
THE VOR ORIENTER



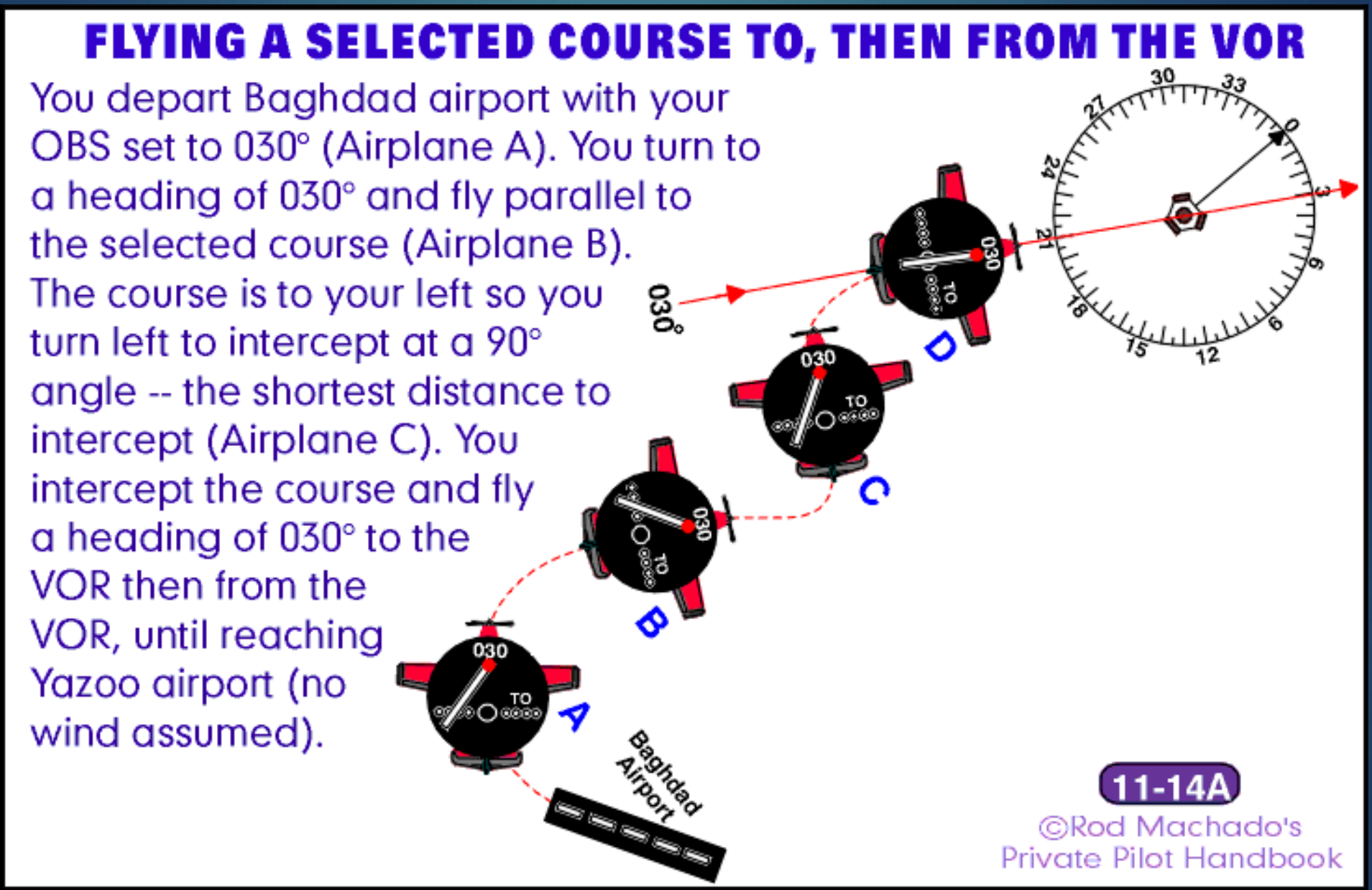
Radials and Courses



Finding the Bigfoot VOR and flying to it



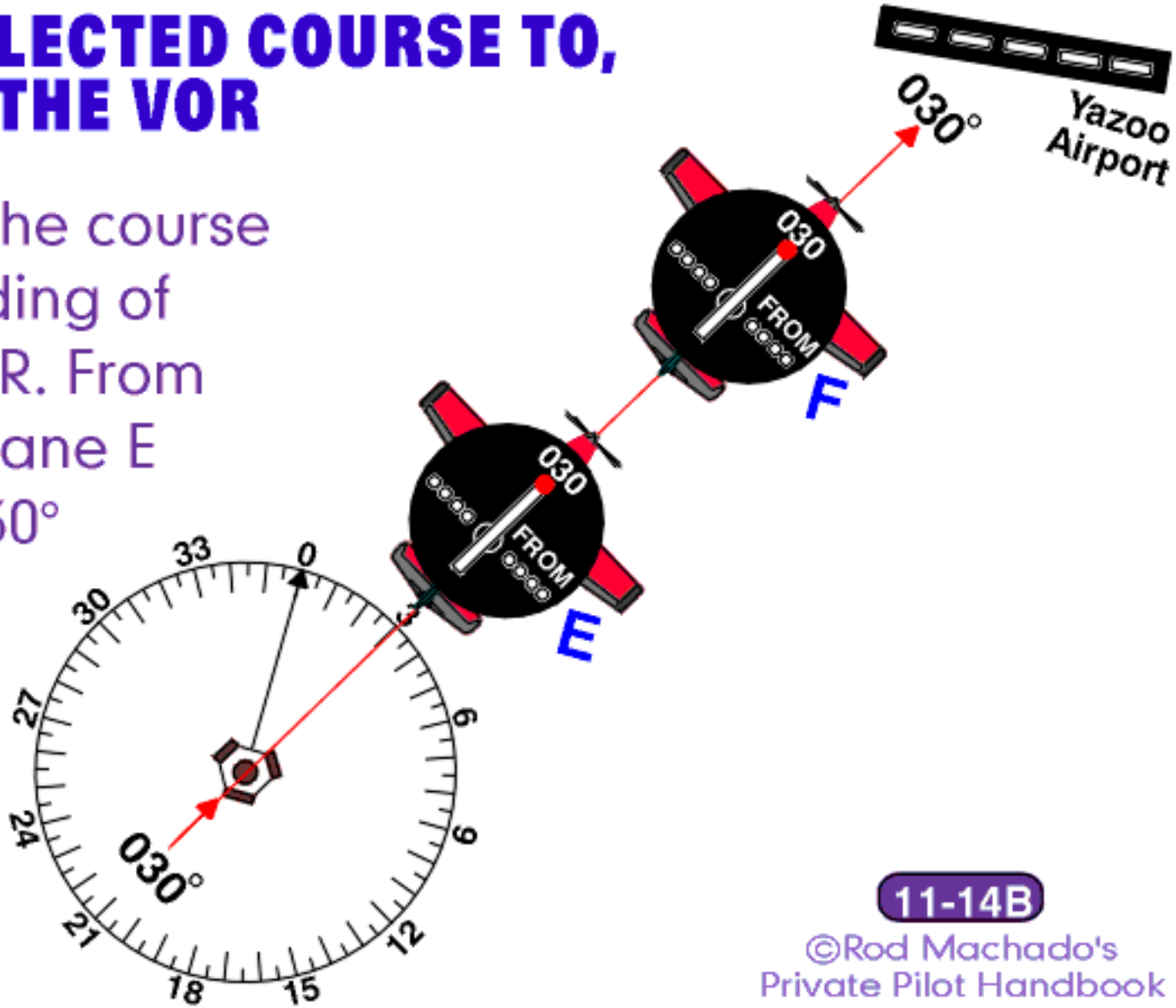
You want to fly from Baghdad to Yazoo. Yazoo is located on the 030° radial of the depicted VOR.



As you pass over the VOR, the indicator flips from **TO** to **FROM**

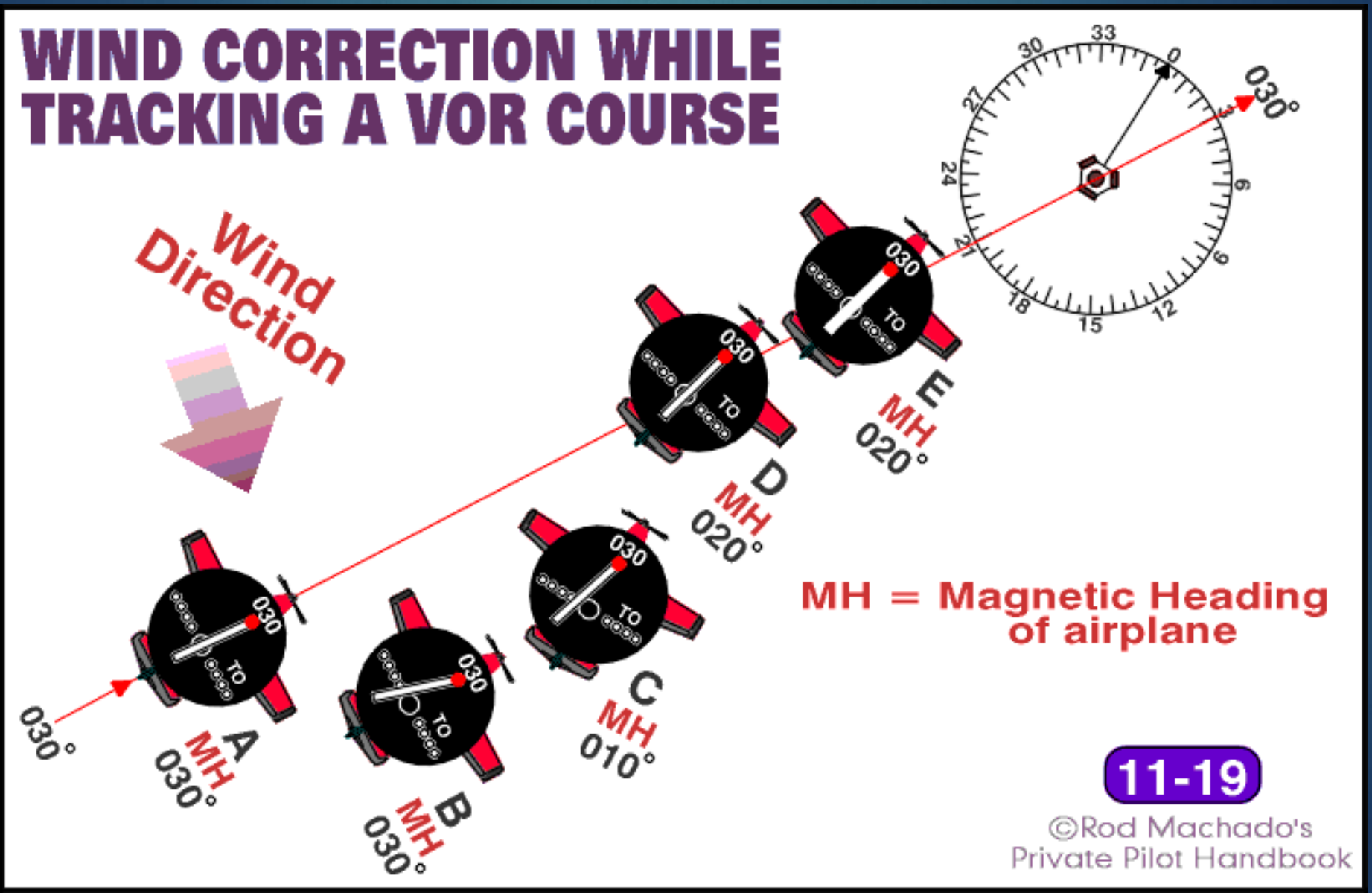
FLYING A SELECTED COURSE TO, THEN FROM THE VOR

You intercept the course and fly a heading of 030° to the VOR. From the VOR (Airplane E & F), you fly 030° until reaching Yazoo airport (no wind assumed).



11-14B

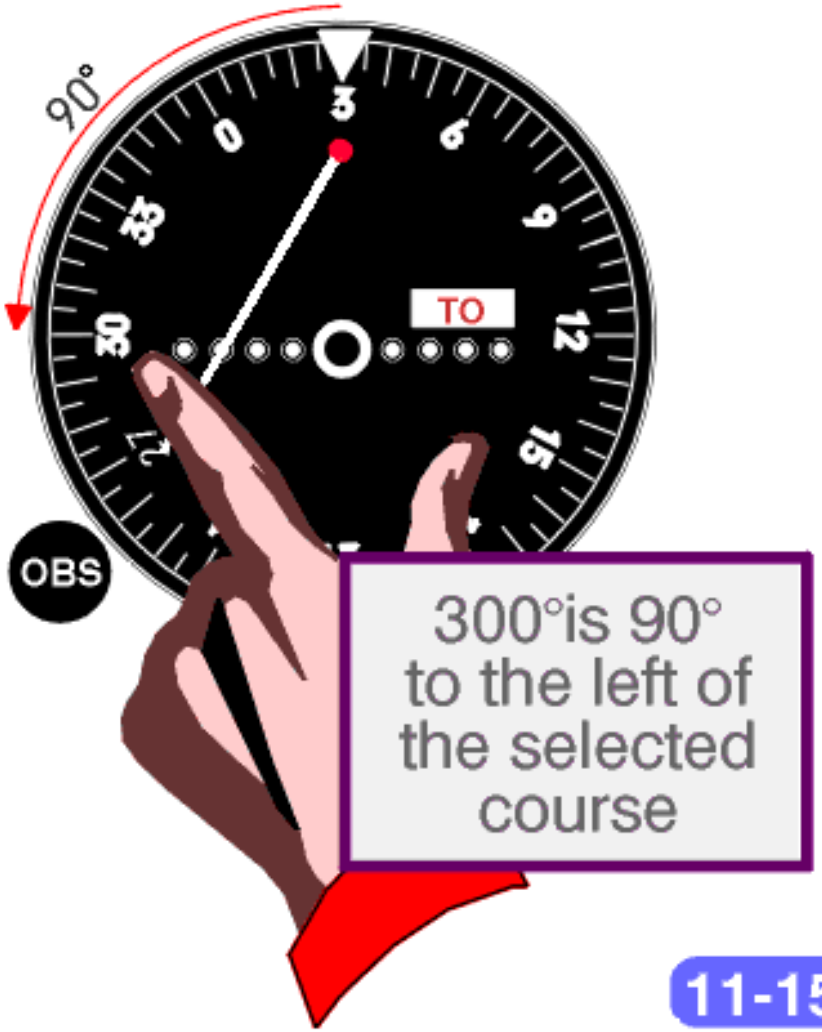
What if there is wind?
(And there's always wind.)



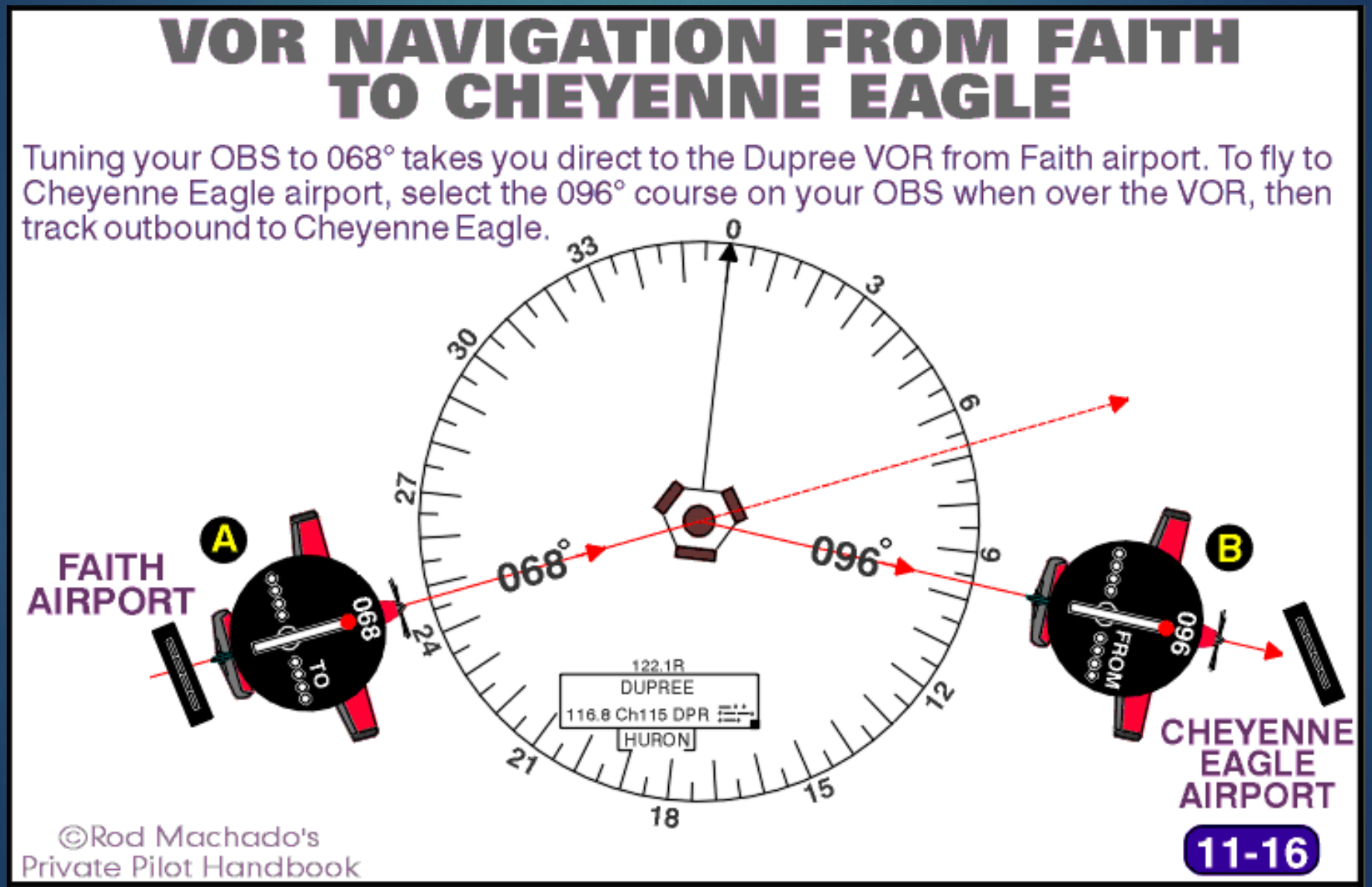
Intercepting a VOR course

VOR COURSE INTERCEPT ANGLE

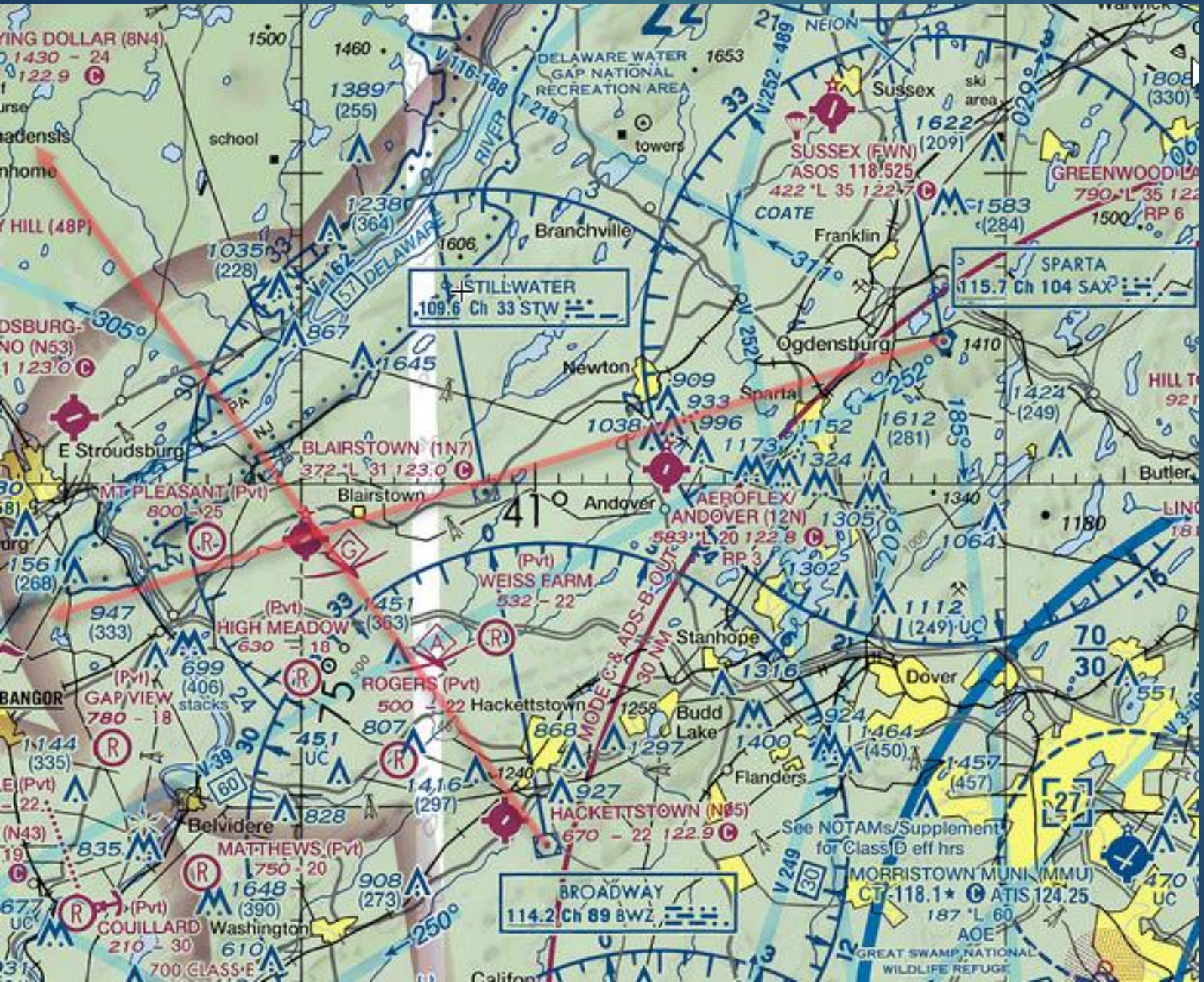
To find an angle to intercept the selected VOR course, look to the left or right of the present course selection on the VOR's compass rose. A heading of 300° provides the shortest distance to intercept the 030° course.



You have determined the angles from Faith to Dupree and from Dupree to Cheyenne with your sectional and a straightedge.



Using two VORs to determine position



Where am I in relation to the VOR?

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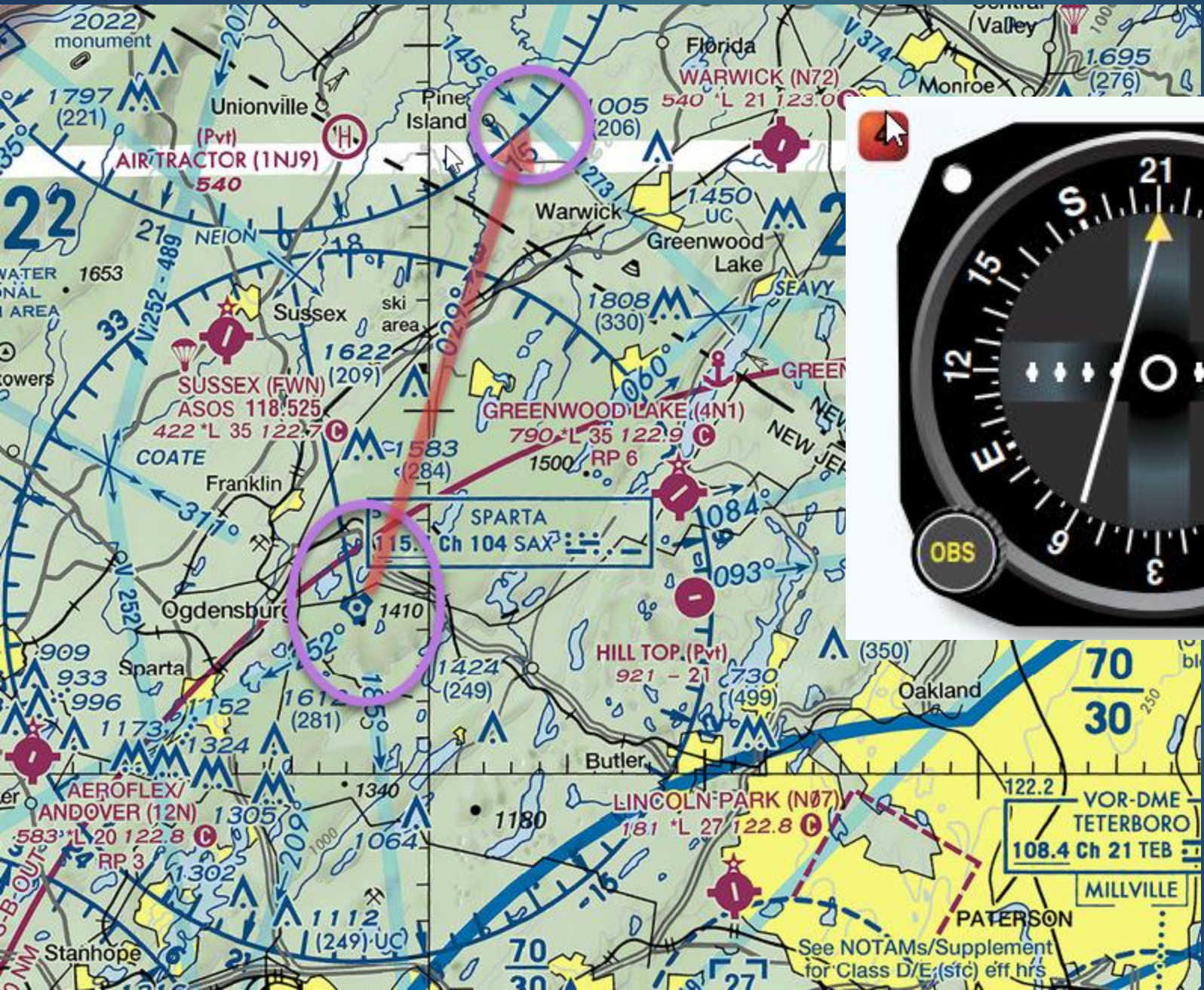
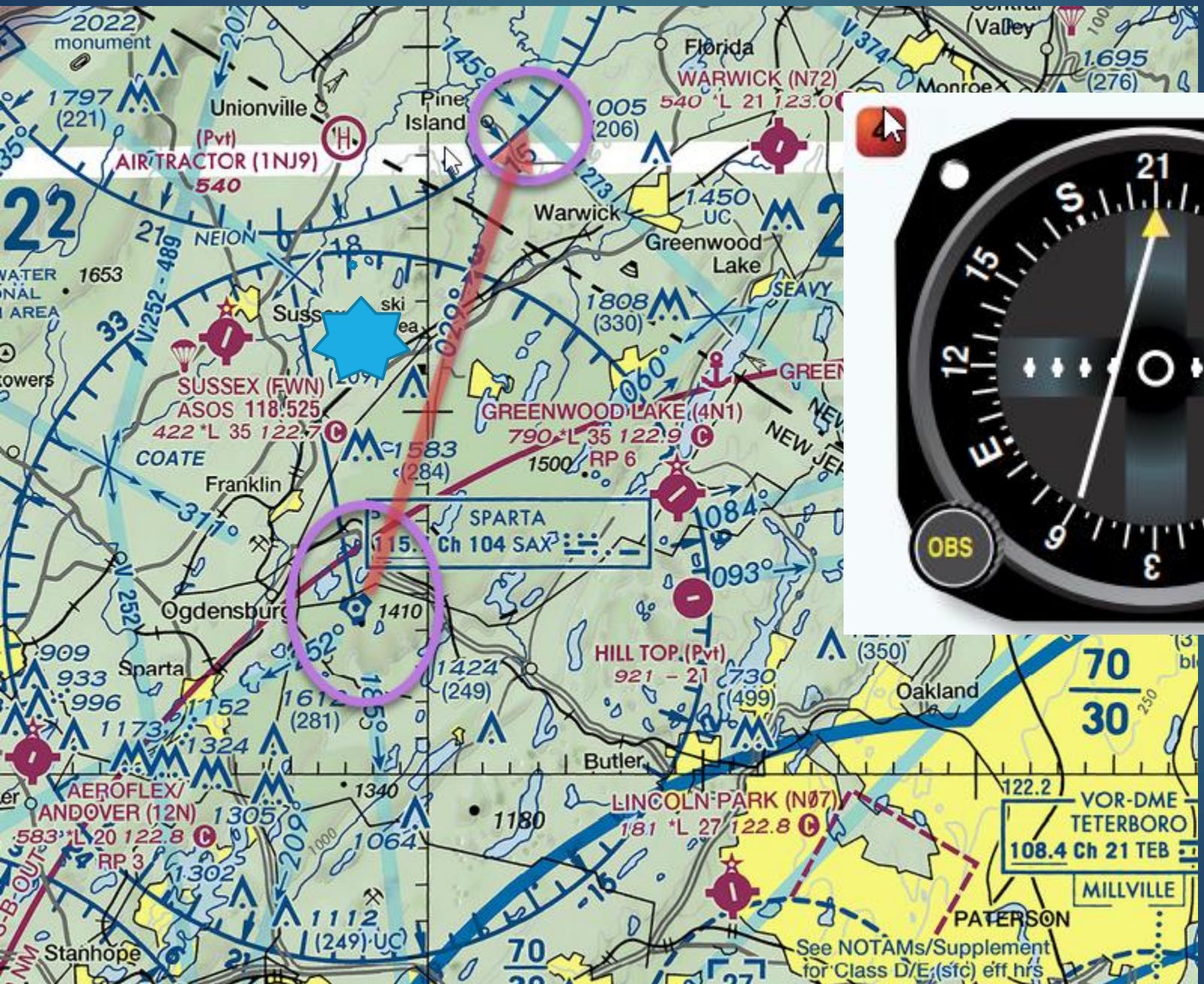
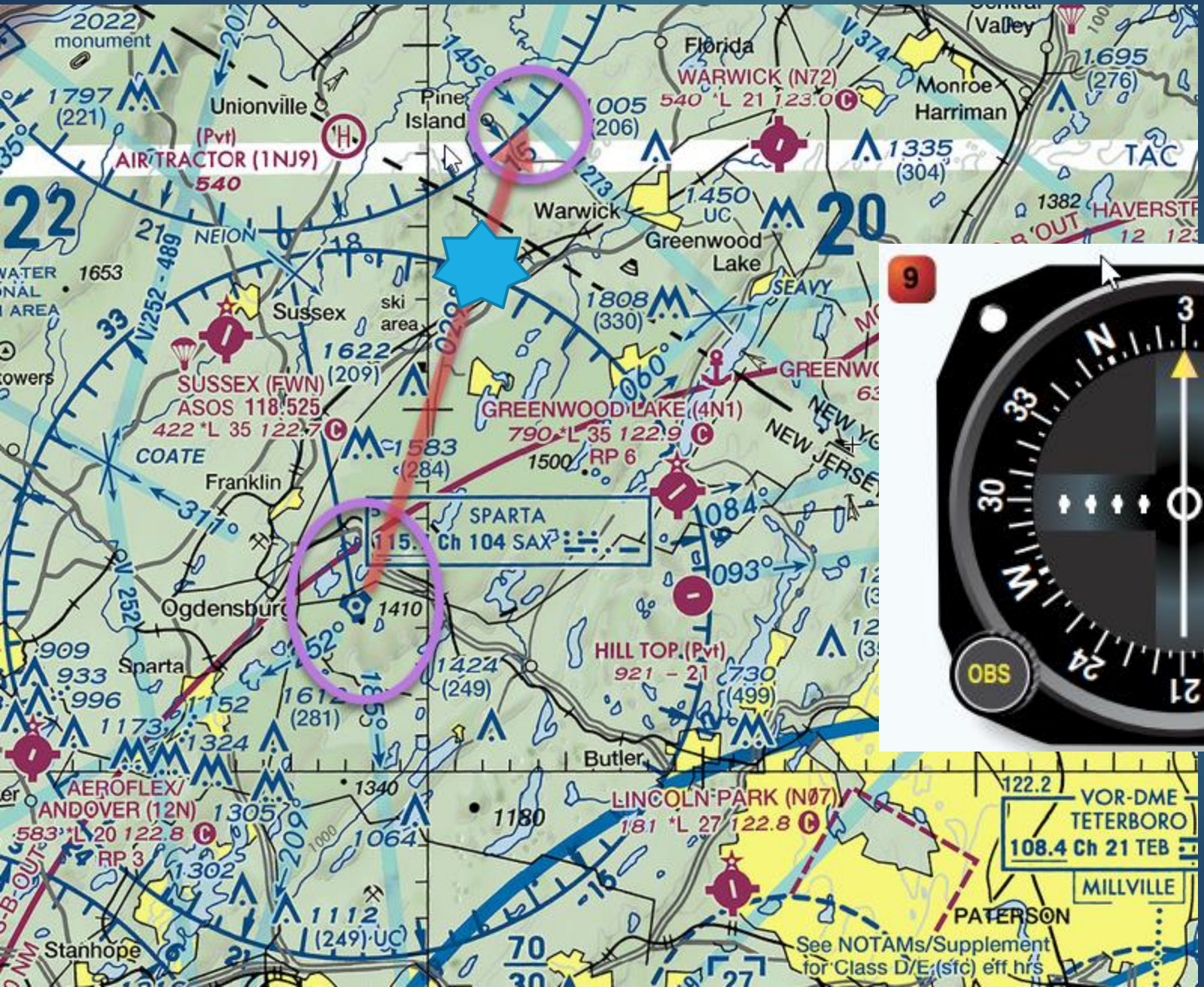


Where am I in relation to the VOR?



Where am I in relation to the VOR?



VOR (Victor) Airways: pathways between VORs

VOR Airways: closer look

VOR Airway Intersections

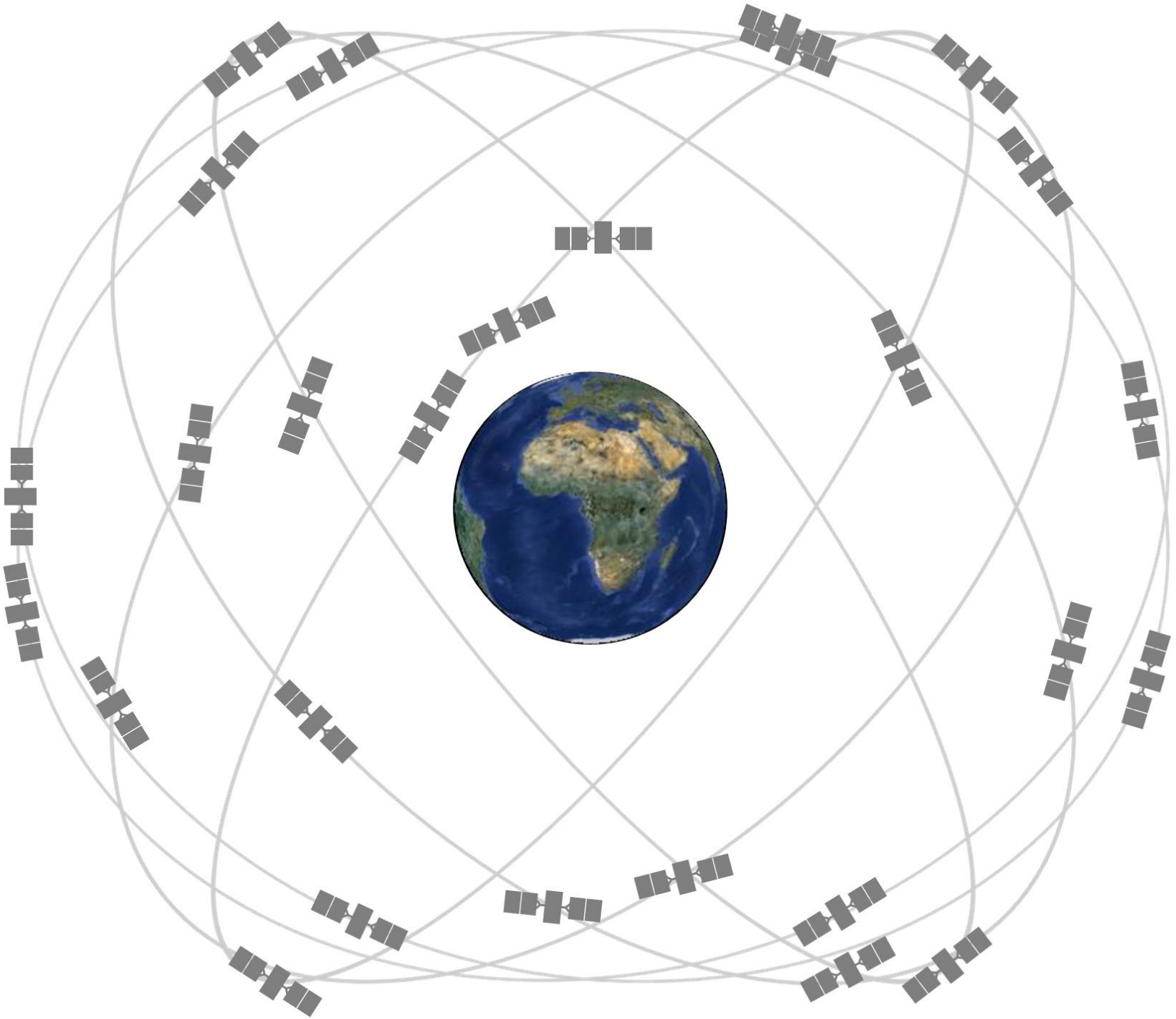
Victor Airways and intersections are very busy places. Use caution when approaching. If climbing or descending on an airway, execute shallow S-turns to improve your traffic scans.

GPS

- Satellite based
- Accurate and reliable for aviation
- Most common NAVAID in use today
- Not subject to line-of-sight limitations
- Are not affected by electrical interference

GPS

- Developed and operated by DOD
- Civilian interface managed by USCG
- VFR pilots need to understand limitations of equipment in use



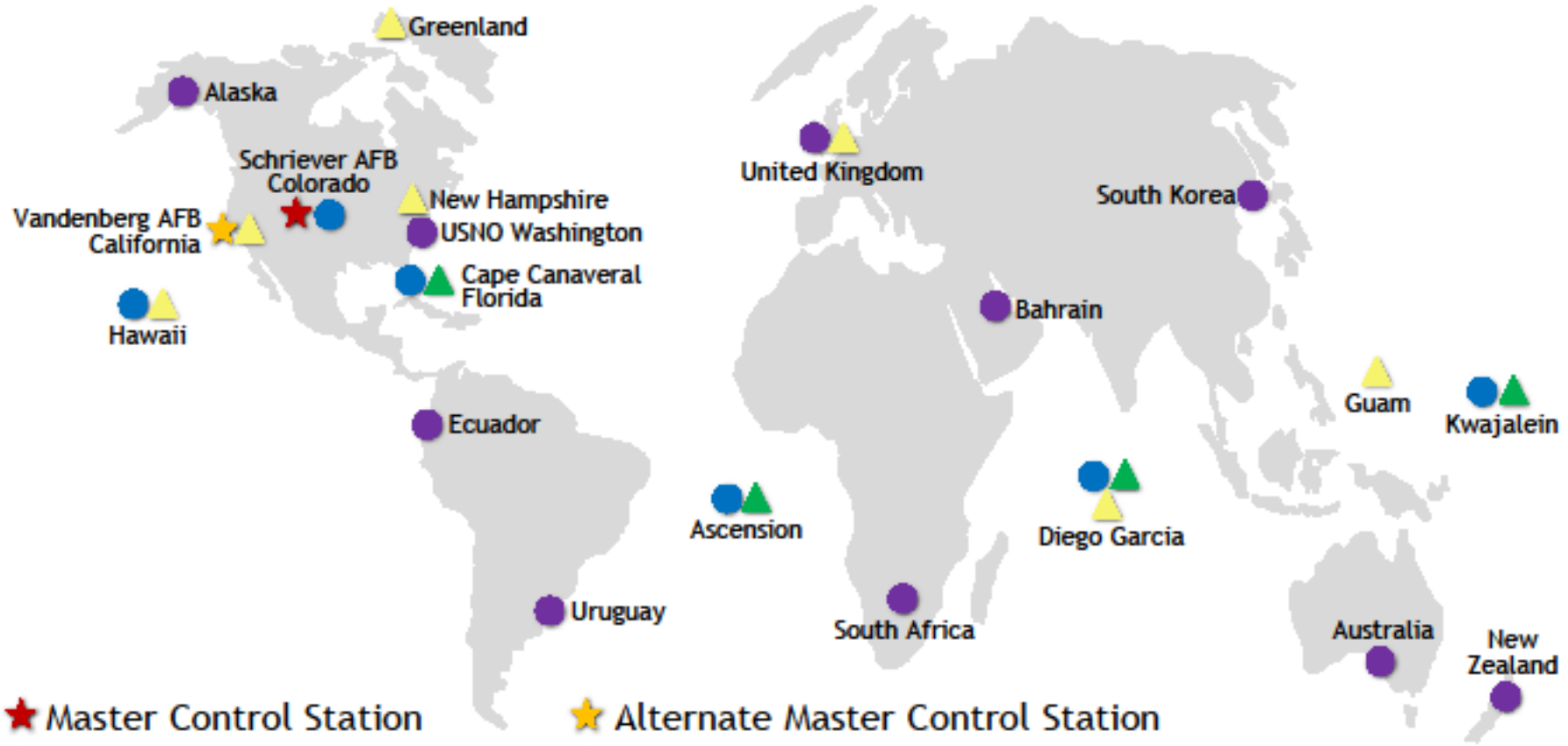
GPS Space Component

- Original Constellation Design
  - Medium Earth Orbit (MEO)~12,550 mi
  - 6 equally spaced orbital planes
  - 4 baseline "slots" per plane
- Current Coverage
  - 24 baseline satellites + 7 "expandables"
  - At least 4 satellites visible from any position on Earth's surface

GPS Satellite Constellation

- Orbital period = 0.5 sideral day = 11:58 hours
- Nearly circular orbits
- Equally spaced around equator

GPS Control Segment



Updated May 2017

GPS Control Component

- Global network of ground facilities that
  - Track GPS satellites
  - Monitor transmissions
  - Perform analyses
  - Transmit commands and data to constellation

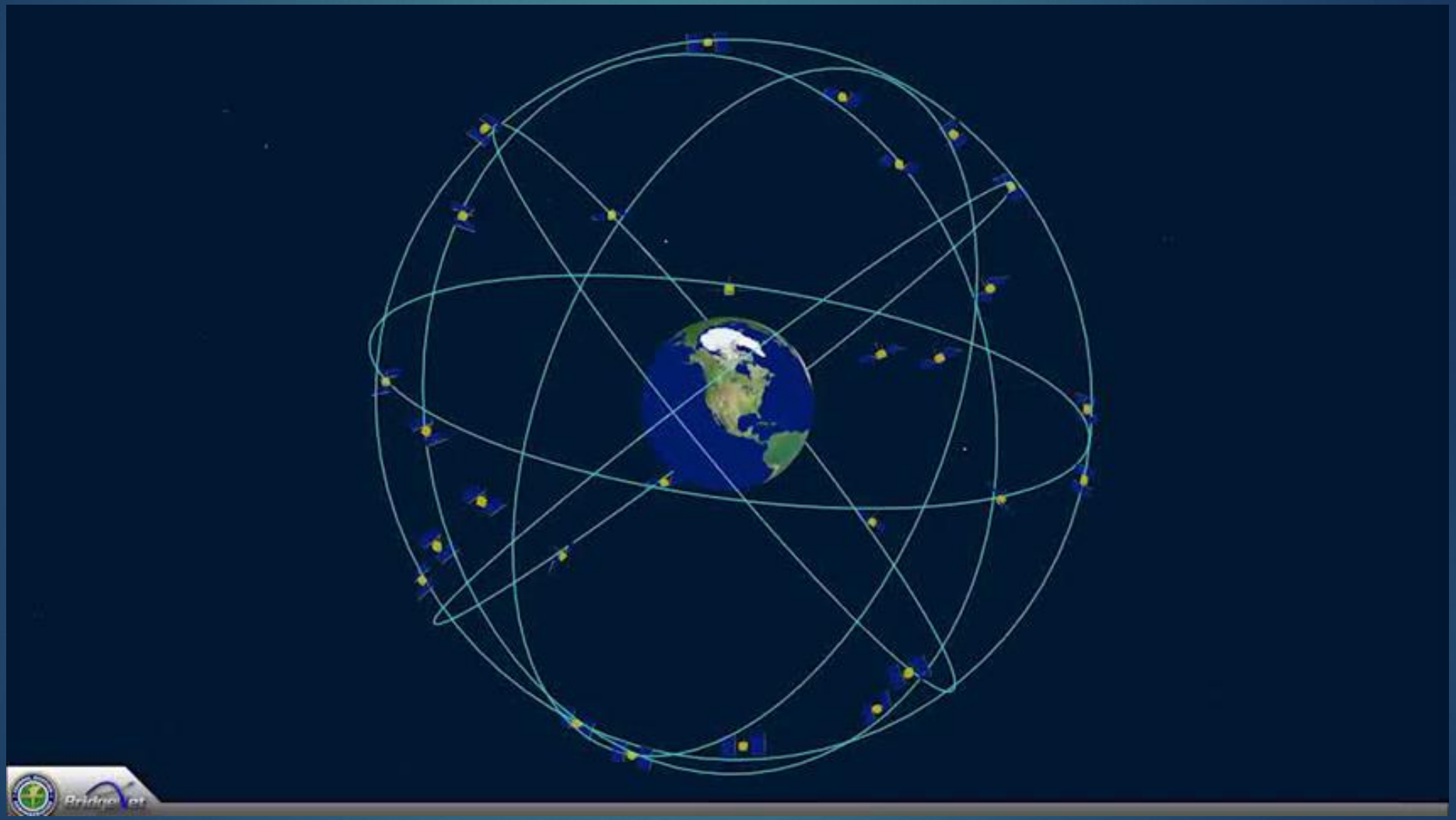
How GPS Works

- Each of the 31 satellites emits a signal that is picked up by GPS receivers
- GPS satellites carry atomic clocks that insert extremely accurate timestamps into the broadcast signal
- The receiver uses the time difference when the signal was broadcast and received to compute the distance from the receiver to the satellite.
- With information about the ranges to three satellites and the location of the satellite when the signal was sent, the receiver can compute its own three-dimensional position.

How GPS Works

- By taking a measurement from a fourth satellite, the receiver also knows the exact time without the need to carry its own synchronized atomic clock
- Thus, the receiver uses four satellites to compute latitude, longitude, altitude, and time
- Adding a fifth satellite allows measurement of signal integrity (Receiver Autonomous Integrity Monitoring, or RAIM). This is important in safety-critical applications such as IFR-certified GPS systems

GPS Animation



RAIM Capability

- IFR-certificated GPS receivers include an alert mode in case minimum satellite connectivity or signal quality is degraded
- Panel-mounted GPS units in VFR aircraft and handheld units may not provide RAIM alerting

RAIM Capability

- A minimum of 3 satellites in view is required for 2-dimensional positioning; 4 satellites for 3-dimensional
- At least 1 additional satellite is required to perform RAIM checks
- Five satellites required to detect an integrity anomaly
- An additional satellite (so we're now up to 6!) is required to isolate which satellite is faulty and remove it from the navigation solution

GPS Databases

- Usually update-able
- Must be maintained
- If outdated, can lead to embarrassing and potentially expensive pilot errors

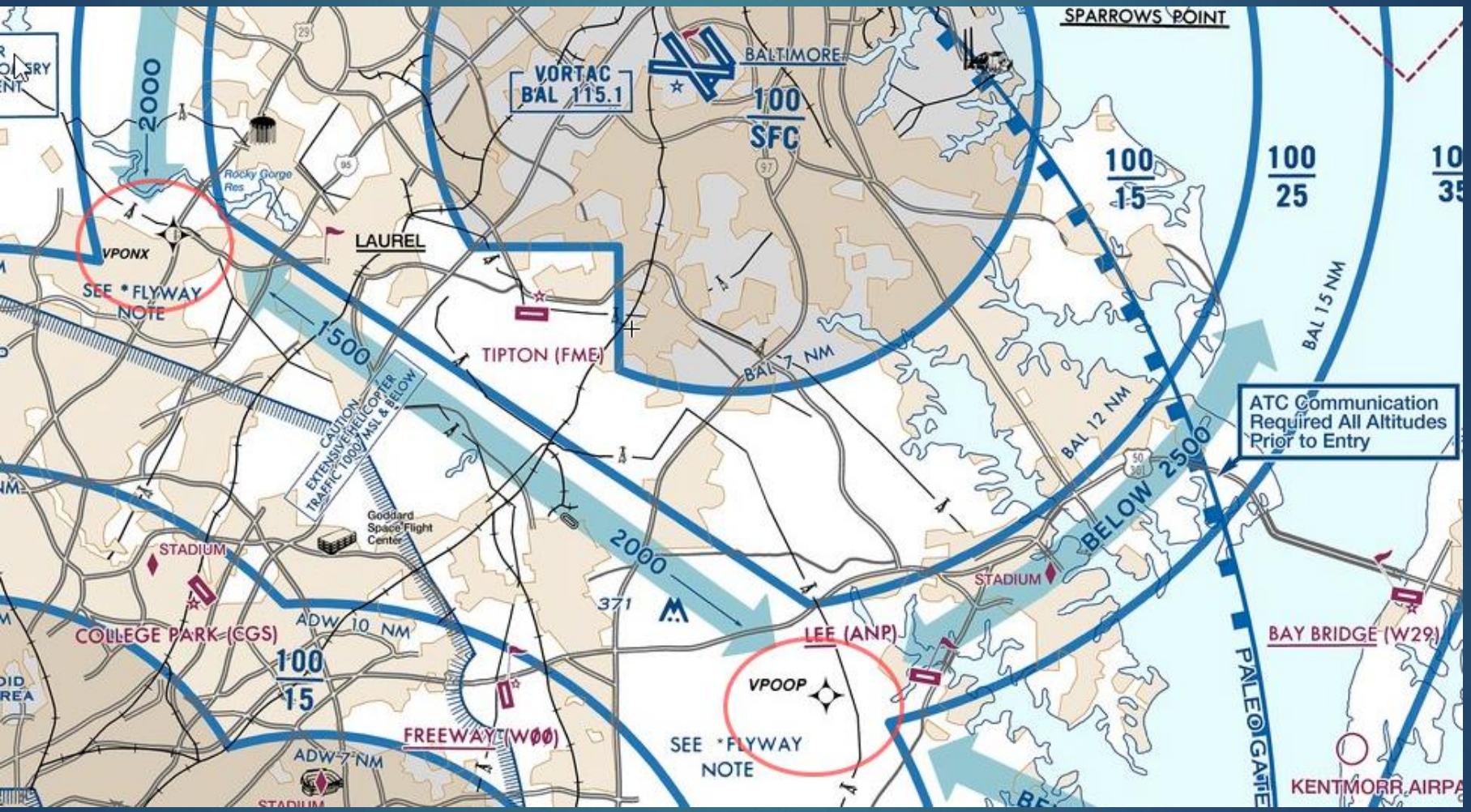
GPS Checklist

- Check to see if unit has RAIM capability. If it does not, be suspicious of a displayed GPS position if it does not agree with other navigation evidence
- Check currency of database. If expired, update if possible; if not, do not rely on moving map displays for any critical navigation decisions
- Named waypoints may no longer exist or may have moved since the last update
- Enter any user-defined waypoints prior to flight

VFR Waypoints

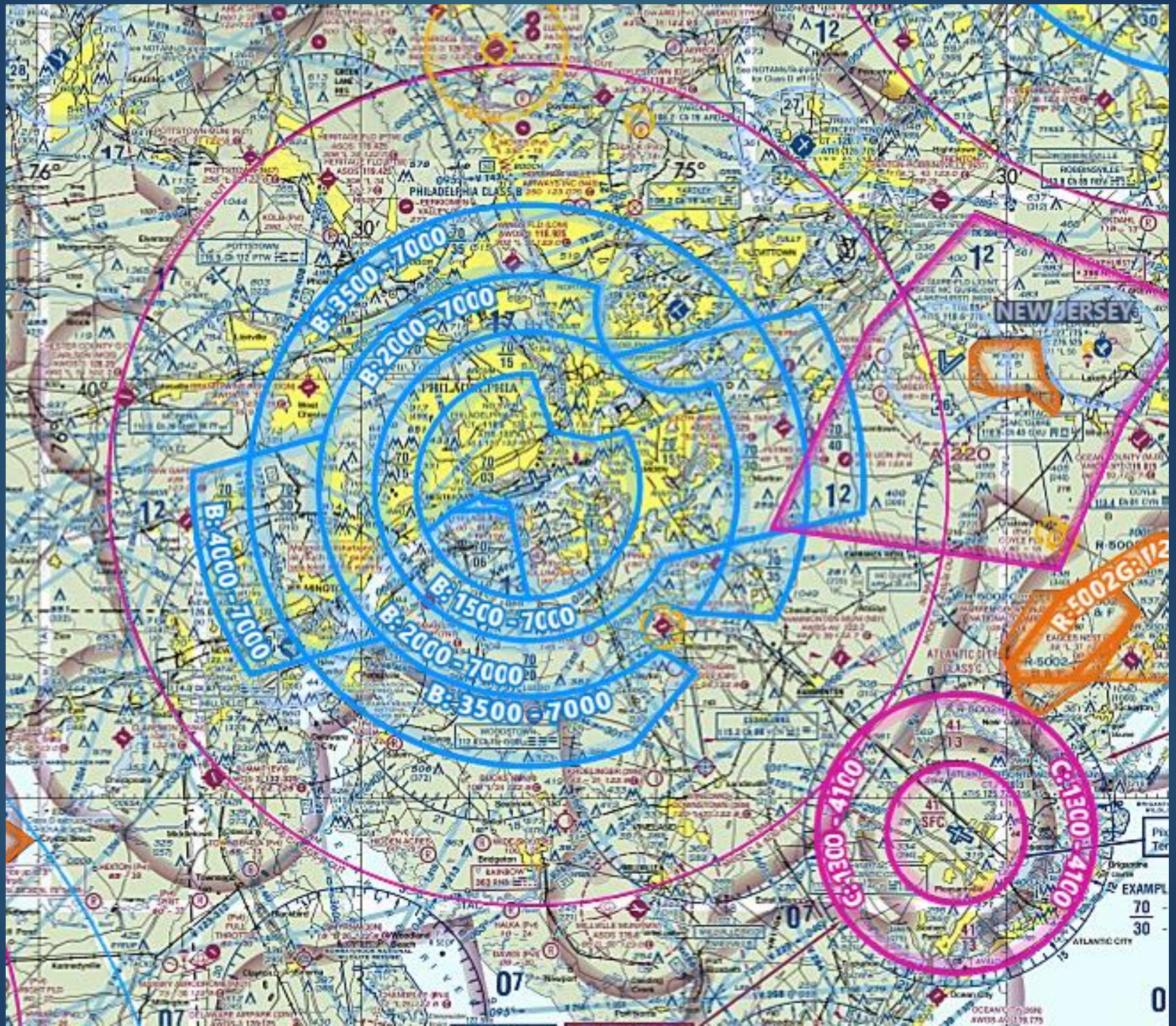
- Supplementary tool to aid VFR pilots
  - Nav aids for pilots unfamiliar with an area
  - Waypoint definition of existing visual waypoints
  - Enhanced navigation in/around Class B and C
  - Assists around Special Use Airspace
- Unlike most GPS waypoints, these are charted on VFR sectionals, TACs, and VFR Flyway charts
- Five letters beginning with “VP”

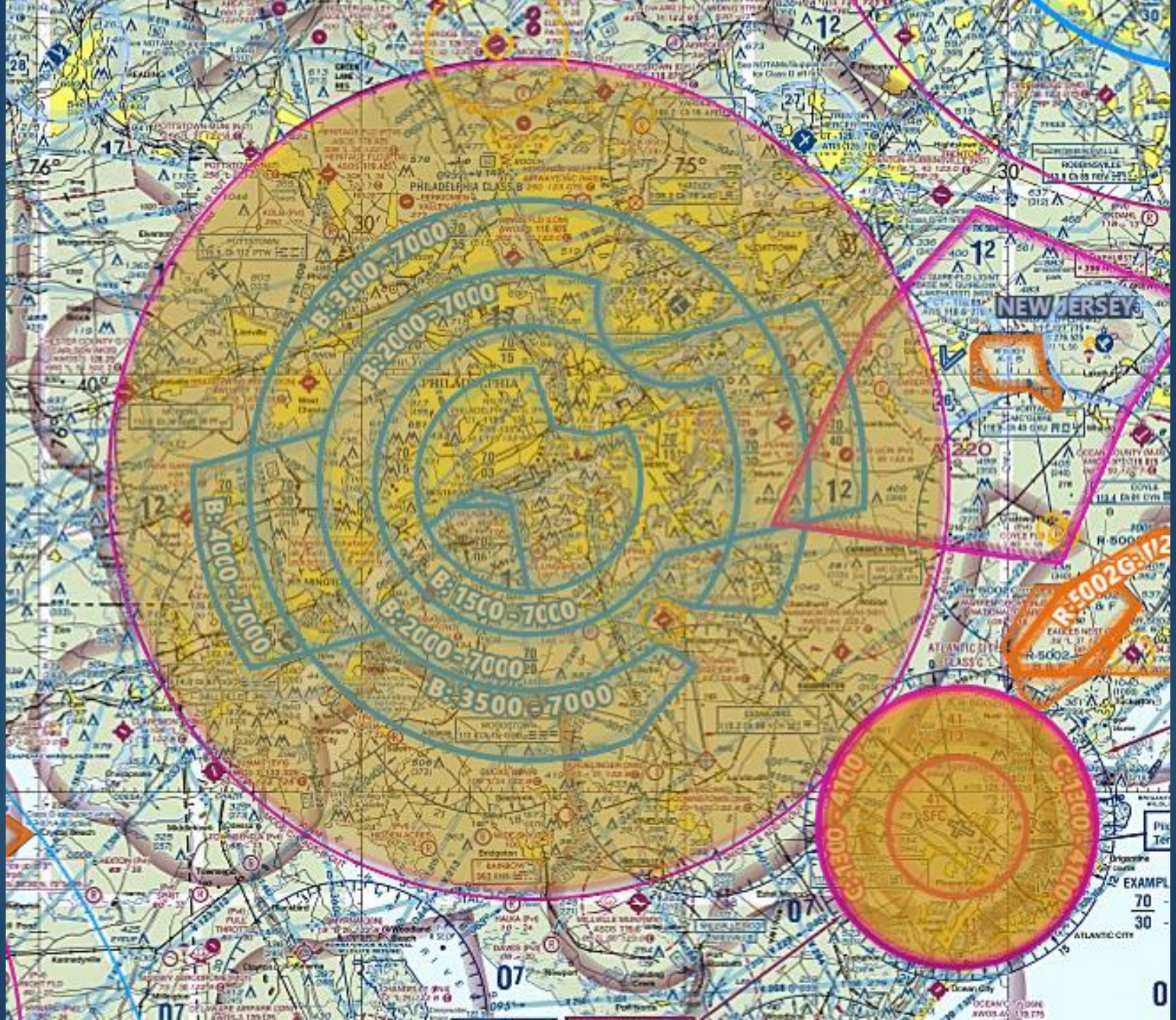
W29's Favorite VFR Waypoints



Transponders

- Aviation transponders are transmitters that send a signal in response to a request ("interrogation") from an ATC ground station
- The type of signal sent depends on the degree of sophistication of the transponder unit
  - A: four digit squawk code: identity + position
  - C: A + pressure altitude: identity + position + altitude
  - S: C + additional data: identity + position + altitude + speed + heading
- MODE C is the minimum transponder requirement for flight in Bravo, Charlie, and "Mode C Veil"


B:3500 - 7000
B:2000 - 7000
B:4000 - 7000
B:1500 - 7000
B:2000 - 7000
B:3500 - 7000
C:1300 - 4100
C:1300 - 4100
PHILADELPHIA CLASS B
NEW JERSEY
R-5002
R-5002G:
ATLANTIC CITY CLASS C
SFC
EXAMPL
ATLANTIC CITY


B:3500-7000
B:2000-7000
B:1500-7000
B:2000-7000
B:3500-7000
B:2000-7000
PHILADELPHIA CLASS B
NEW JERSEY
R-5002
R-5002G
ATLANTIC CITY CLASS C
C:1500-4100
C:1500-4100

Transponder Models

Squawk Codes

- 4-digit octal numeric system: numbers range 0 – 7
- Ordinary VFR = "1200"
- ATC assigns a code when opening a flight plan
- Special transponder codes:
  - 7500 = Hijacking
    - "Seven Five I've Been Taken Alive"
  - 7600 = Communication Failure
    - "Seven Six Need a Radio Fix"
  - 7700 = Mayday
    - "Seven Seven I'm Going to Heaven"
    - This code is also used to acknowledge you are complying if intercepted by military aircraft

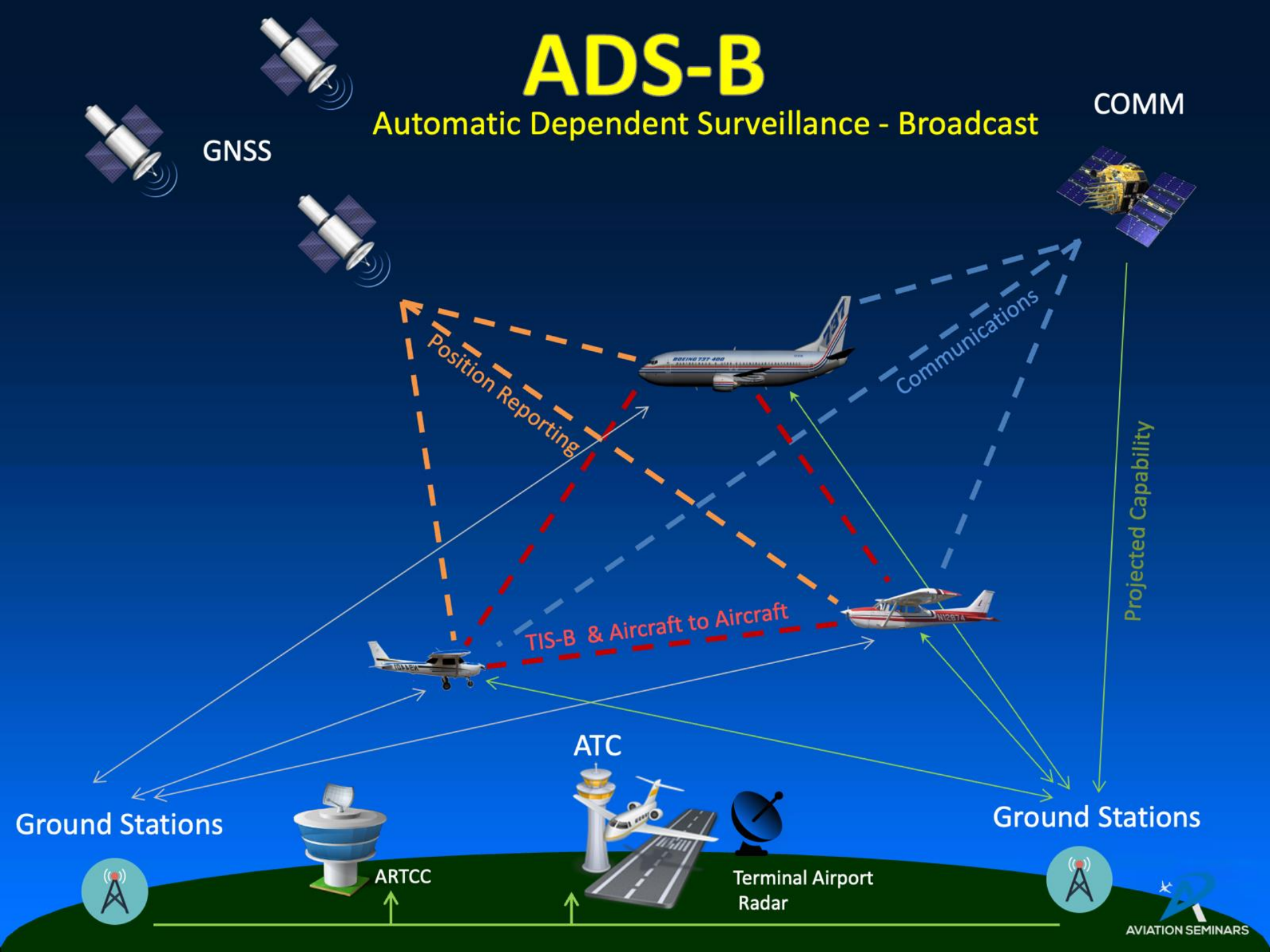
Fun Fact: Why Squawk Code?

- Transponder technology originated with the WWII era "Identification Friend or Foe" system that was used by the Allies to distinguish their own aircraft from the enemy
- Great Britain's IFF system was code-named "PARROT"
- When British bombers returned from runs over Europe, the radar operators would request "***Squawk Your Parrot***"
- (The corresponding order to silence the transponder was "***Strangle Your Parrot***")

ADS-B

(Automatic Dependent Surveillance Broadcast)

- **Automatic:** properly-equipped aircraft automatically report their position, without need for a radar interrogation
- **Dependent:** ADS-B depends on aircraft having an approved GPS on board and an ADS-B Out transmitter
- **Surveillance:** it is a surveillance technology that allows ATC to watch airplanes move around (like radar)
- **Broadcast:** aircraft broadcast their position information to airplanes and ATC


ADS-B
Automatic Dependent Surveillance - Broadcast
GNSS
COMM
Position Reporting
Communications
Projected Capability
TIS-B & Aircraft to Aircraft
ATC
Ground Stations
Ground Stations
ARTCC
Terminal Airport
Radar
AVIATION SEMINARS

ADS-B Out Requirements