Area of Operation **II** - Task **L**

Navigation Systems and Radar Services

westflying

Key References:
- Pilot's Handbook of Aeronautical Knowledge
- Airplane Flying Handbook
- Instrument Flying Handbook, AIM

Content

1. Introduction

- **What**: Learn about different navigation systems in use and types of Radar Services provided by ATC
- **Why**: Particularly during cross-country flights, a pilot can leverage different navigation technology and also expect different levels of radar services from ATC depending on the airspace they are flying into.

- **Types of Navigation System**
  - Ground based: VOR, DME, NDB
  - Satellite based: GNSS (GPS)
- **Radar Services**
  - Safety Alerts
  - Traffic Advisories
  - Vectoring
  - Sequencing
  - Separation

2. NDB (Nondirectional Radio Beacon) AIM 1-1-2

- **What**
  - Points to a station (being decommissioned)
  - Operates between 190-535 KHz and transmit radio energy in all directions
  - Volumes (radial dist.): HH (75nm), H (50nm), MH (25nm), Compass loc. (15nm)
- **Components**
  - NDB (Ground), ADF (Aircraft)
    - ✓ *ADF = Automatic Direction Finder (2 antennas, Receiver and Instrument)*
    - ✓ *ADF operates between 530-1700 kHz and can be tuned to AM stations*
  - Limitations: subject to interference
- **Instrument**
  - Fixed Card (top)
  - Movable Card (middle)
  - RMI (Radio Mag Indicator, bottom)

Relative Bearing
135º

Magnetic Hdg
45º
+
Relative Bearing
135º
=
Mag Bearing
180º

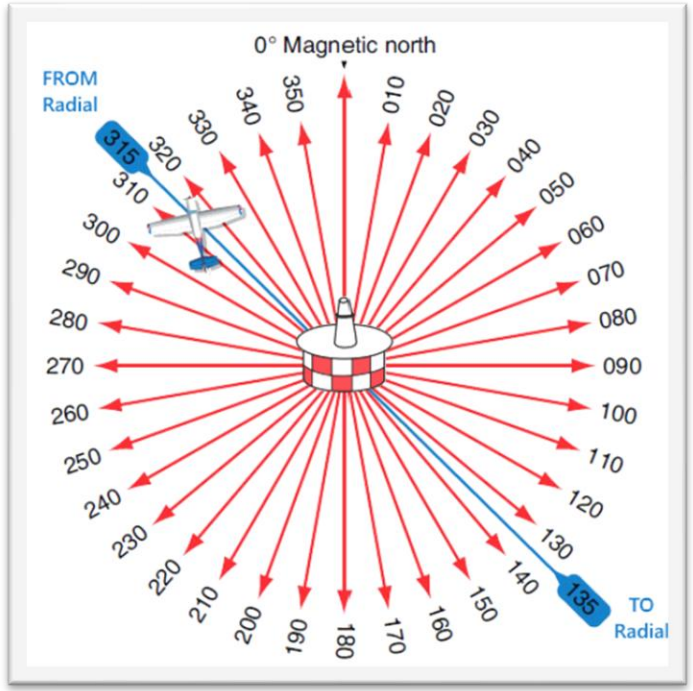
Automatically update hdg (Fluxgate)

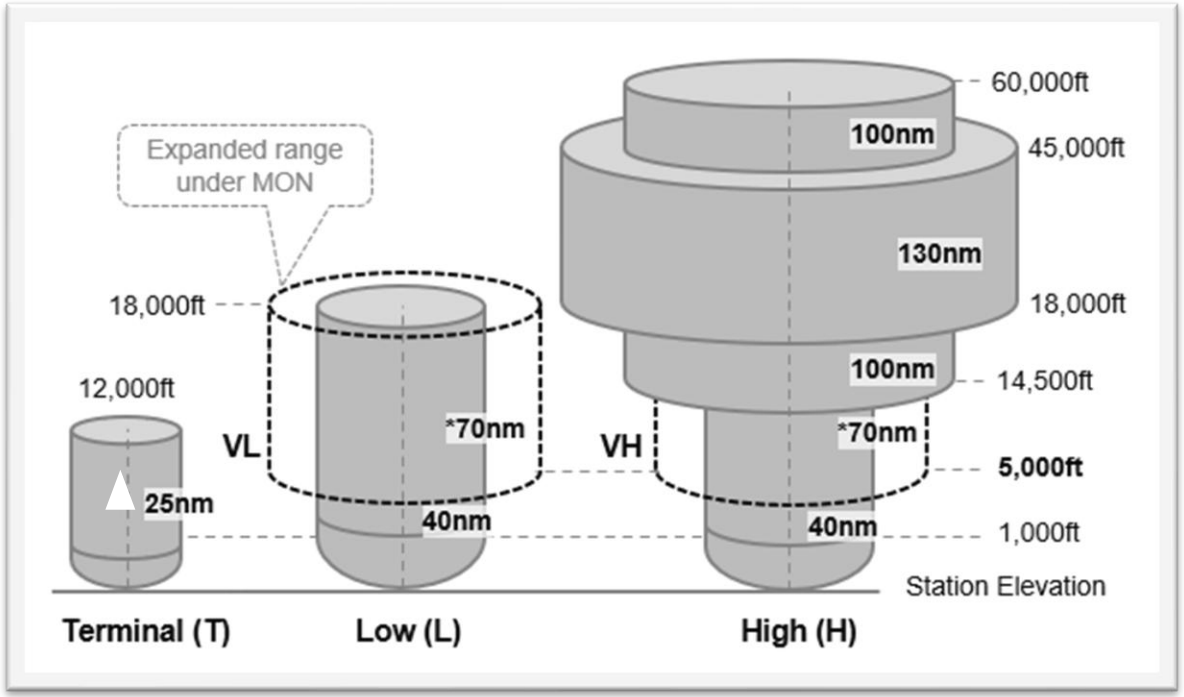
3. VOR (VHF Omni-Directional Range)

AIM 1-1-3

What:

- Allow the pilot to fly magnetic courses or identify radials by using stations as reference (radio signal emitted from the ground)
- 3 Classes: Terminal, Low, High ➔ Based on Service Volumes
- Different variations: VOR, VOR/DME (VOR+DME), VORTAC (VOR + TACAN)



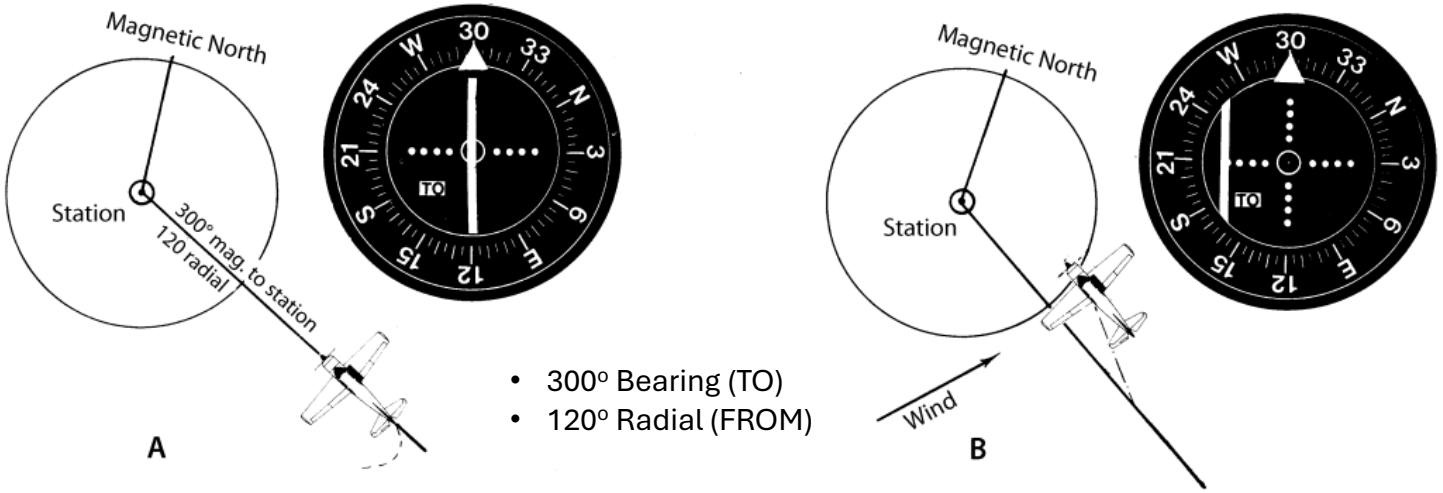


Service Volumes expanded under MON

3. VOR (VHF Omni-Directional Range) AIM 1-1-3

How it Works

- Station: emits a rotating signal (30 times/sec) + ref signal when crossing 360 radial
- Aircraft Receiver: calculates difference between both signals to find its radial
- 108.0 to 117.95 MHz *(excl LOC frequencies of 108.10-111.95 w/ odd tents)*
- Limitations: Line-of-Sight, Cone of confusion, Reverse Sensing
- Minimum Operational Network (MON): VOR within 100nm (>5000ft)
  - ✓ *Reduction from 896 to 590 VORs, expanding service volumes*



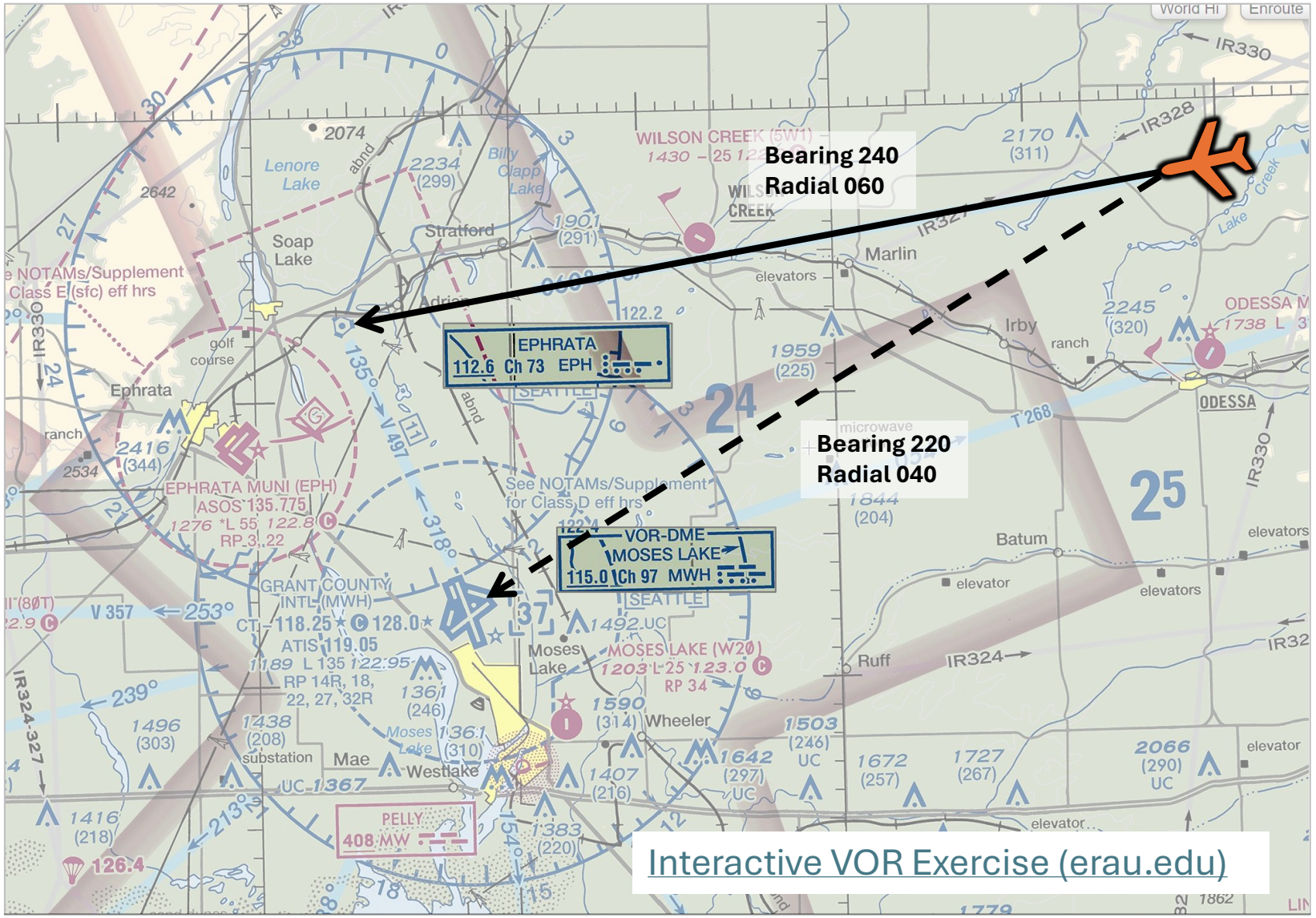
- 300° Bearing (TO)
- 120° Radial (FROM)

VOR Receiver Checks (§91.171)

Every 30 days for IFR Navigation

- VOT (360 From) ➔ ±4°
- Dual VOR ➔ ±4°
- Ground Checkpoint ➔ ±4°
- Repair Station ➔ ±4°
- VOR Airborne Checkpoint ➔ ±6°
- Above landmark within 20nm of a VOR, low altitude ➔ ±6° of selected radial
- Record:
  - ✓ *Date*
  - ✓ *Error*
  - ✓ *Place*
  - ✓ *Signature*

3. VOR (VHF Omni-Directional Range)



[Interactive VOR Exercise (erau.edu)]

Heading

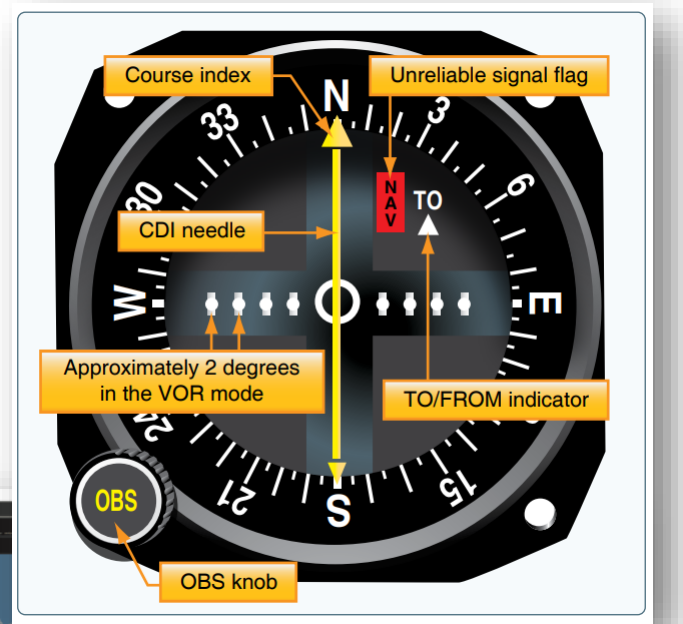
VOR 1
Ephrata Vortac

VOR 2
Moses Lake VOR

3. VOR (VHF Omni-Directional Range)

Steps for VOR Navigation

1. Tune to the VOR frequency and identify it
2. Turn the OBS to determine the bearing you are in (needle centered w/ TO indication)
3. Turn the aircraft until your heading aligns to the VOR course selected
4. If you want to cross the VOR in a different radial, turn the OBS to the desired bearing
5. Turn the airplane to intercept the radial that leads to the desired bearing
6. Wind correction:
    - If drifting, turn 10º into the wind
    - Adjust WCA depending on the results (under/over-shoot)



Avoid reverse sensing

- If flying to the VOR, flag w/ TO
- If flying from the VOR, flag w/ FROM
- *Note: no reverse sensing in the G1000*

Flying heading 030 towards the 240 radial (intercept) and fly bearing 060

4. DME (Distance Measurement Equipment) AIM 1-1-7

What

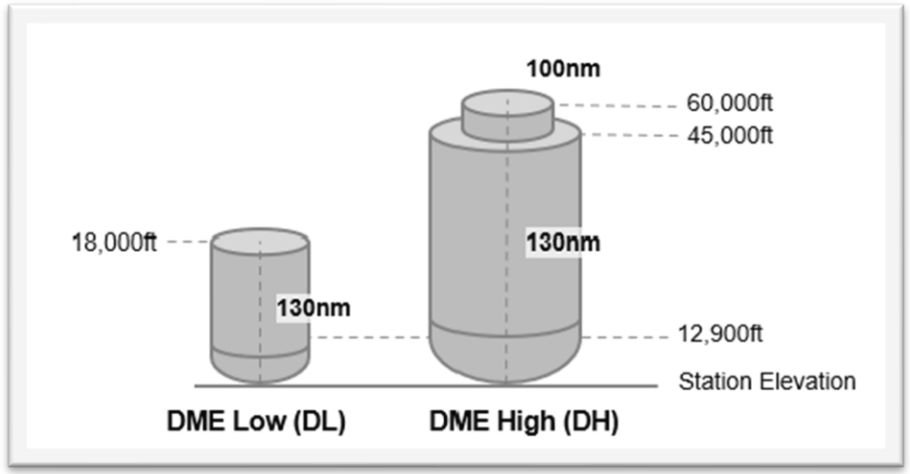
- Provides distance from a station
- 2 classes: Low and High depending on Service Volume

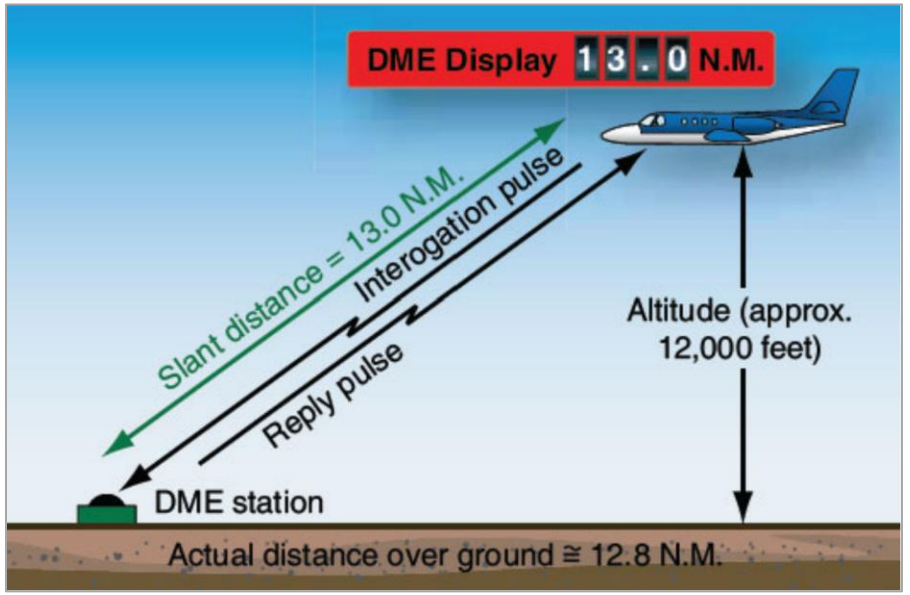
How it Works

- Airplane interrogates, station responds ➔ Receiver calculates distance
- UHF: Operates in the 962-1213 MHz frequencies (paired w/ VOR freq)
- Limitations:
  - Line-of-sight
  - Slant Range
    - ✓ *The higher you are and the closer you are →the higher the error*
    - ✓ *Negligible 1nm horizontal per 1000ft alt*

- DME receiver can be replaced by a RNAV system (G172 doesn't have a DME)
- DME receiver (or RNAV) is required above FY240 (FAR 91.205)

Service Volumes expanded under MON

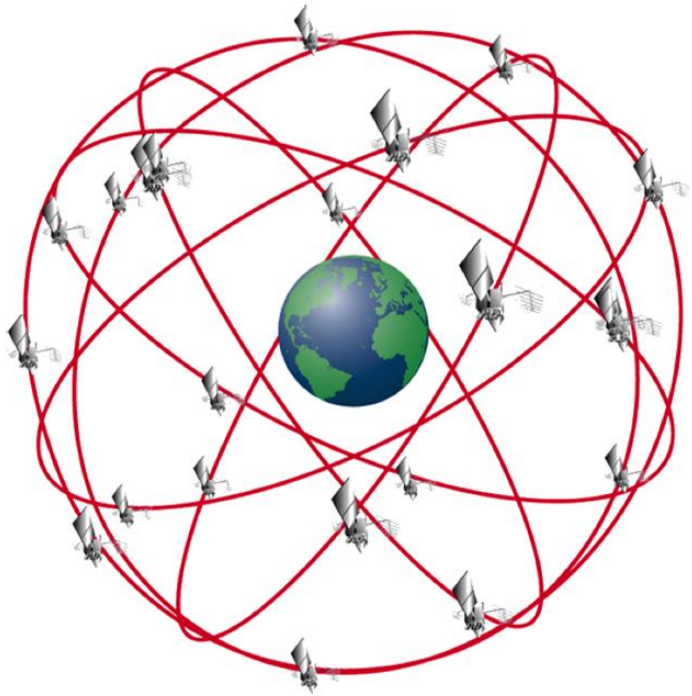


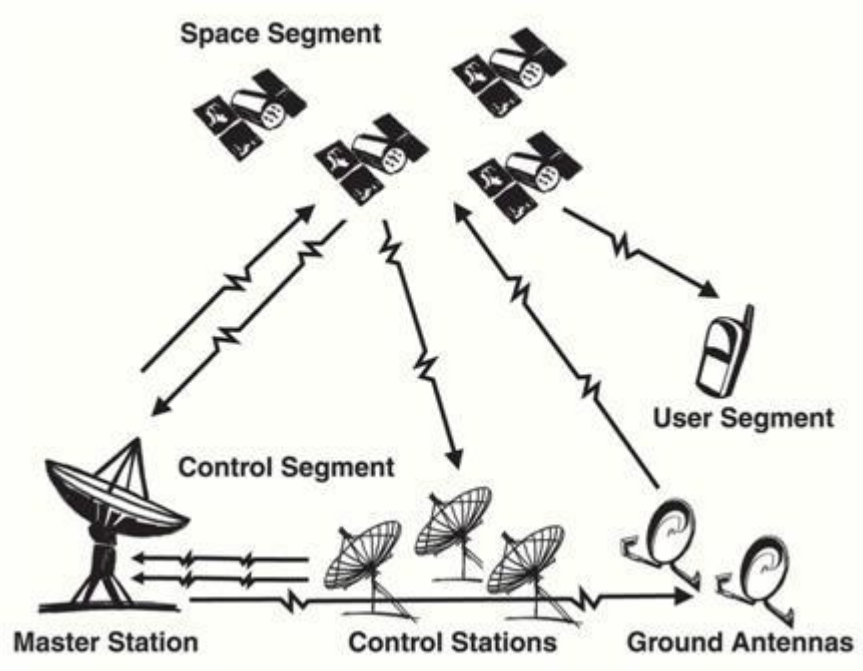


5. Satellite-Based Radio Navigation

GNSS (Global Navigation Satellite System) – AIM 1-1-17

- Types of systems: GPS (US), Galileo (EU), GLONASS (Russia), BeiDou (China)
- GPS Space Segment: constellation of min 24 satellites (current 31) orbiting earth at 11,000 miles
- GPS Control Segment: position/clock accuracy – 1 Master control station, 5 monitoring stations, 3 ground antennas
- Number of satellites required for triangulation: 3 (2D), 4 (3D), 5 (RAIM), 6 (fault exclusion)

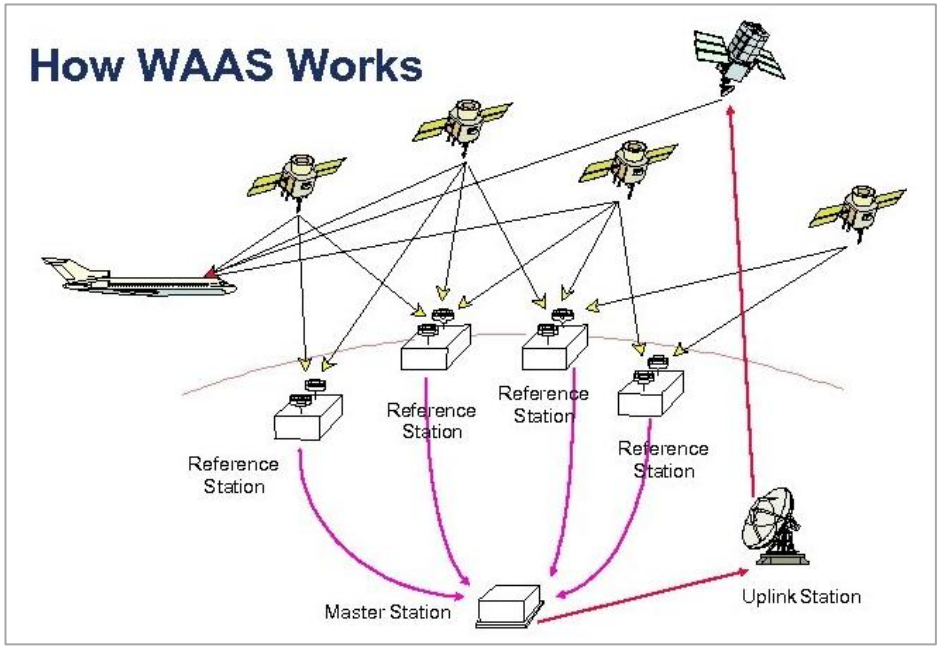




5. Satellite-Based Radio Navigation

SBAS (Satellite Based Augmentation System) – AIM 1-1-18

- Types of systems: WAAS (US), EGNOS (UE), SDCM (Russia, under dev.), etc
- WAAS (Wide Area Augmentation System): improves accuracy of GPS signal
  - ✓ *38 Stations (WRS): compare GPS signal w/ their own surveyed location*
  - ✓ *3 Master Stations (WMS): receive data from the WRSs, calculate the GPS errors and transmit to 6 ground uplink stations*
  - ✓ *3 Geostationary Satellites receive the signal from the uplink stations and broadcast to WAAS receivers, which correct the GPS signal*



5. Satellite-Based Radio Navigation

Using your GPS (multiple models available)

- Steps: **(1)** Load Waypoints ➔ **(2)** Follow the Magenta CDI (like a VOR) ➔ **(3)** Check the moving maps (MFD)
- Be careful with the "Direct To" – GPS will not avoid terrain for you

6. Radar Services

AIM 4-1-17/18

- **Radar Service Requirements**
  - Can communicate with ATC
  - Within radar coverage
  - Can be radar identified

- **Basic Radar Services** (Flight Following)
  - Safety alerts, traffic advisories, limited radar vectoring (workload permitting)
    - ✓ *Safety alerts ➔ Traffic Alert and/or Low-Altitude Alert (prox to terrain)*

Limitations:
- Heading vs Track
- Clouds are not visible
- Precipitation only

- **Class C Services**
  - Basic radar services, sequencing, separation VFR/IFR aircraft

- **Class B Services**
  - Basic radar services, sequencing, separation between all aircraft

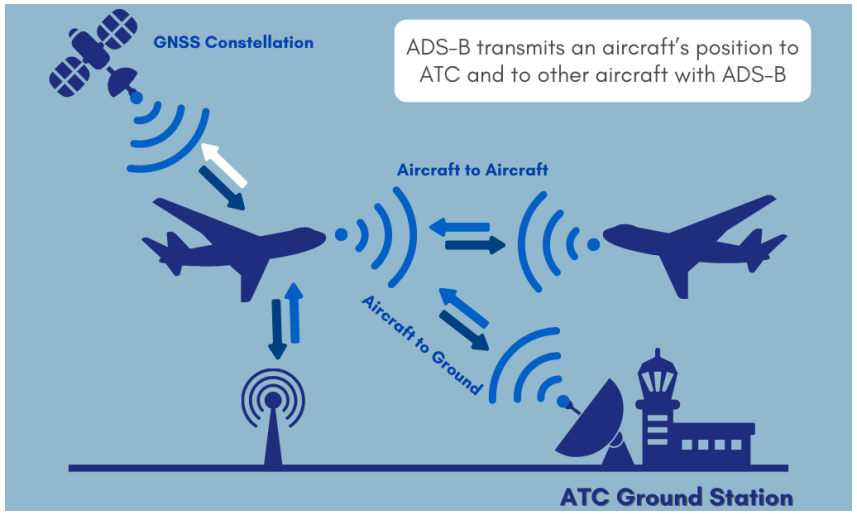
- **TRSA Service**
  - Basic radar services plus separation of IFR traffic and participating VFR aircraft, and sequencing

7. ADS-B

- **Automatic Dependent Surveillance Broadcast**
  - ADS-B Out: Broadcasts GPS location, altitude, groundspeed, and more to ground stations & other aircraft
  - ADS-B In: Pilots can see what controllers see, as well as weather (if installed)
    - ✓ *TIS-B (Traffic Information, 978MHz (UAT)/1090ES): ADS-B Out equipped aircraft + radar (~30nm, ±3,500ft)*
    - ✓ *FIS-B (Flight Information, 978MHz (UAT) only): weather products, clouds, icing, metar, airmet/sigmet, etc*

- **Requirements for ADS-B Out (91.225)**
  - Equipment satisfies 91.227 and 91.225(a)(1) and (b)(1) – note more options below 18,000ft MSL
  - Class A, B, and C airspace (and above Class B and C, up to 10,000ft MSL) and Inside Mode-C veil up to 10,000ft MSL
  - Class E airspace at and above 10,000ft MSL, excluding below 2,500ft AGL
    - ✓ *At and above 3,000ft MSL over the Gulf of Mexico within 12nm of the coast*

Use portable ADS-B In receivers if aircraft not equipped



Questions?