II.L. Navigation Systems and Radar Services

Objectives	The student should develop knowledge of the elements related to the navigation systems and radar services provided by ATC as required in the necessary ACS.
Key Elements	✈ VOR ✈ GPS ✈ Radar services
Elements	✈ VOR/VORTAC ✈ Satellite based navigation ✈ Radar services and procedures
Schedule	1. Discuss objectives 2. Review material 3. Development 4. Conclusion
Equipment	✈ White board ✈ Markers ✈ References
Instructor's Actions	1. Discuss lesson objectives 2. Present lecture 3. Questions 4. Homework
Student's Actions	Participate in discussion Take notes
Completion Standards	The student understands the operation of different navigation systems, as well as their use in the airplane. The student understands and uses the radar services provided by ATC.

References	FAA-H-8083-25B, *Pilot's Handbook of Aeronautical Knowledge* (Chapter 16) FAA-H-8083-15, *Instrument Flying Handbook* (Chapter 9) AIM, *Aeronautical Information Manual* (Chapter 1)

Instructor Notes

Introduction

Overview—review objectives and key ideas.
Why—understanding how navigation systems function helps us use the properly. It is also important to understand the services that ATC can provide to pilots.

VOR

VORTAC—**V**ery **H**igh **F**requency **O**mnidirectional **R**ange

- VOR—by itself, the VOR provides magnetic bearing information to and from the station.
- VOR/DME—distance measuring equipment is also installed with the VOR
- VORTAC—military tactical air navigations (TACAN) equipment also installed with the VOR. DME is always an integral part of a VORTAC.

Omnidirectional range—VHF-radio-transmitting ground station; projects straight line courses (radials) from the station in all directions. Radials projected with reference to the magnetic north.
Radial—a line of magnetic bearing extending outward from the VOR station. Accuracy of course alignment with radials considered to be excellent (within ±1°).
Projection distance depends on power output of the transmitter.

VOR ground stations transmit within a VHF frequency band of 108.0-117.95 MHz. Signal transmitted is subject to line-of-sight restrictions. Range varies in direct proportion to altitude of receiving equipment.

VOR classification

Classified according to operational use—three classes with varying normal useful ranges.

- T—terminal
- L—low altitude
- H—high altitude

Class	Altitudes	Radius (Miles)
T	12,000’ and Below	25
L	Below 18,000’	40
H	Below 14,500’	40
H	14,500 – 17,999’	100
H	18,000’ – FL 450	130
H	FL 450 – 60,000’	100

VOR checks

Periodic checks and calibrations—not required for VFR flight, but the best assurance of maintaining an accurate VOR receiver.

Verifies that the VOR radials the equipment receives are aligned with the radials the station transmits. Checkpoints are listed in the Chart Supplement.

- FAA VOR test facility (VOT)
- Certified airborne checkpoints
- Certified ground checkpoints located on airport surfaces
- Dual VOR check

IFR tolerances required are ±4° for ground checks and ±6° for airborne checks.

Using the VOR

To identify the VOR, use the Morse code identification or a voice stating the name and VOR. If the VOR is out of service, the coded identification is removed and not transmitted, and it should not be used for navigation. VOR receivers also have an alarm flag to indicate when the signal strength is inadequate, either because the plane is too far or too low and out of the line-of-sight of the transmitting signal.

Two required components for VOR radio navigation—the ground transmitter, and the receiver.
The ground transmitter is at a specific position on the ground, and transmits on an assigned frequency.
The airplane equipment includes the receiver with a tuning device, and a VOR instrument that consists of

- An omnibearing selector (OBS) referred to as the course selector
- A course deviation indicator (CDI) needle
- A to/from indicator

The course selector is an azimuth dial that can be rotated to select a radial or to determine the radial the aircraft is on, and to determine the magnetic course to or from the station.
When the OBS is rotated, the CDI moves to show the position of the radial relative to the plane. To determine the radial (magnetic course to) or its reciprocal (magnetic course from), rotate the OBS to center the CDI. The CDI will move to the left or right if the airplane is away from the radial selected.

Tracking

1. Tune the VOR frequency and check the identifiers to verify you are receiving the desired VOR.
2. Rotate OBS to center CDI to a “TO” indication. If centered with a “FROM” indication, rotate another 180°.
3. Turn to the heading indicated on the VOR azimuth dial or course selector, to track directly to the station in a no wind situation.
4. If there is a crosswind, and the heading is maintained, the aircraft will drift off course. Alter the heading to return to the desired radial, and once the CDI is centered and the aircraft is back on the radial, crab into the wind to establish wind correction. Trial and

error will establish the necessary heading to maintain the desired track.
5. Upon arriving and passing the VOR station, the "TO" indication will change to a "FROM" indication.

Reverse sensing

If flying toward a VOR with a "FROM" indication, the CDI will indicate opposite the direction it should. If the plane drifts right of course, the needle will move right. The same applies when flying from a station with a "TO" indication.

Satellite-based navigation

Satellite-based navigation systems include
- GPS—global positioning system
- WAAS—wide area augmentation system
- LAAS—local area augmentation system

Global positioning system (GPS)

GPS system composed of three major elements:
- The space segment
- The control segment
- The user segment

The space segment is composed of a constellation of 26 satellites approximately 11,000 NM above the Earth. Arranged so that at any time, five are in view to any receiver (only four are necessary for operation). Each satellite takes approximately 12 hours to orbit the Earth. Equipped with highly stable atomic clocks, transmit a unique code/nav message. Satellites broadcast in UHF range and are not affected by weather, but are still subject to line-of-sight references. They must be above the horizon (as seen by the antenna) to be usable for navigation.

The control segment consists of a master control station, five monitoring stations, and three ground antennas. The monitoring stations and ground antennas are distributed around the Earth to allow continual monitoring and communications with satellites. Ground antennas can uplink updates/corrections to the nav message broadcast as satellites pass over them.

The user segment consists of all components associated with the GPS receiver. Can range from portable, hand-held receivers, to receivers permanently installed in the plane. The receiver uses the satellite signals to provide position, velocity, and precise timing.

The receiver uses the signals of at least four of the best positioned satellites to yield a 3D fix (latitude, longitude, and altitude). The receiver calculates location by calculating distance/position info from the satellite.

	VFR GPS navigation can be as simple as selecting a destination and tracking the course. For tracking purposes, course deviation is linear—there is no increase in sensitivity when approaching a waypoint. GPS makes it tempting to reply exclusively on it for navigation—you should never rely on just one means of navigation.
WAAS	Satellite-based augmentation system—augments basic GPS satellite constellation with additional ground stations/enhanced info transmitted from geostationary satellites. Improves GPS signals for use in precision approaches. WAAS accuracy is at a minimum of approximately 25 ft 95% of the time.
LAAS	Functions similarly to WAAS, but relies more on ground stations for signal correction/improvement. Less cost effective than WAAS; capable of handling Cat III instrument approaches.
Radar services and procedures	ATC provides a variety of services to participating VFR aircraft on a workload permitting basis. Participating aircraft must be able to communicate with ATC, be within radar coverage, and be radar identified. Services provided include ✈ VFR radar traffic advisory service (flight following) and safety alerts ✈ Vectoring (when requested) ✈ Terminal radar programs (TRSA) to separate all participating VFR aircraft and IFR traffic ✈ Radar assistance to lost aircraft ✈ Class C services include separation between IFR/VFR traffic, and sequencing of VFR traffic to the airport. ✈ Class B services include separation based on IFR/VFR and/or weight, and sequencing of VFR arrivals.
Conclusion	Brief review of main points. To navigate with a VOR, if you wish to head toward the station, ensure the flag indicates “TO” and follow the indicated heading. If tracking away from station, ensure the flag indicates “FROM” and follow the indicated heading. Doing otherwise can result in reverse sensing.

CFI PTS

Objective: To determine that the applicant exhibits instructional knowledge of the elements related to navigation systems and radar service, by describing:

1. One ground-based navigational system (VOR/VORTAC, NDB, DME).
2. Satellite-based navigation system.
3. Radar service and procedures.
4. Global positioning system (GPS).

PPL ACS

Objective: To determine that the applicant exhibits instructional knowledge of the elements related to navigation systems and radar service, by describing:

1. Exhibits knowledge of the elements related to navigation systems and radar services.
2. Demonstrates the ability to use an airborne electronic navigation system.
3. Locates the airplane's position using the navigation system.
4. Intercepts and tracks a given course, radial or bearing, as appropriate.
5. Recognizes and describes the indication of station passage, if appropriate.
6. Recognizes signal loss and takes appropriate action.
7. Uses proper communication procedures when utilizing radar services.
8. Maintains the appropriate altitude, ±200 feet (60 meters) and headings ±15°.

CPL ACS

Objective: To determine that the applicant exhibits instructional knowledge of the elements related to navigation systems and radar service, by describing:

1. Exhibits knowledge of the elements related to navigation systems and radar services.
2. Demonstrates the ability to use an airborne electronic navigation system.
3. Locates the airplane's position using the navigation system.
4. Intercepts and tracks a given course, radial or bearing, as appropriate.
5. Recognizes and describes the indication of station passage, if appropriate.
6. Recognizes signal loss and takes appropriate action.
7. Uses proper communication procedures when utilizing radar services.
8. Maintains the appropriate altitude, ±100 feet (30 meters) and headings ±10°.