BASICS FOR AIR TRAFFIC CONTROL – RADIO AND SATELLITE NAVIGATION

MODULE OVERVIEW

Purpose: This module discusses how the federal airway system works, how navigational aids (NAVAIDs) function, and the different approach procedures for landing aircraft.

MODULE OUTLINE

Lesson: Radio-Based Navigation

Purpose: The purpose of this lesson is to identify types, characteristics, and the components of radio-based navigational aids (NAVAIDs).

Objectives:

- Identify types radio-based NAVAIDs
- Identify characteristics of radio-based NAVAIDs
- Identify components of radio-based NAVAIDs

Topics:

- Radio-Based Navigation
    - Radio Navigation
    - Systems
- Nondirectional Radio Beacon (NDB)
    - NDB Characteristics
- Knowledge Check
- VHF Omnidirectional Range (VOR)
    - VOR Characteristics
    - Line-of-Sight
    - Range and Classification
    - VOR Identification
    - VOR Effectiveness
- Knowledge Check
- Tactical Air Navigation (TACAN)
    - TACAN Characteristics
- Distance Measuring Equipment (DME)
    - DME Characteristics
- Knowledge Check
- VHF Omnidirectional Range/Tactical Air Navigation (VORTAC)
    - VORTAC Characteristics
- Knowledge Check
- Review/Summary

Question and Answer Session – *Parking Lot*

Lesson: Instrument Landing System (ILS)

Purpose: The purpose of this lesson is to explain components and characteristics of the instrument landing system (ILS).

Objectives

- Identify components of Instrument Landing System (ILS)
- Identify characteristics of ILS

Topics:

- Instrument Landing System (ILS)
- ILS Transmitter Components
  - Primary
  - Supplementary
  - Localizer Transmitter
  - Localizer Signal
  - Glideslope/Glidepath
  - Marker Beacons
  - Approach Lights

Video – Instrument Landing System Summary (5:23 mins.)

- Knowledge Check
- Review/Summary

Question and Answer Session – *Parking Lot*

Study Aid – Radio and Satellite Navigation Grid

Study Aid – The Instrument Landing System

Lesson: Inertial and Satellite Navigation Systems

Purpose: The purpose of this lesson is to identify the types of satellite-based navigation systems and the components and characteristics of both Inertial Navigation (INS) and satellite-based navigation systems.

Objectives:

- Identify components of INS
- Identify characteristics of INS
- Identify types of satellite-based navigation systems
- Identify components of satellite-based navigation systems
- Identify characteristics of satellite-based navigation systems

Topics:

- Inertial Navigation System (INS)
  - Characteristics
- Knowledge Check
- Global Navigation Satellite System (GNSS)
- GPS Navigation
- GPS Augmentation Systems
  - Wide Area Augmentation System (WAAS)
  - Ground Based Augmentation System (GBAS)
  - Receiver Autonomous Integrity Monitoring (RAIM)
  - WAAS / GBAS Implementation

Video – Navigation at the Crossroads (9:13 mins.)

- Area Navigation (RNAV)
  - Characteristics
  - Waypoints
  - Area Navigation (RNAV) Routes
  - Performance-Based Navigation (PBN)
- Knowledge Check
- Summary/Review

Question and Answer Session – *Parking Lot*

Lesson: Airways and Routes

Purpose: The purpose of this lesson is to explain Air Traffic Service (ATS) routes and airways established for air navigation purposes.

Objectives:

- Identify characteristics of airways established for federal airway system
- Identify characteristics of routes established for federal airway system

Topics:

- Air Traffic Service (ATS) Routes
- Airways and Routes
- VOR-to-VOR Navigation
- Airway System
  - Characteristics
  - Two Airways Sharing the Same Route
- Jet Route System
  - Jet Route Characteristics
- RNAV Route
  - RNAV Route Characteristics
- Knowledge Check
- Review/Summary

Activity – NAVAID Know-How

Question and Answer Session – *Parking Lot*

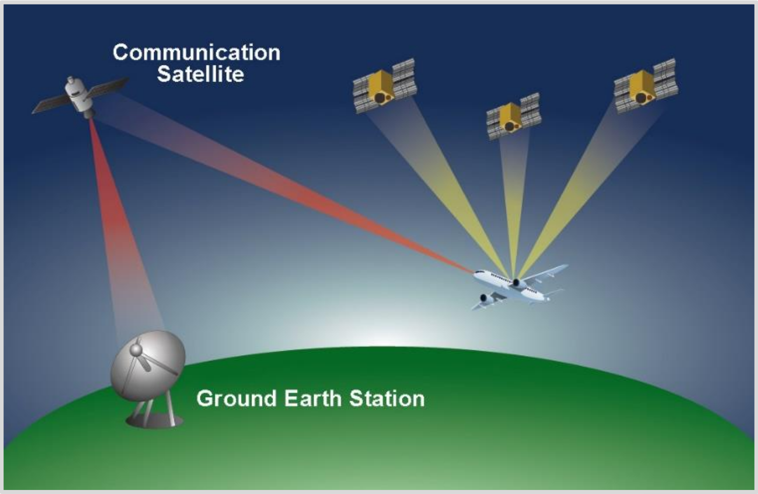
End-of-Module (EOM) Test

INTRODUCTION

LESSONS	■ Radio-Based Navigation ■ Instrument Landing System (ILS) ■ Inertial and Satellite Navigation Systems ■ Airways and Routes
TOTAL ESTIMATED RUN TIME	4 hrs. 22 mins.
MODULE CONTENT	■ Module Overview ■ Lesson: Radio-Based Navigation ■ Q&A Session – Parking Lot ■ Lesson: Instrument Landing System (ILS) ■ Q&A Session – Parking Lot ■ Study Aid – Radio and Satellite Navigation Grid ■ Study Aid – The Instrument Landing System ■ Lesson: Inertial and Satellite Navigation Systems ■ Q&A Session – Parking Lot ■ Lesson: Airways and Routes ■ Activity – NAVAID Know-How ■ Q&A Session – Parking Lot ■ End-of-Module Test

FACILITATOR INSTRUCTIONS	DELIVERY METHOD
■ Instruct students to select ***Radio and Satellite Navigation*** module link within Blackboard ■ Instruct students to read the module introduction and then wait quietly for additional instructions	Blackboard
	EST. RUN TIME
	2 mins.

Even the best-marked roadways can be confusing. On the ground, at least a driver can stop and ask directions. Since pilots have no lines to follow or signs to read in the air, they must depend on other methods to help them reach their destination, such as ground-based, satellite-based, and approach navigational aids (NAVAIDs). Your understanding of the uses and functions of NAVAIDs will provide you with guidelines to issue realistic clearances.



This module discusses how the federal airway system works, how NAVAIDs function, and the different approach procedures for landing aircraft.

FACILITATOR INSTRUCTIONS	DELIVERY METHOD
■ **ENABLE *Radio-Based Navigation*** lesson in Blackboard ■ Instruct students to navigate to the ***Radio-Based Navigation*** lesson in Blackboard ■ Instruct students to work individually through the lesson content ■ Upon completion of the lesson, students should review previously introduced content or wait quietly until other students have completed	Blackboard **EST. RUN TIME** 30 mins.

RADIO-BASED NAVIGATION

Purpose: This lesson identifies types, characteristics, and the components of radio-based navigational aids.

Objectives:

- Identify types radio-based NAVAIDs
- Identify characteristics of radio-based NAVAIDs
- Identify components of radio-based NAVAIDs

The references for this lesson are as follows:

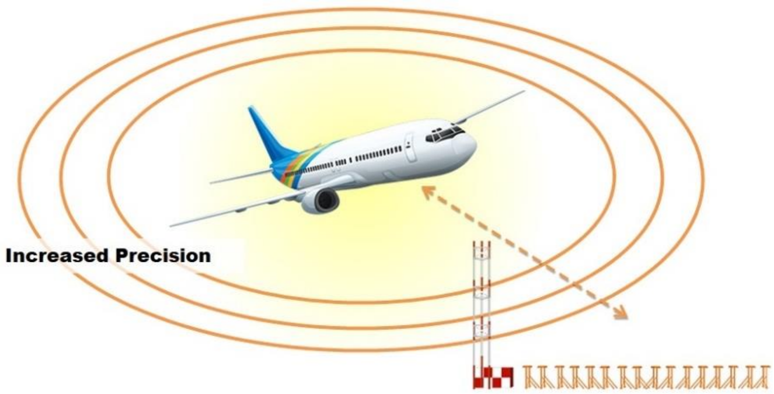
- FAA Order JO 7110.65, Air Traffic Control
- FAA-H-8083-15, Instrument Flying Handbook
- FAA-H-8083-25, Pilot's Handbook of Aeronautical Knowledge
- Aeronautical Information Manual (AIM)

Radio-Based Navigation

A radio NAVAID is any electronic device, airborne or on the surface, which provides point-to-point guidance information or position data to aircraft in flight. Aircraft are equipped with radios that provide a means of navigation and communication with ground stations.

Radio Navigation

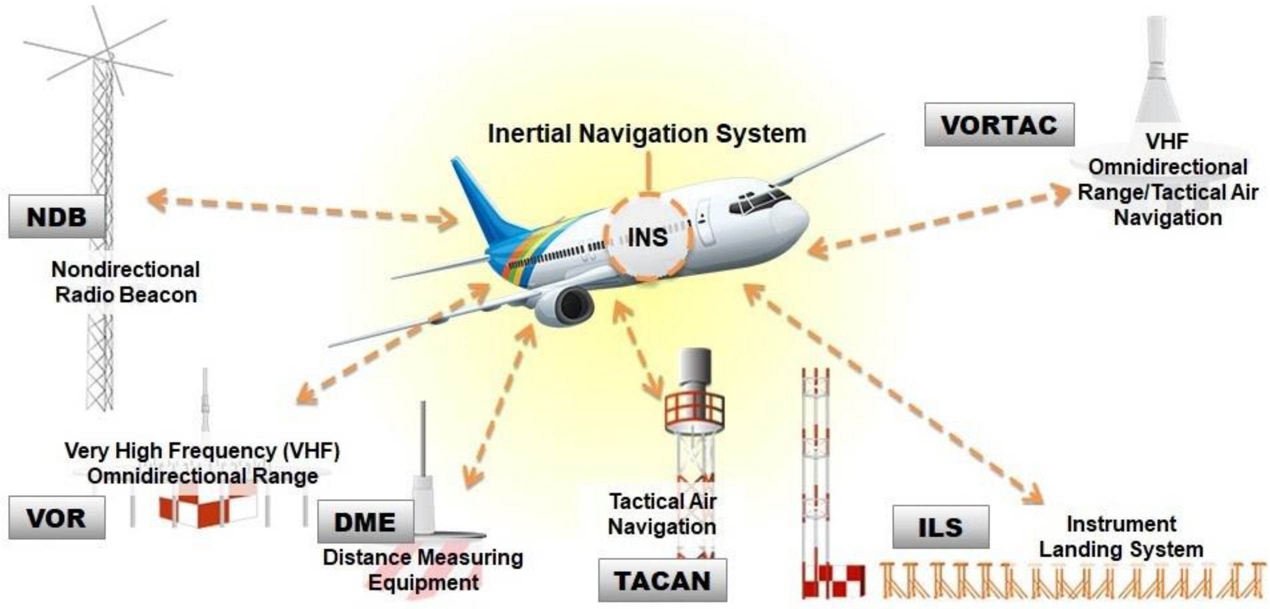
Advances in aircraft navigational radio receivers, refined cockpit instrumentation, and aeronautical charts show the exact location of ground-transmitting stations and their frequencies. These advancements make it possible for pilots to navigate with precision to almost any point desired.



Systems

There are radio and self-contained navigation systems available for use. They are:

- Nondirectional Radio Beacon (NDB)
- VHF Omnidirectional Range (VOR)
- Tactical Air Navigation (TACAN)
- Distance Measuring Equipment (DME)
- VHF Omnidirectional Range/Tactical Air Navigation (VORTAC)
- Instrument Landing System (ILS)
- Inertial Navigation System (INS)



***Note:** Satellite Navigation Systems are covered in a different lesson.*

This lesson covers the ground-based navigation systems highlighted below.

Nondirectional Beacon (NDB)

An NDB is a low/medium frequency (L/MF) radio beacon transmitting nondirectional signals whereby the pilot of an aircraft equipped with direction-finding equipment can determine his/her bearing to or from the radio beacon and "home" on or track to or from the station.

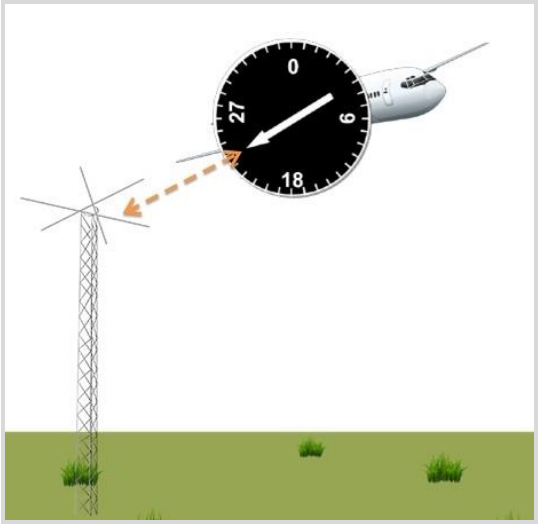
NDB Characteristics

- These facilities normally operate in the low frequency (LF)/medium frequency (MF) band and transmit a continuous signal
- All radio beacons, except compass locators, transmit a continuous three-letter identification in Morse code, except during voice transmissions
- A compass locator, which is associated with an instrument landing system, transmits a two-letter identification
- Voice transmissions can be made on radio beacons unless the letter "W" (without voice) is included in the class designator (HW)

Note:

	very low frequency	low frequency	medium frequency	high frequency	very high frequency	ultrahigh frequency	super high frequency	extra high frequency
	VLF	LF	MF	HF	VHF	UHF	SHF	EHF
frequency	3-30 kHz	30-300 kHz	300-3000 kHz	3-30 MHz	30-300 MHz	300-3000 MHz	3-30 GHz	30-300 GHz
wavelength in air	100km-10km	10km-1km	1km-100m	100m-10m	10m-1m	1m-100mm	100mm-10mm	10mm-1mm

The NDB receiver in the aircraft converts a nondirectional signal to directional information in relative bearing from the aircraft. The needle points to the specific station that was selected, using the aircraft receiver.



Erroneous Bearings

Radio beacons are subject to disturbances that may result in erroneous bearing information.

- Such disturbances result from electrical disturbances, such as lightning
- Disturbances create excessive static, needle deviations, and signal fades
- At night, radio beacons are vulnerable to interference from distant stations

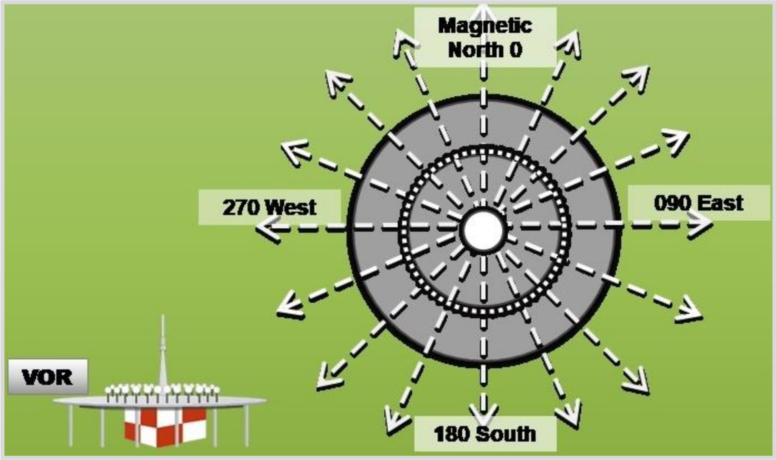
Knowledge Check A

REVIEW what you have learned so far about NDB navigational systems. ANSWER the question listed below.

1. How are all NDBs, except compass locators, identified? *(Select the correct answer.)*
   - ❑ **Three-letter identifier in Morse Code**
   - ❑ Two-letter identifier in Morse Code
   - ❑ Aural tone

VHF Omnidirectional Range (VOR)

A VOR is a ground-based electronic NAVAID transmitting VHF navigation signals, 360 degrees in azimuth, oriented ***from magnetic north***. Used as the basis for navigation in the National Airspace System (NAS). The VOR identifies itself by Morse Code and may have an additional voice identification feature. Voice features may be used by air traffic control (ATC) or Flight Service Stations (FSSs) for transmitting instructions/information to pilots.



VOR Characteristics

The VOR is the primary navigation facility for civil aviation in the NAS.

- The courses oriented from the station are called radials
- Radials can be envisioned as spokes of a wheel on which the aircraft is on one specific radial at any time
- The radial the aircraft is on does not necessarily correspond to the aircraft's heading

Line-of-Sight

VORs are subject to line-of-sight restrictions.

VHF-UHF Omnidirectional facilities, VOR (VHF), TACAN (UHF), and VORTAC (VHF/UHF) are all line-of-sight.

Note: *TACANs and VORTACs will be covered later in this lesson.*

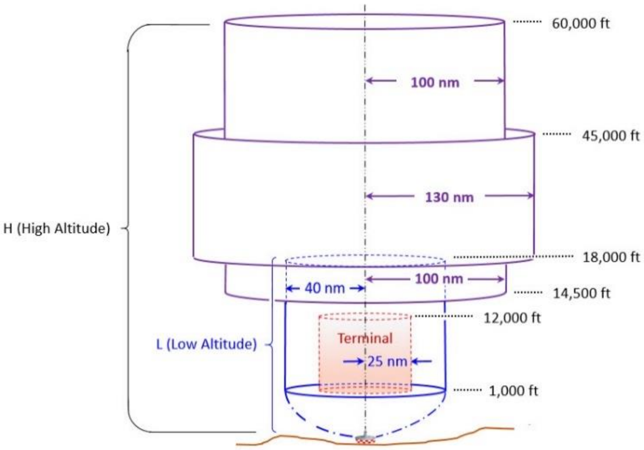
Range and Classification

VORs have a power output necessary to provide coverage within their assigned operational service volume and are classified according to operational use.

The three classes are:

- **T (Terminal)** – Used for navigation in a terminal area around an airport
- **L (Low altitude)** – Generally used to navigate on airways
- **H (High altitude)** – Used to navigate on all Air Traffic Service (ATS) routes

The normal usable altitudes and radius distances for various classes of VORs, TACANs, and VORTACs are shown in the table.		
VOR/VORTAC/TACAN NAVAIDs		
CLASS	**ALTITUDES**	**DISTANCE (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	Above FL 450	100

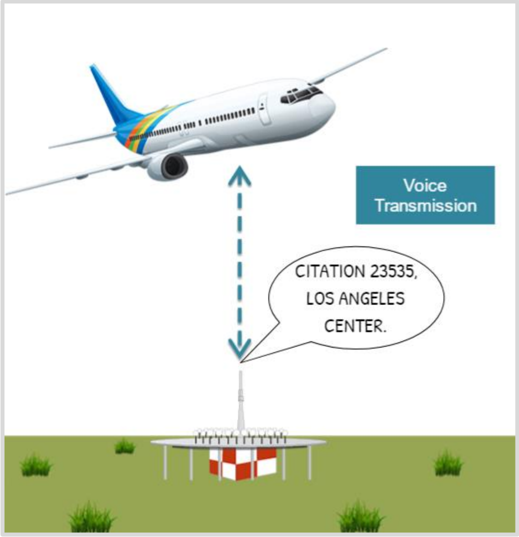


VOR Identification

VORs may be equipped for voice transmission on the VOR frequency.

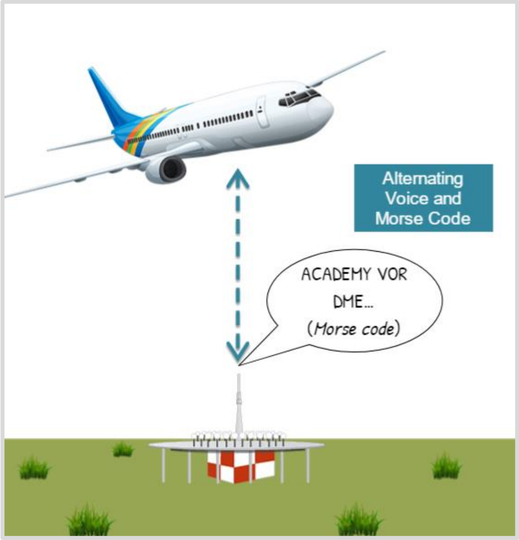
- VORs without voice capability are indicated by the letter "W" (without voice) in the Chart Supplement
- VOR class is listed prior to the type of NAVAID in the Chart Supplement (for example: Will Rogers VORTAC is listed as (H) VORTAC)

Class and voice capability are also annotated on the charts.



The only positive methods of identifying a VOR are by its Morse Code identification or by the recorded automatic voice identification, which is always indicated by use of the word "VOR" following the name.

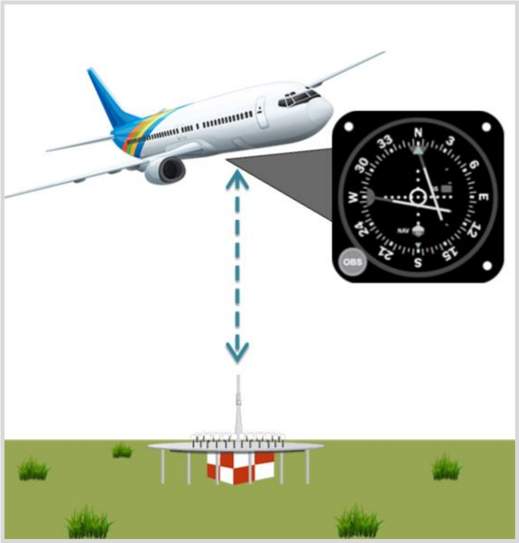
- The transmission consists of a voice announcement, e.g., "AIRVILLE VOR," alternating with the Morse Code identification
  - FSSs are able to communicate through many VORs with different names; in most cases, none of the VORs have the name of the "parent" FSS
- During periods of maintenance, the facility may radiate a T-E-S-T code (- ● ●●● -) or the code may be removed



VOR Effectiveness

The effectiveness of the VOR depends upon proper use and adjustment of both ground and airborne equipment.

- The accuracy of course alignment of the VOR is excellent, generally plus or minus 1 degree
- On some VORs, an intermittent signal may be observed (some receivers are more susceptible to these irregularities than others)
  - At a few stations, usually in mountainous terrain, the pilot may occasionally observe a brief course needle oscillation



Knowledge Check B

REVIEW what you have learned so far about the VOR navigational system. ANSWER the questions listed below.

1. A VOR antenna transmission pattern is _______________. *(Select the correct answer.)*
   - ❑ **Omnidirectional**
   - ❑ Nondirectional
   - ❑ Fan-shaped

2. A VOR station projects ________________. *(Select the correct answer.)*
   - ❑ 360 usable true radials
   - ❑ **360 usable magnetic radials**
   - ❑ An infinite number of bearings

3. The different classes of VORs are __________. *(Select the correct answer.)*
   - ❑ **High, Low, and Terminal**
   - ❑ High, Medium, and Low
   - ❑ High, Low, and Compass Locator

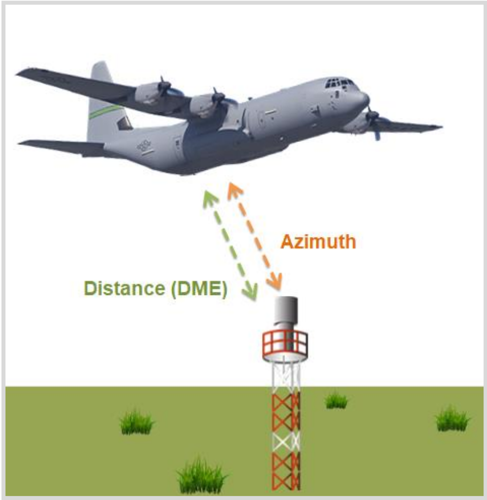
Tactical Air Navigation (TACAN)

TACAN is a UHF electronic rho-theta air NAVAID which provides suitably equipped aircraft a continuous indication of bearing and distance to the TACAN station.

TACAN Characteristics

- Azimuth and distance information is transmitted in the UHF band
  - The azimuth and distance frequencies are paired and assigned a channel number (**Example:** Channel 101)
- For reasons peculiar to military or naval operations (e.g., unusual site conditions, the pitching and rolling of a naval vessel, etc.) the civil VOR/DME system of air navigation is considered unsuitable for military or naval use
- TACANs generate directional information and transmit it by ground equipment to the aircraft, providing 360 usable magnetic courses, called radials, measured outbound from the station
- TACANs are subject to line-of-sight restrictions

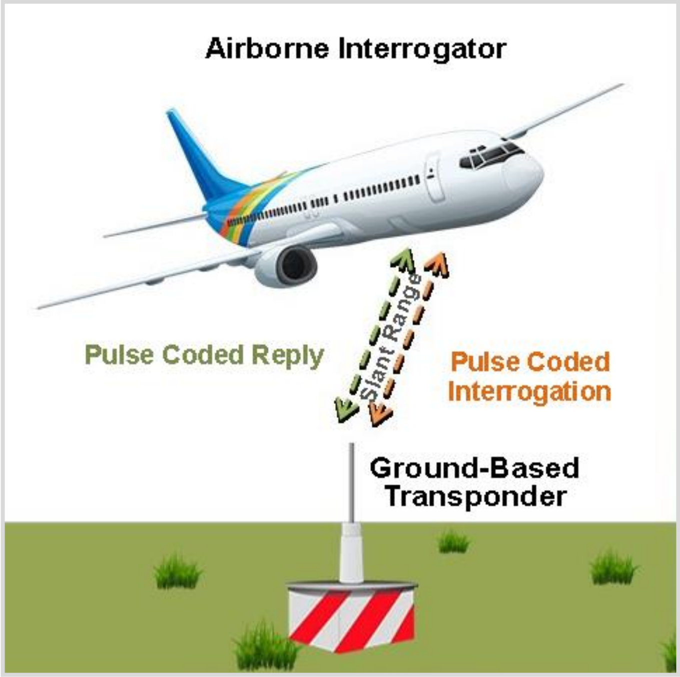
Note: *With a rho-theta navigation system, one or more signals are emitted from a facility to produce simultaneous indication of azimuth and distance.*



Distance Measuring Equipment (DME)

DME (airborne and ground) is the equipment used to measure, in nautical miles, the slant range distance of an aircraft from the DME NAVAID.

DME Characteristics



- Distance information received from DME equipment is slant range distance and not actual horizontal distance

Note: *Difference between slant range and horizontal distance is greatest near the NAVAID at high altitude.*

  - In the operation of DME, paired pulses at a specific spacing are sent out from the aircraft (this is the interrogation) and are received at the ground station
  - The ground station (transponder) then transmits paired pulses back to the aircraft at the same pulse spacing but on a different frequency
  - The time required for the round trip of this signal exchange is measured in the airborne DME unit and is translated into distance (nautical miles) from the aircraft to the ground station
- Operating on the line-of-sight principle, DME furnishes distance information with a very high degree of accuracy
- DME operates on frequencies in the UHF spectrum
  - Aircraft using TACAN equipment will receive distance information from a VORTAC automatically
  - To receive DME, a VOR-equipped aircraft must have a DME airborne unit

Note:

	very low frequency	low frequency	medium frequency	high frequency	very high frequency	ultrahigh frequency	super high frequency	extra high frequency
	VLF	LF	MF	HF	VHF	UHF	SHF	EHF
frequency	3-30 kHz	30-300 kHz	300-3000 kHz	3-30 MHz	30-300 MHz	300-3000 MHz	3-30 GHz	30-300 GHz
wavelength in air	100km-10km	10km-1km	1km-100m	100m-10m	10m-1m	1m-100mm	100mm-10mm	10mm-1mm

Knowledge Check C

REVIEW what you have learned so far about the TACAN and DME navigational systems. ANSWER the questions listed below.

1. TACAN frequencies are in the __________ band. *(Select the correct answer.)*
   - ❑ L/MF
   - ❑ VHF
   - ❑ **UHF**

2. DME measures ____________ to the aircraft. *(Select the correct answer.)*
   - ❑ **Slant range distance**
   - ❑ Vertical distance
   - ❑ Horizontal range distance

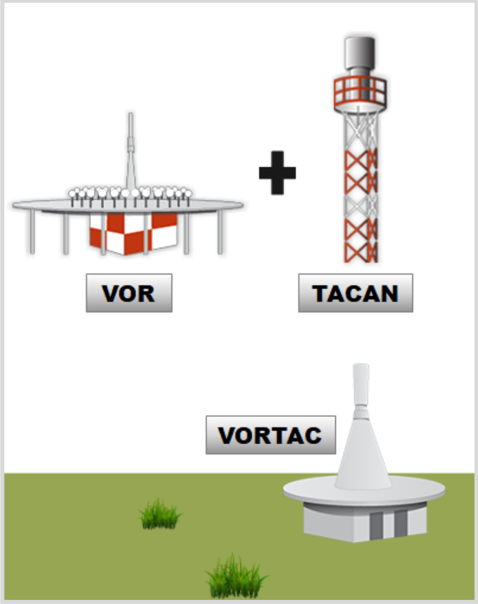
3. What DME on the ground is required to respond to the aircraft interrogator? *(Select the correct answer.)*
   - ❑ Transmitter
   - ❑ **Transponder**
   - ❑ VOR

VHF Omnidirectional Range/Tactical Air Navigation (VORTAC)

A VORTAC is a NAVAID providing VOR azimuth, TACAN azimuth, and TACAN DME at one site.

VORTAC Characteristics

- A VORTAC is considered to be a unified NAVAID, although it consists of more than one component, incorporates more than one operating frequency, and uses more than one antenna system
  - Both components of a VORTAC are envisioned as operating simultaneously and providing the three services at all times
- Transmitted signals of VOR and TACAN are each identified by a three-letter Morse Code transmission and are interlocked so that pilots using VOR azimuth with TACAN distance can be assured that both signals being received are definitely from the same ground station
  - The frequency channels of the VOR and the TACAN at each VORTAC facility are paired to simplify airborne operation



Knowledge Check D

REVIEW what you have learned so far about the VORTAC navigational system. ANSWER the question listed below.

1. VORTAC offers a combination of which NAVAIDs? *(Select the correct answer.)*
   - ❑ VOR, NDB, and DME
   - ❑ VOR, TACAN, and NDB
   - ❑ **VOR and TACAN**

Radio-Based Navigation Summary

Depending on the equipment installed on their aircraft, pilots have access to several different radio-based navigational aids, each with its own unique set of characteristics. This lesson identified the types, characteristics, and components of radio-based navigational aids. The FAA establishes, operates, and maintains these air navigation facilities, which are crucial aids to instrument flight.

FACILITATOR INSTRUCTIONS	DELIVERY METHOD
■ Review content presented in ***Radio-Based Navigation*** lesson ■ Navigate to the ***Parking Lot*** link within Blackboard and review any student questions ■ Address ***Parking Lot*** questions and facilitate a brief discussion of the lesson content	Facilitated Discussion **EST. RUN TIME** 15 mins.

FACILITATOR INSTRUCTIONS	DELIVERY METHOD
■ **ENABLE *Instrument Landing System (ILS)*** lesson in Blackboard ■ Instruct students to navigate to the ***Instrument Landing System (ILS)*** lesson in Blackboard ■ Instruct students to work individually through the lesson content ■ Upon completion of the lesson, students should review previously introduced content or wait quietly until other students have completed	Blackboard **EST. RUN TIME** 20 mins.

INSTRUMENT LANDING SYSTEMS (ILS)

Purpose: This lesson explains components and characteristics of the instrument landing system (ILS).

Objectives

- Identify components of Instrument Landing System (ILS)
- Identify characteristics of ILS

The references for this lesson are as follows:

- FAA-H-8083-15, Instrument Flying Handbook
- Aeronautical Information Manual (AIM)
- FAA Order 6750.16, Siting Criteria for Instrument Landing Systems

Instrument Landing System (ILS)

Navigational Systems

The ILS is one of the navigational systems available for use.

The ILS is designed to provide:

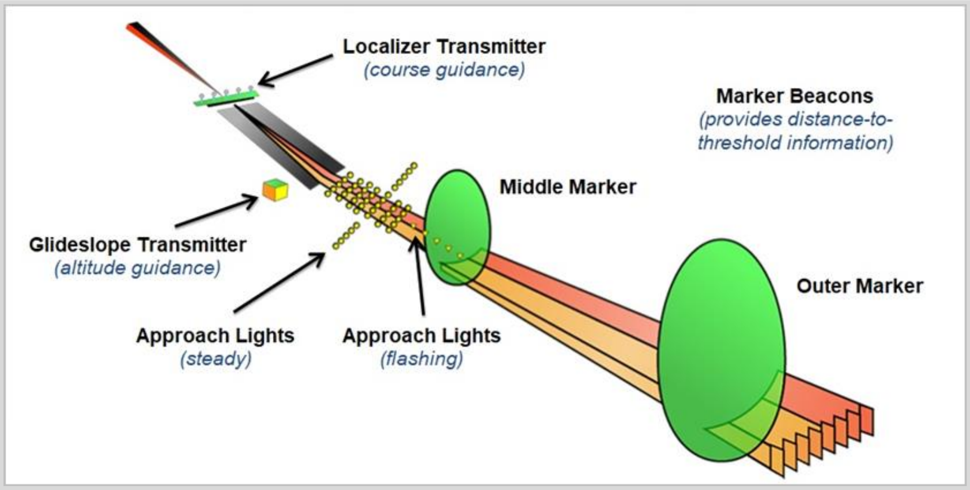
- An approach path with both course and altitude guidance
- An exact alignment and descent of an aircraft on final approach to a specific runway

The ground equipment consists of two highly directional transmitting systems and, along the approach, three (or fewer) marker beacons.

- The directional transmitters are known as the localizer and glideslope transmitters

ILS Transmitter Components

The ILS may be divided functionally into the following parts: Primary and Supplementary components. Where a complete ILS system is installed on each end of a runway (e.g., the approach end of Runway 4 and the approach end of Runway 22), the ILS systems are **NOT** in service simultaneously.

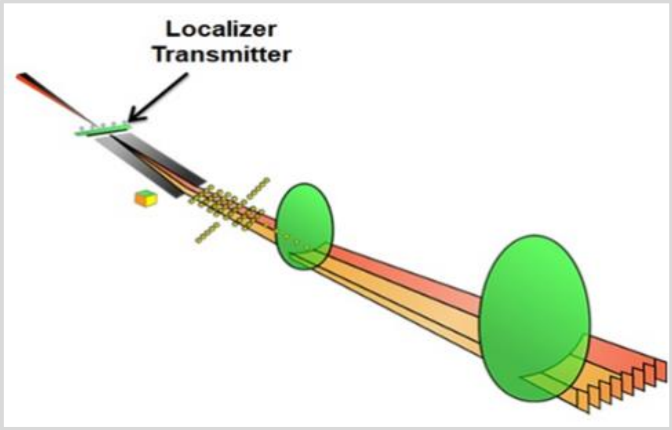
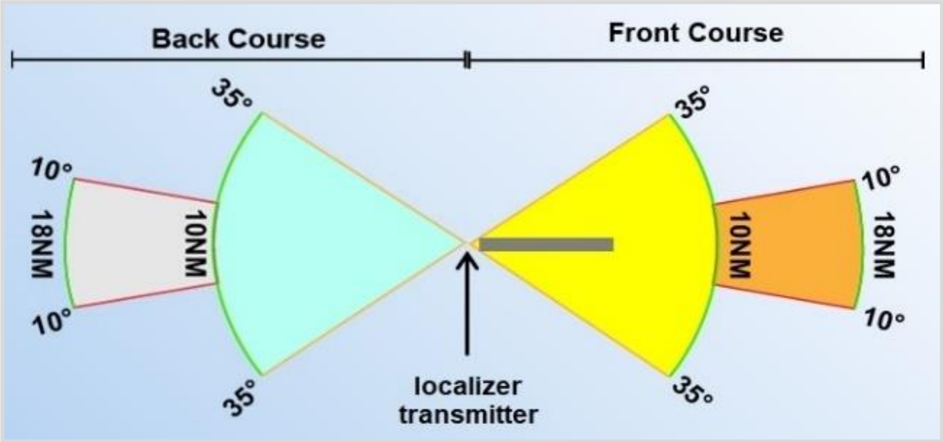


Primary

- **Localizer Transmitter** (course guidance) provides horizontal (left/right) guidance along the extended centerline of the runway
- **Glideslope Transmitter** (altitude guidance) provides vertical (up/down) guidance along the descent path toward the runway touchdown point
- **Marker Beacons** (provides distance-to-threshold information) give range information along the approach path

Supplementary

- **Approach lights** assist in the transition from instrument to visual flight
- **Compass locator** is a low power, low or medium frequency (L/MF) radio beacon installed at the site of the outer or middle marker
- **Distance Measuring Equipment (DME)** is typically installed as an ancillary aid to the ILS. The DME is normally collocated with the localizer when used as a component of the ILS, but other locations may provide improved coverage or operational benefits

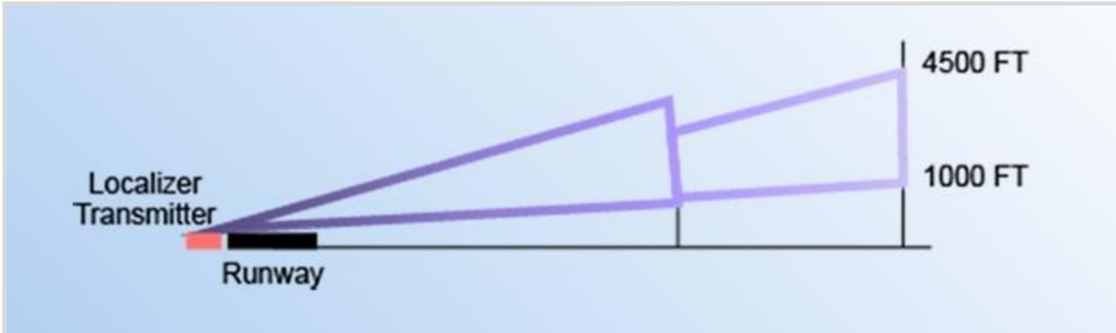
COMPONENT	DESCRIPTION
Localizer Transmitter	The localizer provides the pilot with course guidance to the runway centerline. ■ The localizer transmitter operates in the Very High Frequency (VHF) band ■ The approach course of the localizer is called the front course and is used with other functional parts, e.g., glideslope, marker beacons ■ The localizer signal is transmitted from the departure end of the runway; the course line along the extended centerline of a runway in the opposite direction to the front course is called the Back Course (BC) ■ Identification is in Morse Code and consists of a three-letter identifier preceded by the letter **I** (●●) transmitted on the localizer frequency *(Ex. I-DIA)*  

Localizer Signal

The localizer signal is usable from the following precise distances.

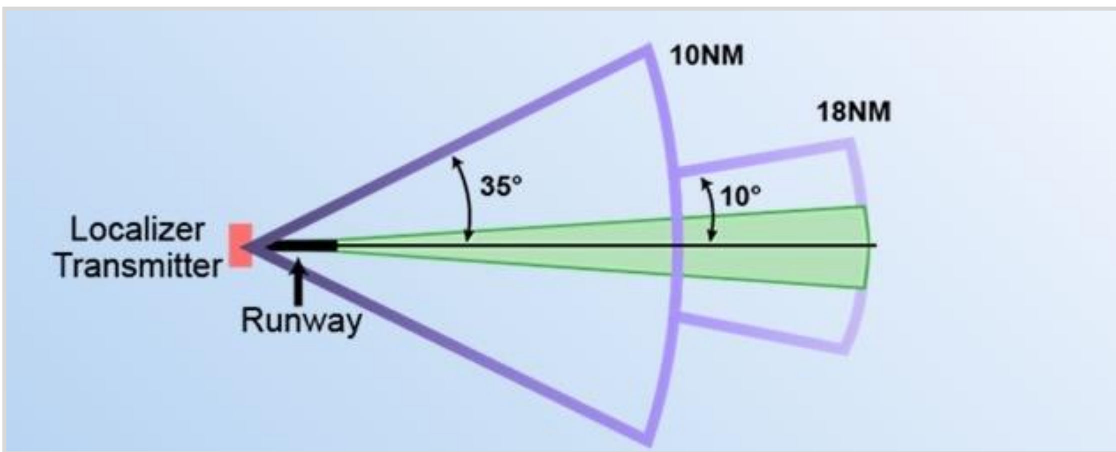
Vertical

- **Vertically** from a distance of 18NM from the antenna, between an altitude of:
  - 1,000 feet above the highest terrain along the course line
  - 4,500 feet above the elevation of the antenna site

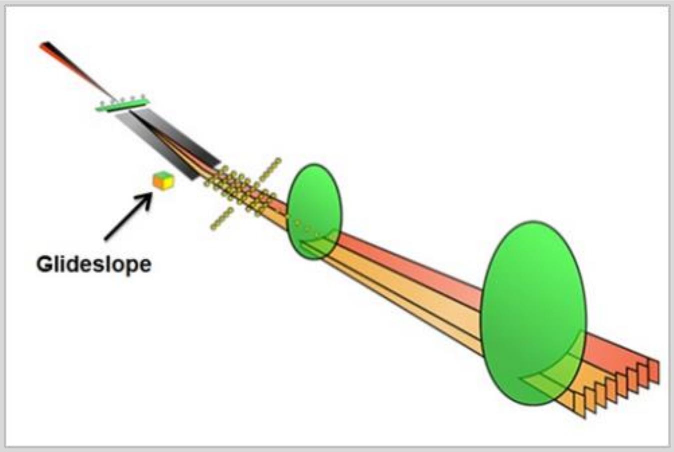
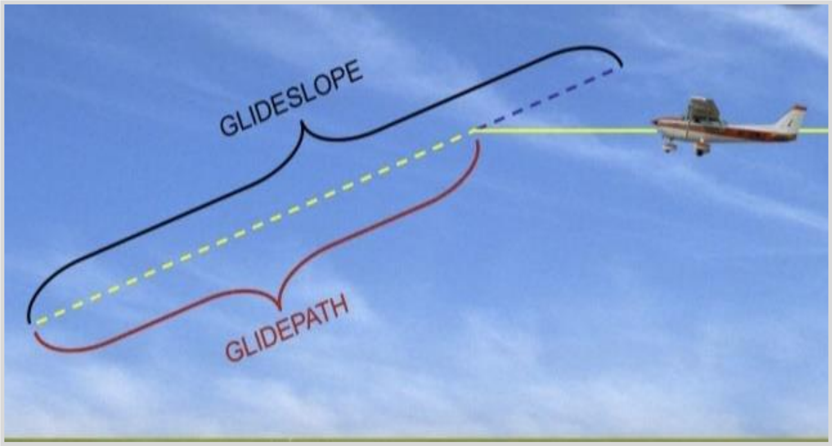


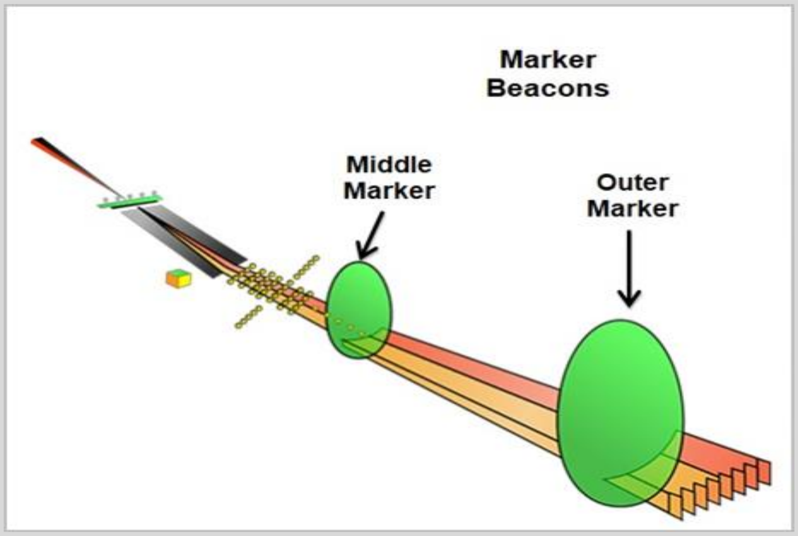
Lateral

- On-course indications are provided to the pilot 2½ degrees either side of the centerline
- Proper off-course indications are provided throughout the following angular areas of the operational service volume:
  - To 10 degrees either side of the course along a radius of 18NM from the antenna
  - From 10 to 35 degrees either side of the course along a radius of 10NM
- Unreliable signals may be received outside these areas (the pilot will receive an indication on their instruments if the signal is unreliable)



Note: *ILS approach is not usable if localizer is out of service.*

Glideslope/ Glidepath	The glideslope provides the pilot with vertical guidance to the runway in the direction of the localizer front course. ▪ The glideslope transmitter operates in the Ultrahigh Frequency (UHF) band ▪ Glideslopes and localizer frequencies are paired via channelization ▪ The glidepath is the portion of the glideslope that intersects the localizer The glideslope transmitter is located approximately 1,000 feet from the approach end of the runway (down the runway). The signal provides descent information for navigation down to the lowest authorized decision altitude (DA).  

Marker Beacons	The purpose of marker beacons is to identify particular locations on the approach to an instrument runway. ■ Marker beacons have a rated power output of 3 watts or less and an antenna array designed to produce an elliptical pattern with dimensions: • At 1,000 feet above the antenna • Approximately 2,400 feet in width and 4,200 feet in length ■ Ordinarily, there are two marker beacons associated with an ILS: • Outer Marker (OM) • Middle Marker (MM)  
Approach Lights	Approach lights provide the basic means to transition from instrument flight to visual flight for landing. ■ They are a configuration of signal lights starting at the runway threshold and extending into the approach area • The configuration depends on the operational requirements of the runway ■ Some systems include sequenced flashing lights that appear to the pilot as a ball of light traveling towards the runway at high speed 

Video – *Instrument Landing System Summary* (5:23 mins.)

Knowledge Check E

REVIEW what you have learned so far about the ILS navigational system. ANSWER the questions listed below.

1. Match the ILS components to the description of the component. Enter your answers in the spaces below.

d	Provides horizontal guidance along the extended centerline of the runway	a. Compass Locator
e	Provides vertical guidance along the descent path toward the runway touchdown point	b. Marker Beacons
b	Give range information along the approach path	c. DME
f	Assist in transition from instrument to visual flight	d. Localizer
a	An L/MF radio beacon installed at the site of the outer or middle marker	e. Glideslope
c	Provide positive distance-to-touch information along with the GS transmitter	f. Approach Lights

2. Which of the following are primary components of the ILS? *(Select all correct answers that apply.)*
   - ❑ DME
   - ❑ **Glideslope**
   - ❑ Approach Lights
   - ❑ **Marker Beacons**
   - ❑ **Localizer**

3. Which of the following correctly describe a usable lateral localizer signal? *(Select all correct answers that apply.)*
   - ❑ At 4,500 ft. above the elevation of the antenna site
   - ❑ **Off-course indications provided 10 to 35º either side of the course along a radius of 10NM**
   - ❑ Between an altitude of 1,000 ft. above the highest terrain along the course line
   - ❑ **Off-course indications provided 10º either side of the course along a radius of 18NM from the antenna**
   - ❑ **On-course indications are provided 2 ½º either side of the centerline**

4. A localizer transmitter operates in the ____ band and the glideslope operates in the ___ band. *(Select the correct answer.)*
   - ❑ UHF, VHF
   - ❑ **VHF, UHF**
   - ❑ UHF, UHF

5. What is the purpose of the marker beacons on the ILS? *(Select the correct answer.)*
   - ❑ Provide the pilot with vertical guidance to the runway in the direction of the localizer front course
   - ❑ **Identify particular locations on the approach to an instrument runway**
   - ❑ Provide basic means to transition from instrument flight to visual flight for landing

ILS Summary

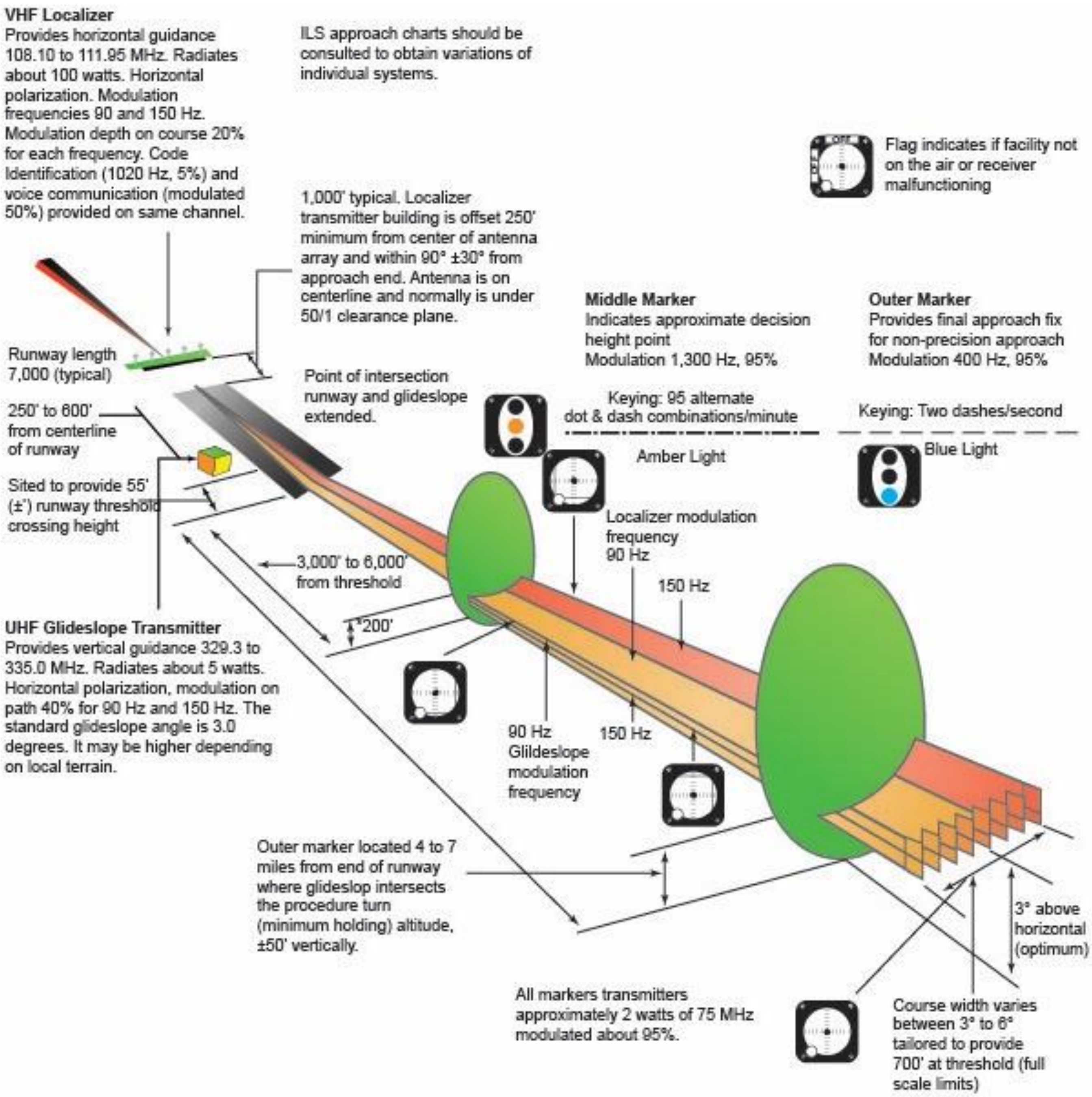
An instrument landing system enables aircraft to land if the pilots are unable to establish visual contact with the runway by way of transmitted radio signals. The lesson identified components and characteristics of ILS. Understanding how the system functions will enable the air traffic controller to communicate with pilots that need assistance with landing procedures.

FACILITATOR INSTRUCTIONS	DELIVERY METHOD
■ Review content presented in ***Instrument Landing System (ILS)*** lesson and ***ILS Summary*** video ■ Navigate to the ***Parking Lot*** link within Blackboard and review any student questions ■ Address ***Parking Lot*** questions and facilitate a brief discussion of the lesson content	Facilitated Discussion **EST. RUN TIME** 15 mins.

FACILITATOR INSTRUCTIONS	DELIVERY METHOD
■ This portion of training will be conducted by the facilitator ■ Instruct students to navigate to the study aids ***Radio and Satellite Navigation Grid*** and ***The Instrument Landing System*** located in the Student Guides ■ Facilitator will review content presented in the study aids ■ Instruct students to reference the study aids as they continue working through the module	Study Aid **EST. RUN TIME** 15 mins.

STUDY AID: RADIO AND SATELLITE NAVIGATION GRID

NAVIGATION SYSTEM	FREQUENCY BAND	FREQUENCY RANGE	KEY CONCEPT
VOR	VHF	108.0-117.95 MHz	360 MAG Radials
TACAN	UHF	960-1215 MHz	360 MAG Radials + DME
DME	UHF	962-1213 MHz	Transponder on Ground
VORTAC	VHF/UHF	-	Combined VOR and TACAN
RNAV (CLC)	-	-	Course Line Computer "Offsets" NAVAID Waypoint must be within NAVAID Reception Range
INS	-	-	Self-Contained
NDB	L/MF	190-535 KHz	Least Accurate/Lightning Precipitation Static
ILS	LOC-VHF GS-UHF	LOC - 108.10-111.95 MHz GS - 329.15-335.0 MHz	Both Horizontal and Vertical Guidance NDB Used with Marker Beacon is Compass Locator



Speed (Knots)	Angle		
	2.5°	2.75°	3°
90	400	440	475
110	485	535	585
130	575	630	690
150	665	730	795
160	707	778	849

Compass locators, rated at 25 watts output 190 to 535 KHz, are installed at many outer and some middle markers. A 400 Hz or a 1020 Hz tone, modulation the carrier about 95%, is keyed with the first two letters of the ILS identification on the outer locator and the last two letters on the middle locator. At some locations, simultaneous voice transmissions from the control tower are provided, with appropriate reduction in identification percentage

*Figures marked with asterisk are typical. Actual figures vary with deviations in distances to markers, glide angles and localizer widths.

FACILITATOR INSTRUCTIONS	DELIVERY METHOD
■ **ENABLE *Inertial and Satellite Navigation Systems*** lesson in Blackboard ■ Instruct students to navigate to the ***Inertial and Satellite Navigation Systems*** lesson in Blackboard ■ Instruct students to work individually through the lesson content ■ Upon completion of the lesson, students should review previously introduced content or wait quietly until other students have completed	Blackboard **EST. RUN TIME** 35 mins.

INERTIAL AND SATELLITE NAVIGATION SYSTEMS

Purpose: This lesson explains the types of satellite-based navigation systems and the components and characteristics of both Inertial Navigation (INS) and satellite-based navigation systems.

Objectives:

- Identify components of INS
- Identify characteristics of INS
- Identify types of satellite-based navigation systems
- Identify components of satellite-based navigation systems
- Identify characteristics of satellite-based navigation systems

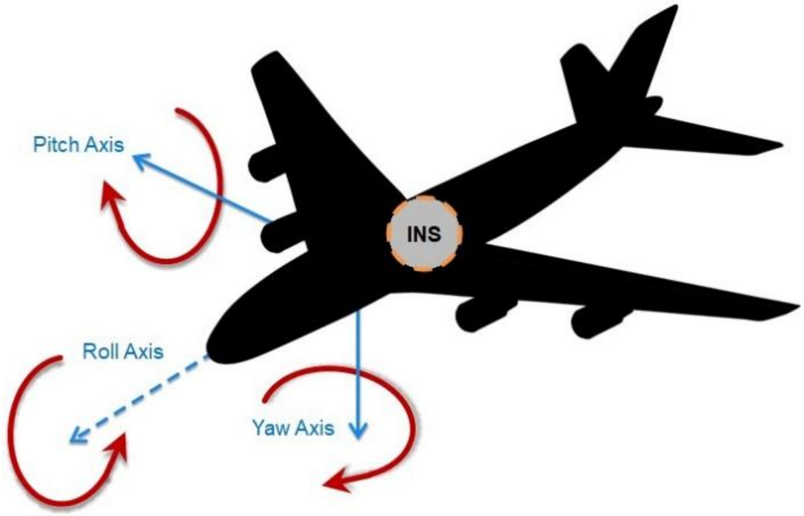
The references for this lesson are as follows:

- FAA Order JO 7110.65, Air Traffic Control
- FAA-H-8083-15, Instrument Flying Handbook
- FAA-H-8083-25, Pilot's Handbook of Aeronautical Knowledge
- Aeronautical Information Manual (AIM)

Inertial Navigation System (INS)

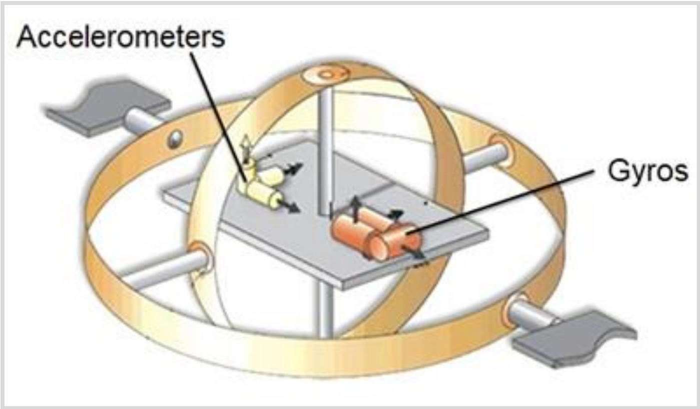
Inertial Navigation System (INS) is a system that navigates precisely without any input from outside of the aircraft. It is fully self-contained. The INS is initialized by the pilot, who enters into the system the exact location of the aircraft on the ground before the flight. The INS is also programmed with waypoints along the desired route of flight.

INS is considered a stand-alone navigation system, especially when more than one independent unit is onboard.



The airborne equipment consists of:

- An **accelerometer** to measure acceleration which, when integrated with time, gives velocity
- **Gyros** to measure direction



Characteristics

The principal error associated with INS is degradation of position with time. INS computes position by starting with accurate position input which is changed continuously as accelerometers and gyros provide speed and direction inputs. Both accelerometers and gyros are subject to very small errors; as time passes, those errors accumulate.

- Position update alignment can be accomplished in-flight using ground-based references
- Many INS systems now have sophisticated automatic updates using dual DME and or VOR inputs

INS may be approved as the sole means of navigation or may be used in combination with other systems.

Knowledge Check F

REVIEW what you have learned so far about the INS. ANSWER the question listed below.

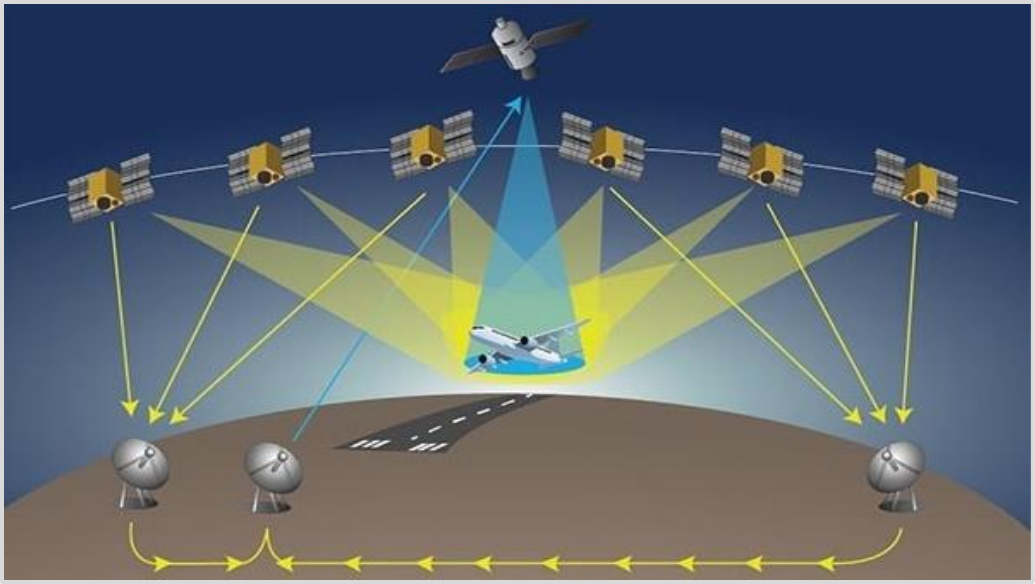
1. How does the INS receive information to provide aircraft position and navigation information? *(Select the correct answer.)*
   - ❑ Information is in response to movement of accelerometer
   - ❑ **<u>Information is in response to inertial effects on system components</u>**
   - ❑ Information is in response to navigational positioning

Global Navigation Satellite System (GNSS)

GNSS refers collectively to the worldwide positioning, navigation, and timing determination capability available from one or more satellite constellations in conjunction with a network of ground stations.

GPS Navigation

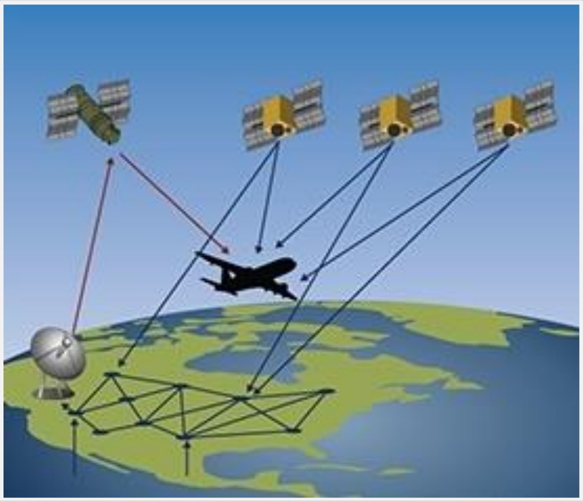
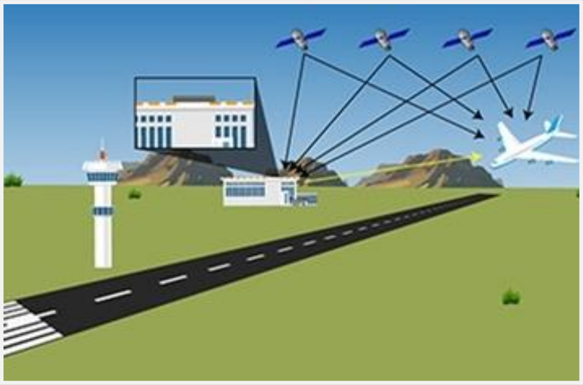
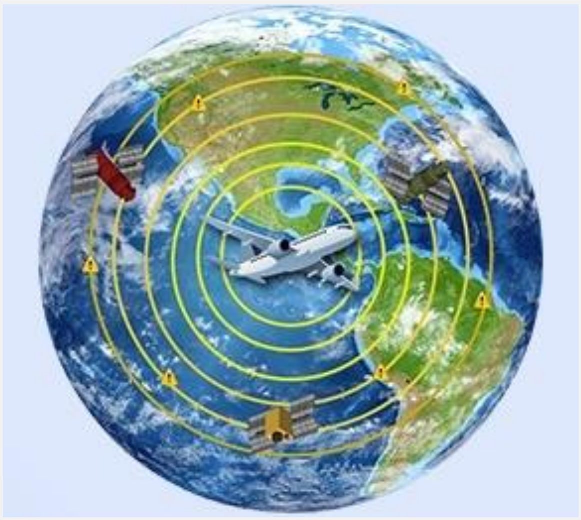
The **Global Positioning System (GPS)** is a satellite−based radio navigation system, which broadcasts a signal that is used by receivers to determine precise position anywhere in the world.



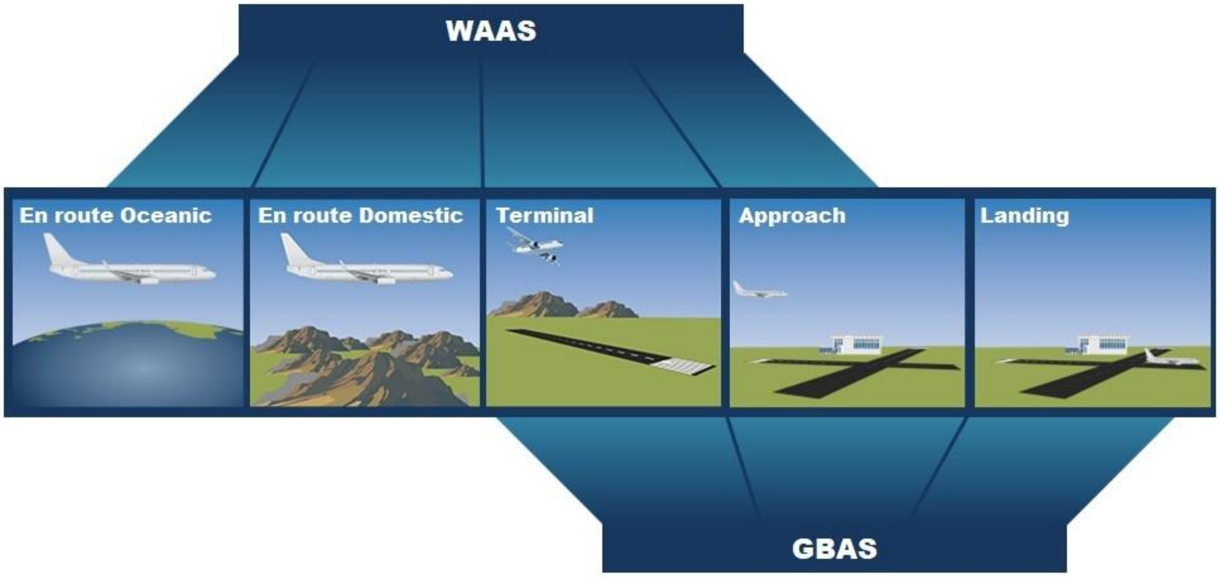
- The receiver tracks multiple satellites and determines a pseudorange measurement that is then used to determine the user location
- The GPS constellation of 24 satellites is designed so that a minimum of five is always observable by a user anywhere on Earth
- A minimum of four satellites is necessary to establish an accurate three-dimensional position (latitude, longitude and altitude)
- The Department of Defense (DOD) is responsible for operating the GPS satellite constellation and monitoring the GPS satellites to ensure proper operation

GPS Augmentation Systems

There are three systems used in aviation to confirm and improve GPS accuracy:

SYSTEM	FEATURES/CHARACTERISTICS
Wide Area Augmentation System (WAAS) 	**WAAS** is a satellite navigation system consisting of the equipment and software which augments the GPS Standard Positioning Service (SPS). ▪ The WAAS provides enhanced integrity, accuracy, availability, and continuity over and above GPS SPS ▪ The differential correction function provides improved accuracy required for precision approach
Ground Based Augmentation System (GBAS) 	**GBAS** is a system that provides differential corrections and integrity monitoring of Global Navigation Satellite Systems (GNSSs). ▪ GBAS provides navigation and precision approach service in the vicinity of the host airport ▪ Broadcasts differential correction message via a very high frequency (VHF) radio data link from a ground-based transmitter
Receiver Autonomous Integrity Monitoring (RAIM) 	**RAIM** is used by the GPS receiver to verify the integrity (usability) of the signals received from the GPS constellation. RAIM determines if a satellite is providing corrupted information. At least one satellite, in addition to those required for navigation, must be in view for the receiver to perform the RAIM function; thus, RAIM needs a minimum of five satellites in view.

WAAS / GBAS Implementation

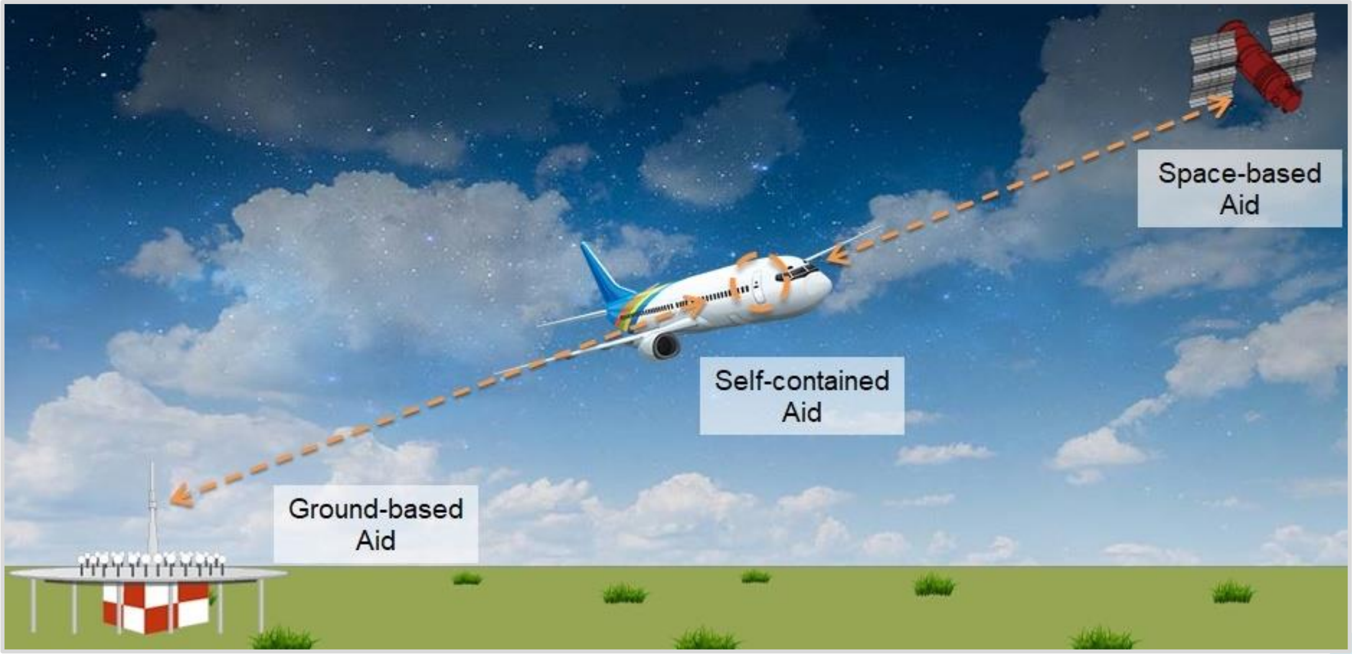


Video – *Navigation at the Crossroads* (9:13 mins.)

Note: *The term Local Area Augmentation System (LAAS) has been replaced with Ground Based Augmentation System (GBAS), the ICAO equivalent.*

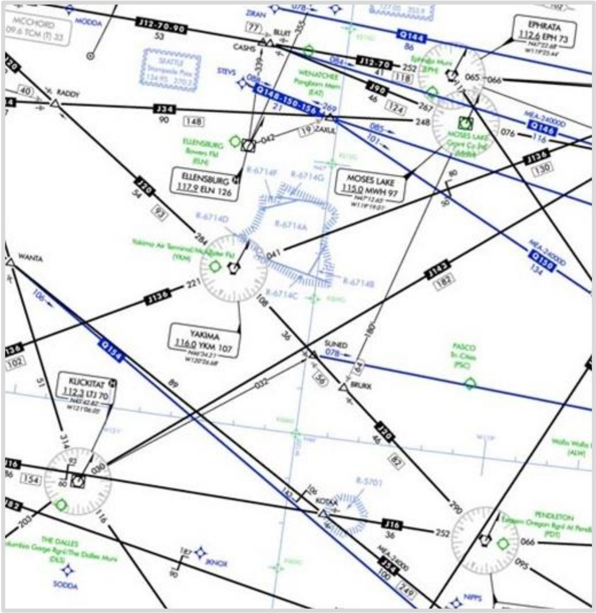
Area Navigation (RNAV)

Area Navigation (RNAV) is a method of navigation which permits aircraft operation on any desired flight path within the coverage of ground- or space-based navigation aids (NAVAIDs) or within the limits of the capability of self-contained aids, or a combination of these.



Characteristics

- Most RNAV systems include a Flight Management System (FMS) computer
  - The FMS uses a large database to allow routes to be preprogrammed
  - The system is constantly updated by reference to conventional NAVAIDs
- This sophisticated program and its associated database ensure that the most appropriate aids are automatically selected during the information update cycle

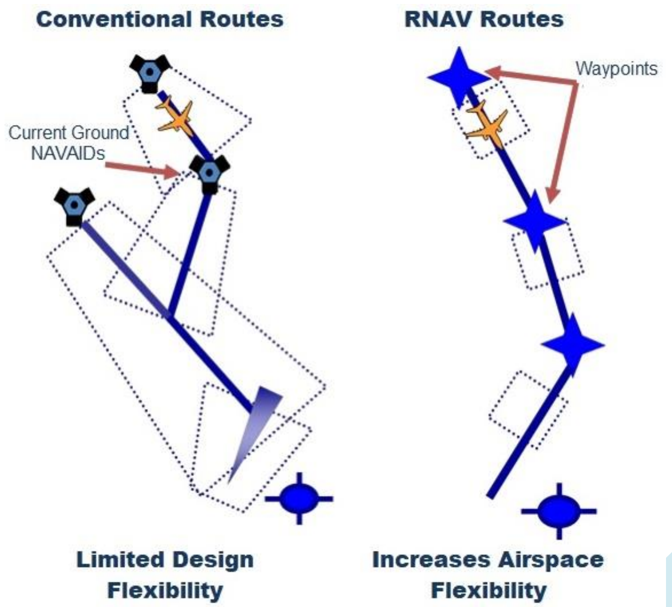


Waypoints

A **waypoint** is a predetermined geographical position used for route/instrument approach definition, progress reports, published VFR routes, or visual reporting points that are defined relative to a VORTAC station or in terms of latitude/longitude coordinates.

- A series of waypoints make up an RNAV route

Area Navigation (RNAV) Routes

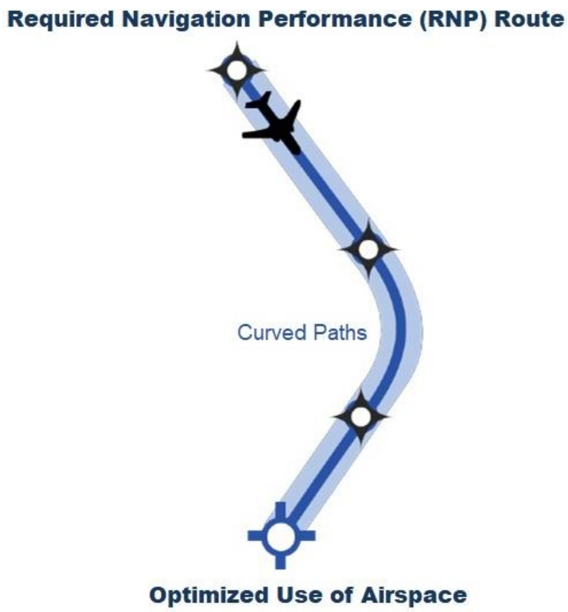


- Published RNAV routes are permanent routes which can be flight-planned for use by aircraft with RNAV capability
- Unpublished, or "random," RNAV routes are direct routes, based on RNAV capability, between waypoints defined in terms of any of the following:
  - Published fixes
  - Latitude/longitude coordinates
  - Degree-distance fixes
  - Offsets from established routes/airways at a specified distance and direction
- Radar monitoring by air traffic control (ATC) is required for all Instrument Flight Rules (IFR) aircraft on all random RNAV routes (except in Alaska)

Performance-Based Navigation (PBN)

PBN is area navigation based on performance requirements for aircraft operating along an Air Traffic Service (ATS) route, on an instrument approach procedure, or in designated airspace.

- Composed of Area Navigation (RNAV) and Required Navigation Performance (RNP)
- Required navigation performance (RNP), is a specified level of accuracy defined by a lateral area of confined airspace in which an RNP-certified aircraft operates
- Describes an aircraft's capability to navigate using performance standards



Knowledge Check G

REVIEW what you have learned so far about navigational systems. ANSWER the questions listed below.

1. What navigational system is a self-contained navigation system that provides aircraft position and navigation information? *(Select the correct answer.)*
   - ❑ WAAS
   - ❑ RNAV
   - ❑ **INS**

2. Match the type of navigation system to the description of the system. Enter your answers in the spaces below.

__c__	Satellite-based navigation system consisting of the equipment and software which augments the GPS SPS	a. GBAS
__a__	Provides differential corrections and integrity monitoring of GNSS	b. RAIM
__b__	GPS receiver verifies the integrity of the signals received from the GPS constellation, to determine if a satellite is providing corrupted information	c. WAAS

3. Who is responsible for operating the GPS satellite constellation and monitoring the GPS satellites to ensure proper operation? *(Select the correct answer.)*
   - ❑ NASA
   - ❑ FAA
   - ❑ **DOD**

4. Which of the following are characteristics of RNAV systems? *(Select all correct answers that apply.)*
   - ❑ **Database ensures that the most appropriate aids are automatically selected during updates**
   - ❑ Receiver tracks multiple satellites and then determines the user location
   - ❑ **Most systems include an FMS computer**
   - ❑ Does not require information from external references

5. A series of ________________ make up an RNAV route. *(Select the correct answer.)*
   - ❑ Stars
   - ❑ **Waypoints**
   - ❑ Constellations

6. Which navigation system is based on performance requirements for aircraft operating along an ATS route? *(Select the correct answer.)*
   - ❑ INS
   - ❑ **PBN**
   - ❑ WAAS

Inertial and Satellite Navigation Systems Summary

INS and satellite-based navigational systems are available for use in aviation. Successful air navigation involves planning and controlling the movement of the aircraft from one destination to another without getting lost. Constant awareness of position is critical and must be maintained; therefore, having knowledge of these systems will provide options while navigating.

FACILITATOR INSTRUCTIONS	DELIVERY METHOD
■ Review content presented in ***Inertial and Satellite Navigation Systems*** lesson ■ Navigate to the ***Parking Lot*** link within Blackboard and review any student questions ■ Address ***Parking Lot*** questions and facilitate a brief discussion of the lesson content	Facilitated Discussion **EST. RUN TIME** 15 mins.

FACILITATOR INSTRUCTIONS	DELIVERY METHOD
■ **ENABLE *Airways and Routes*** lesson in Blackboard and ***NAVAID Know-How*** activity in ***Exercises and Activities*** folder in Blackboard ■ Instruct students to navigate to the ***Airways and Routes*** lesson in Blackboard ■ Instruct students to work individually through the lesson content ■ Upon completion of the lesson, instruct students to proceed to ***NAVAID Know-How*** activity in ***Exercises and Activities*** folder in Blackboard ■ The activity may be performed individually ■ Instruct students to answer each question ■ At the end of the activity, the activity will evaluate the students' performance ■ Suggest allowing opportunities to repeat the activity during periods of down time	Blackboard and Activity **EST. RUN TIME** 15 mins.

AIRWAYS AND ROUTES

Purpose: This lesson explains Air Traffic Service routes and airways established for air navigation purposes.

Objectives:

- Identify characteristics of airways established for federal airway system
- Identify characteristics of routes established for federal airway system

The references for this lesson are as follows:

- FAA Order JO 7110.65, Air Traffic Control
- Aeronautical Information Manual (AIM)

Air Traffic Service (ATS) Routes

The term “ATS route” is a generic term that includes “Very High Frequency Omnidirectional Range (VOR) Federal airways (called Victor Airways),” “colored Federal airways,” “jet routes,” and “Area Navigation (RNAV) routes.” The term “ATS routes” does not replace these more familiar names, but serves only as an overall title when listing the types of routes that comprise the United States route structure.

Note: *Except for G13 in North Carolina, the colored airway system exists only in the state of Alaska. All other such airways formerly so designated in the conterminous U.S. have been rescinded.*

Airways and Routes

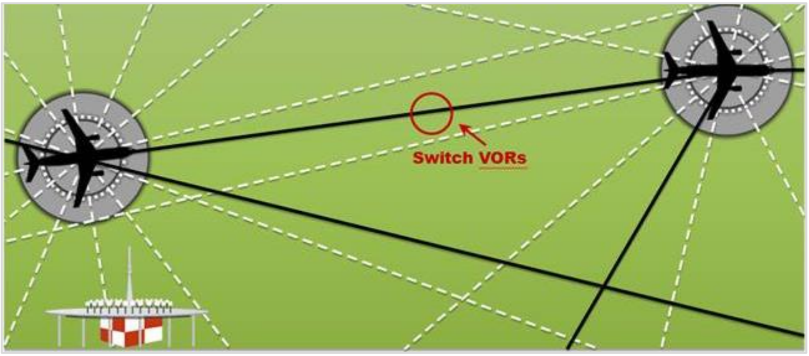
Three fixed route systems are established for air navigation purposes. They are:

- Airways (Class E Airspace)
- Jet Route System (Class A Airspace)
- RNAV Routes (Class A and Class E Airspace)

VOR-to-VOR Navigation

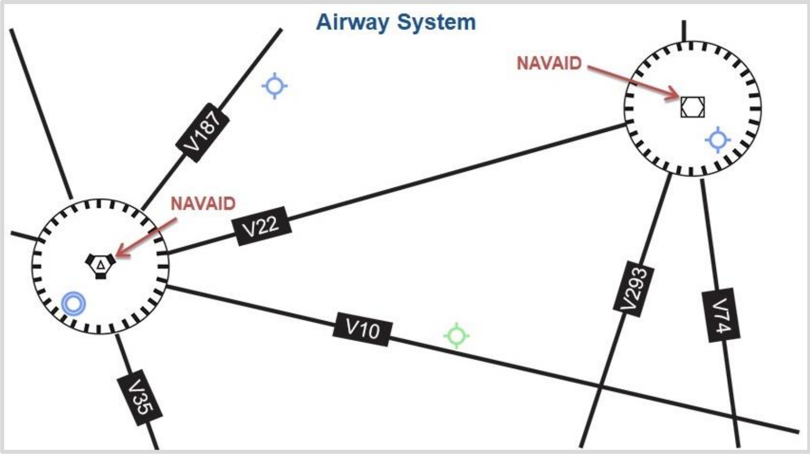
Many VORs are connected by specific radials, forming routes called jet routes or victor airways.

- Pilots navigate outbound from one VOR until reaching the changeover point, then navigate inbound to the second VOR
- Unless otherwise charted, the changeover point is midway between navigation aids (NAVAIDs)



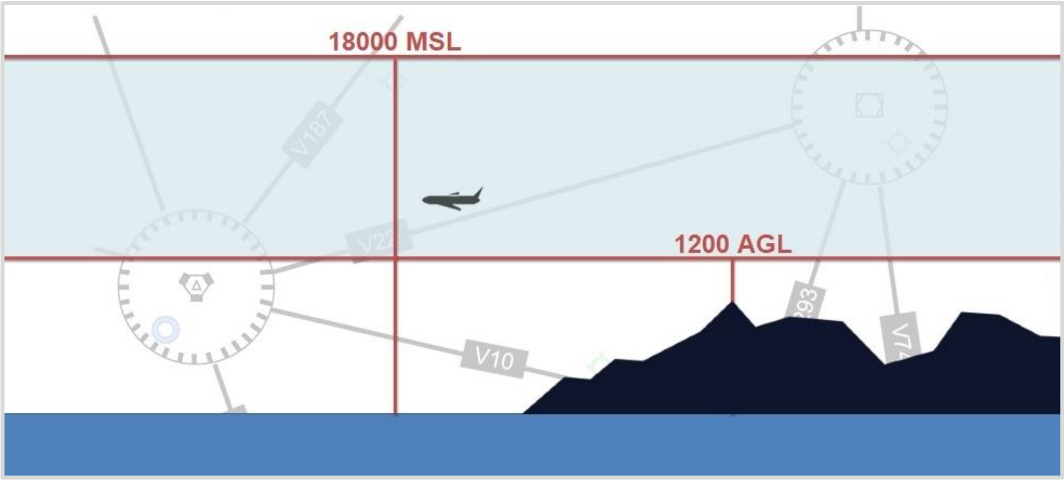
Airway System

VOR airways are established in Class E airspace in the form of a corridor, the centerline of which is defined by radio NAVAIDs. VOR airways are defined by radials of VORs.



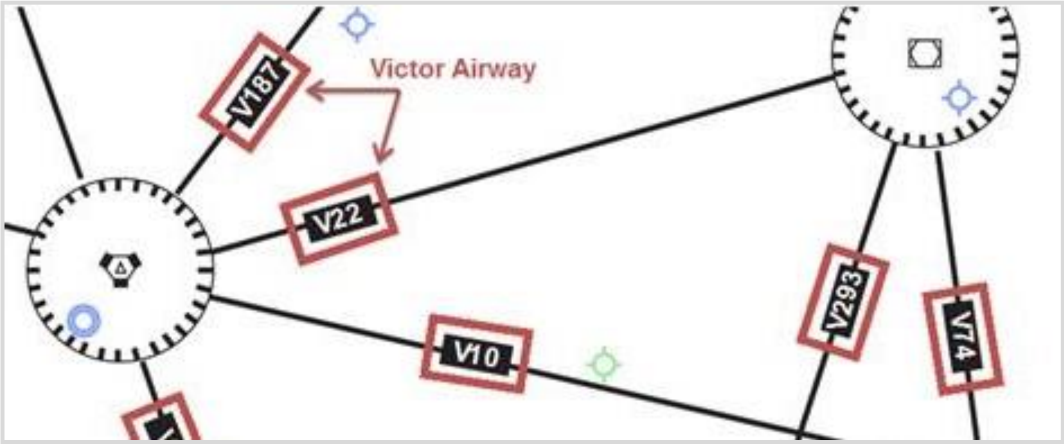
Characteristics

The VOR airway system consists of airways designated generally from 1200 AGL up to, ***but not including***, 18000 mean sea level (MSL). VOR airways and jet routes are generally aligned in an overlying manner to facilitate transition between Class A and Class E airspace.



VOR airways are identified on charts by the letter “V” followed by the route’s identifying number.

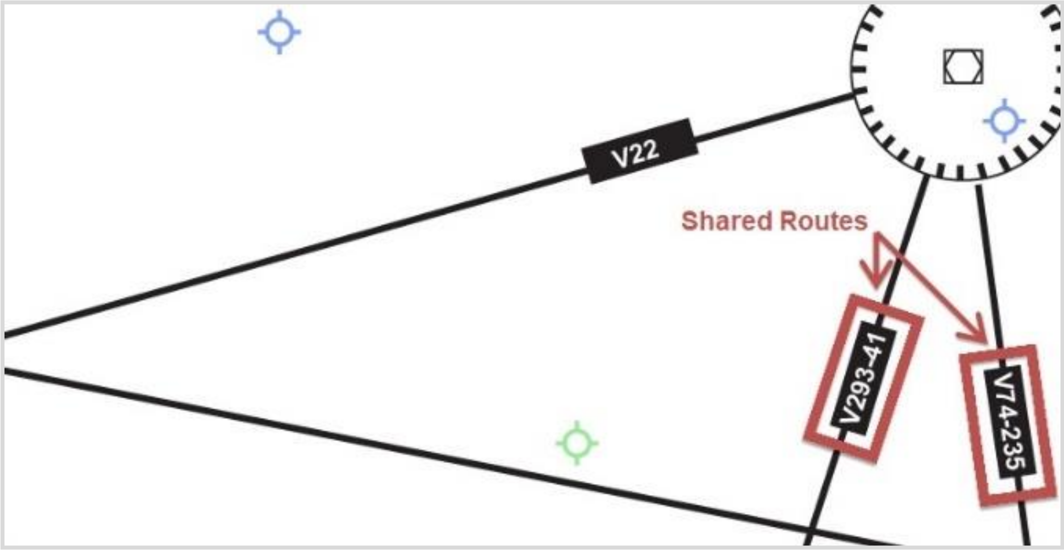
- Odd-numbered airways are generally oriented north-south, while even-numbered airways are generally oriented east-west
- The phraseology for VOR airways is to state the letter “V” phonetically (Victor) followed by the number in group form



Example: V611 is spoken “VICTOR SIX-ELEVEN”

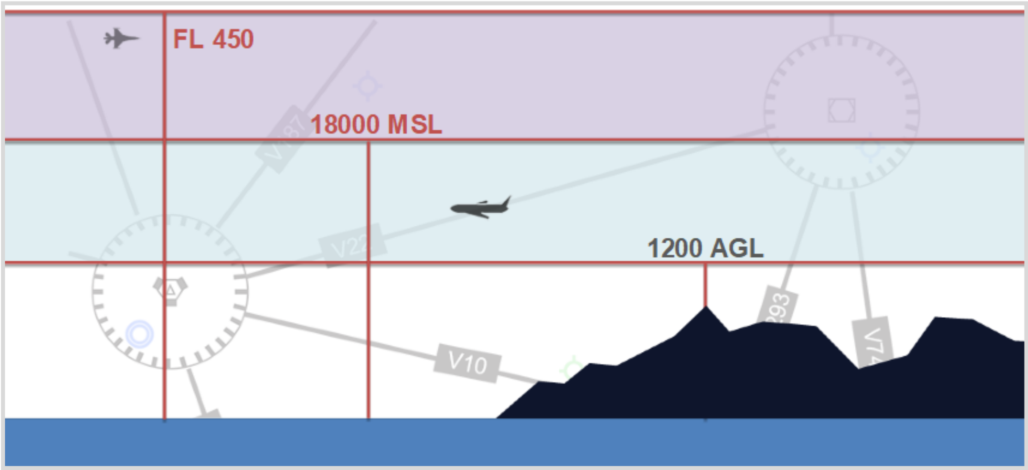
Two Airways Sharing the Same Route

A segment of an airway that is common to two or more routes carries the numbers of all the airways that coincide for that segment.



Jet Route System

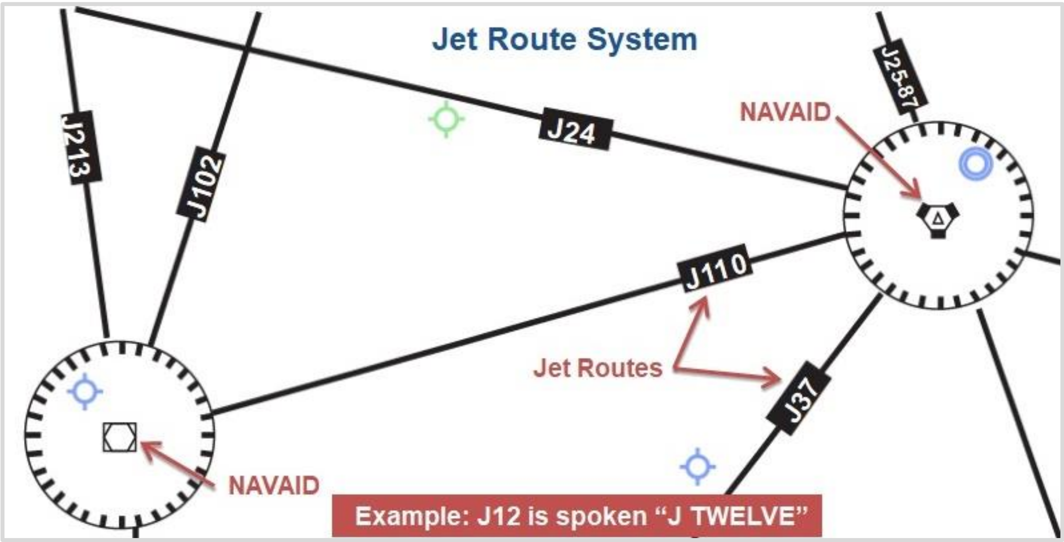
The jet route system consists of routes established from 18000 MSL to flight level FL 450, inclusive. These routes are depicted on En Route High Altitude Charts. In the conterminous United States, jet routes are defined in terms of radials of VORs. NAVAID limitations prohibit the establishment of jet routes above FL 450.



Jet Route Characteristics

Jet routes are identified on charts by the letter “J” followed by the route’s identifying number.

- Odd-numbered routes generally go in a north-south direction, while even-numbered routes generally go east-west
- The phraseology for jet routes is to state the letter “J” followed by the number in group form

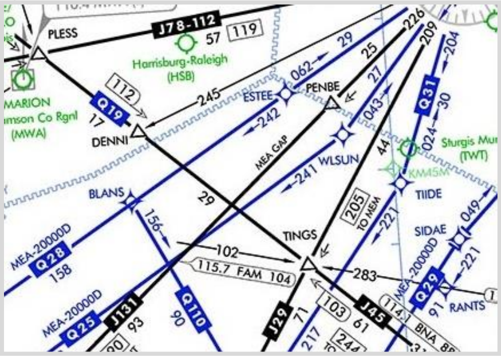


RNAV Route

Published RNAV routes are routes which can be flight-planned for use by aircraft with RN AV capability.

RNAV Route Characteristics

RNAV Route System

Q Routes 	Q routes are for use by aircraft operating from 18000 MSL up to and including FL 450 and are depicted on En Route High Altitude Charts. ▪ The phraseology for Q routes is to state the letter “Q” followed by the number in group form **Example:** Q34 is spoken “Q THIRTY-FOUR”
T Routes 	T routes are for use by aircraft operating up to, but not including, 18000 MSL, and are depicted on En Route Low Altitude Charts. ▪ The phraseology for T routes is to state the letter “T” phonetically (Tango), followed by the number in group form **Example:** T210 is spoken “TANGO TWO-TEN”

Knowledge Check H

REVIEW what you have learned so far about ATS routes. ANSWER the questions listed below.

1. What are the three fixed route systems established for air navigation purposes? *(Select the correct answer.)*
   - ❑ Airways, jet routes, RNP routes
   - ❑ Military routes, airways, RNAV routes
   - ❑ **Jet routes, airways, RNAV routes**

2. Which airspace is established for RNAV routes? *(Select the correct answer.)*
   - ❑ **Class A and E**
   - ❑ Class E
   - ❑ Class B

3. Which example of an airway label shows an airway with two routes? *(Select the correct answer.)*
   - ❑ J102_45
   - ❑ **V293-41**
   - ❑ T95 and 109

4. What is the upper limit of a low altitude VOR airway? *(Select the correct answer.)*
   - ❑ Up to and including 18000 MSL
   - ❑ **<u>Up to, but NOT including, 18000 MSL</u>**
   - ❑ Up to, but **NOT** including, FL 180

5. The upper limit of the jet route structure is ________. *(Select the correct answer.)*
   - ❑ **<u>Up to and including FL 450</u>**
   - ❑ Up to and including FL 600
   - ❑ Up to, but not including, FL 600

6. Q routes are __________________. *(Select the correct answer.)*
   - ❑ RNAV routes designed for low altitude charts
   - ❑ Radio navigation routes designed for low altitude charts
   - ❑ **<u>RNAV routes designed for high altitude charts</u>**

Airways and Routes Summary

Airways can be thought of as three-dimensional highways for aircraft. Each of the different types of routes that comprise the United States route structure has its purpose. This lesson explained Air Traffic Service routes and airways established for air navigation purposes.

FACILITATOR INSTRUCTIONS	DELIVERY METHOD
▪ ***Note: NAVAID Know-How*** should have already been enabled in Blackboard, if not ensure it is enabled ▪ Instruct students to navigate to the ***Exercises and Activities*** folder in Blackboard ▪ Instruct students to locate student activity ***NAVAID Know-How*** ▪ The activity may be performed individually ▪ Instruct students to answer each question ▪ At the end of the activity, the activity will evaluate the students' performance ▪ Suggest allowing opportunities to repeat the activity during periods of down time	Activity **EST. RUN TIME** 25 mins.

ACTIVITY: NAVAID KNOW-HOW (ANSWER KEY)

Note: *The questions in the key and their distractors may appear in a different order than displayed here due to activity question randomization.*

Answers for questions 1–12 come from this word bank:

NDB	INS	DME
VOR	TACAN	ILS
VORTAC	GNSS	

Question	Answer
1. Select the NAVAID that consists of a localizer, glideslope, marker beacons, and approach lights.	**ILS**
2. Select the NAVAID that is an L/MF radio beacon transmitting nondirectional signals where the aircraft is equipped with direction-finding equipment and the pilot can determine his or her bearing to or from the radio beacon.	**NDB**
3. Select the NAVAID that is a UHF electronic rho-theta air NAVAID which provides aircraft with a continuous indication of bearing and distance to itself.	**TACAN**
4. Select the NAVAID that consists of one or more satellite constellations in conjunction with a network of ground stations.	**GNSS**
5. Select the NAVAID that is used to measure the slant range distance of an aircraft from itself.	**DME**
6. Select the NAVAID that provides VOR azimuth, TACAN azimuth, and TACAN DME at one site.	**VORTAC**
7. Select the NAVAIDs that are ground-based.	**NDB; VOR; DME; TACAN; ILS; VORTAC**
8. Select the NAVAID that does not require information from any external references.	**INS**
9. Select the NAVAID that the DOD is responsible for operating and monitoring to ensure proper operation.	**GPS**
10. Select the NAVAID that is composed of a gyro, accelerometer, and navigation computer.	**INS**
11. Select the NAVAIDs that are ground-based, electronic, and transmit VHF navigation signals 360 degrees in azimuth oriented from magnetic north.	**VOR; VORTAC**
12. Select the NAVAID that is a self-contained navigational system.	**INS**

SUMMARY

The purpose of this module was to discuss how the federal airway system works, how NAVAIDs function, and the different approach procedures for landing aircraft.

In accordance with FAA Order JO 7110.65, Air Traffic Control; FAA-H-8083-15, Instrument Flying Handbook; FAA-H-8083-25, Pilot's Handbook of Aeronautical Knowledge; and the Aeronautical Information Manual (AIM), you should now be able to:

- Identify types of radio-based NAVAIDs
- Identify characteristics of radio-based NAVAIDs
- Identify components of radio-based NAVAIDs
- Identify components of ILS
- Identify characteristics of ILS
- Identify components of INS
- Identify characteristics of INS
- Identify types of satellite-based navigation systems
- Identify characteristics of satellite-based navigation systems
- Identify characteristics of airways established for federal airway system
- Identify characteristics of routes established for federal airway system

FACILITATOR INSTRUCTIONS	DELIVERY METHOD
■ Navigate to the ***Parking Lot*** link within Blackboard and review any student questions ■ Address ***Parking Lot*** questions and facilitate a brief discussion of the lesson content ■ Instruct students to prepare for the End-of-Module test by putting away their Student Guides	Facilitated Discussion **EST. RUN TIME** 15 mins.

FACILITATOR INSTRUCTIONS	DELIVERY METHOD
■ **ENABLE *Radio and Satellite Navigation End-of-Module Test*** link in Blackboard ■ Instruct students: ○ Clear desks ○ Do not write anything during or after the test ○ Navigate to the ***Radio and Satellite Navigation End-of-Module Test*** link in Blackboard ○ Once they are satisfied with their responses, click “Save and Submit;” do not click “OK” to review results until directed to do so ○ Choose “Cancel” if they receive a warning message that the test has unanswered questions; choosing OK will submit the test and not allow them to go back and answer the questions ○ Leave the room after submitting the test and return at the “Be Back” time ■ ***Note:*** *This test is scored but not graded* ■ During test, monitor students to ensure a secure testing environment ■ Identify the most commonly missed questions by reviewing student statistics in Blackboard ■ Instruct students to click “View Results” when ready to review commonly missed questions ■ Review commonly missed questions with students	Blackboard Assessment **EST. RUN TIME** 35 mins.

END-OF-MODULE TEST (ANSWER KEY)

Note: *Test questions in Blackboard are presented to the students in random order. Please be aware the test key question order will not match the student version.*

1. What DME equipment on the ground is required to respond to the aircraft interrogator? *(Select the correct answer.)*
   - ❑ **<u>Transponder</u>**
   - ❑ Transmitter
   - ❑ VOR
   - ❑ Receiver

   Reference(s): FAA-H-8083-15, Glossary; AIM, Chap. 1

2. Which of the following make it possible for pilots to navigate with precision to almost any position? *(Select the correct answer.)*
   - ❑ **<u>All of the answers</u>**
   - ❑ Global satellite positioning systems
   - ❑ Refined cockpit instruments
   - ❑ Advanced navigational radio receivers

   Reference(s): FAA-H-8083-25, Chap. 15

3. The effectiveness of the VOR depends upon proper use and adjustment of both _______ and _______ equipment. *(Select the correct answer.)*
   - ❑ **Ground; airborne**
   - ❑ Marker beacons; bearing
   - ❑ Transponder; ground
   - ❑ Airborn; bearing

   Reference(s): Chap. 1; FAA-H-8083-15, Chap. 9

4. The component of the ILS that gives lateral course guidance to the runway is the _________. *(Select the correct answer.)*
   - ❑ **Localizer**
   - ❑ Marker beacon
   - ❑ Glideslope
   - ❑ DME

   Reference(s): FAA-H-8083-15, Chap. 9

5. Which component of the INS measures direction? *(Select the correct answer.)*
   - ❑ **Gyro**
   - ❑ Pitch
   - ❑ Accelerometer
   - ❑ Waypoints

   Reference(s): AIM, Chap. 1; FAA-H-8083-15, Chap. 9

6. What is the principal error associated with INS? *(Select the correct answer.)*
   - ❑ **Degradation of position with time**
   - ❑ Degradation of speed and direction
   - ❑ Computes position by starting with accurate position input
   - ❑ Computes inaccurate position alignment updates

   Reference(s): AIM Chap. 1; FAA-H-8083-15, Chap. 9

7. Which of the following make up an RNAV route? *(Select the correct answer.)*
   - ❑ **Series of waypoints**
   - ❑ Series of NAVAIDs
   - ❑ Set of coordinates
   - ❑ A designated airspace

   Reference(s): JO 7110.65, Pilot/Controller Glossary

8. What does a GBAS navigation system provide? *(Select the correct answer.)*
   - ❑ **Precision approach service in the vicinity of the host airport**
   - ❑ Enhanced integrity, accuracy, availability, and continuity over and above SPS
   - ❑ Alerts when questionable data is being received
   - ❑ Position calculation as it progresses to the destination

   Reference(s): AIM, Chap. 1

9. Odd-numbered airways are generally oriented __________. *(Select the correct answer.)*
   - ❑ **North-south**
   - ❑ East-west
   - ❑ Northwest-southeast
   - ❑ Southwest-northeast

   Reference(s): JO 7110.65 Pilot/Controller Glossary

10. NAVAID limitations prohibit the establishment of jet routes above _______. *(Select the correct answer.)*
   - ❑ **FL 450**
   - ❑ FL 600
   - ❑ FL 850
   - ❑ FL 300

   Reference(s): JO 7110.65 Pilot/Controller Glossary