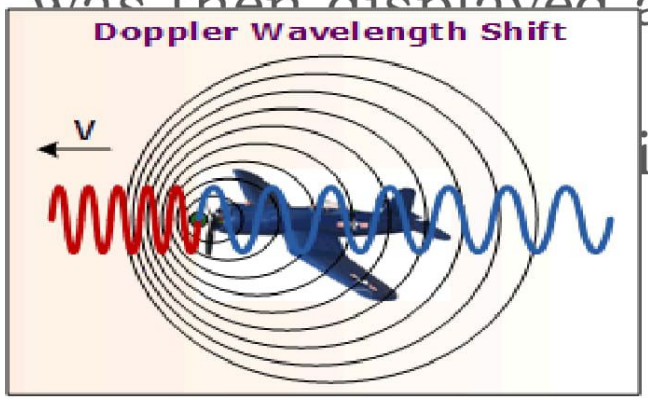
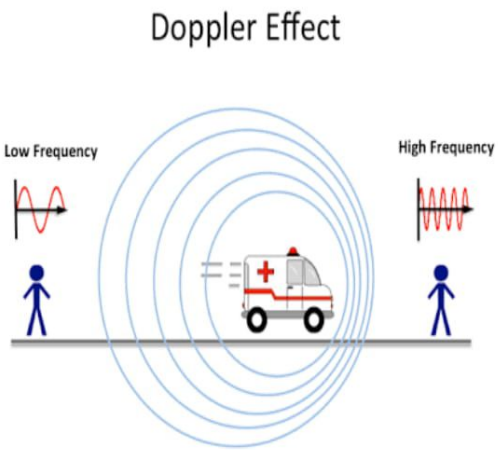
DOPPLER NAVIGATION

The change of frequency of reflected radar waves due to the Doppler effect is utilized by automatic devices to give information on velocity and position.

➢ DOPPLER NAVIGATION

- ✓ A Doppler Navigation System uses the Doppler principle to measure an aircraft's ground speed and drift.
- ✓ The Doppler radar functions by continuous measurement of Doppler shift and converting the measured values to groundspeed and drift angle.
- ✓ In early systems the aircraft's departure point was loaded into a navigation computer, which then converted the aircraft's heading and Doppler ground speed/drift inputs into a continuous display of aircraft position; this was then displayed as latitude and longitude, and / or as track and posi f iles.



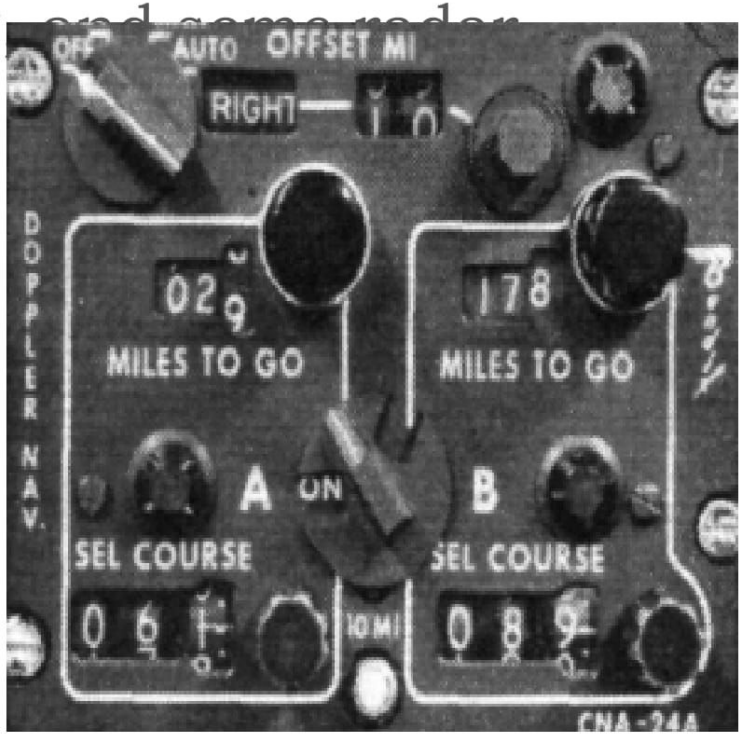


➢ DOPPLER NAVIGATION

- ✓ A Doppler navigation system is a completely self-contained and requires no ground based navigation aids.
- ✓ It is usable worldwide and most accurate overland.
- ✓ The system accuracy drops during flight over the sea because the surface winds, tides and currents move the surface in random directions.
- ✓ At times, the Doppler system also fails to measure a ground speed and drift during flight over a smooth, glassy sea.
- ✓ The latest improved Doppler Navigation Systems combine the inherent accuracy of Doppler ground speed and drift measurement with information from Decca, Inertial Reference Units, Loran C, Global Positioning Systems and VOR/DME, in various combinations to suit customer requirements.

➢ DOPPLER NAVIGATION

- ✓ These navigational inputs also help to eradicate the errors of the original Doppler Navigation Systems, caused by inaccurate heading reference and degradation, or loss, of Doppler ground speed and drift when flying over large expanses of water.
- ✓ The Doppler principle is also utilized in other navigation systems, such as VOR and VDF and some radar equipment.



➢ DOPPLER NAVIGATION

○ THE DOPPLER RADAR

- ✓ The Doppler radar measures groundspeed and drift angle using the "Doppler Effect".
- ✓ The "Doppler Effect" is the frequency shift induced into a signal when the transmitter or receiver, or both, are in motion in relation to each other.
- ✓ The amount of Doppler shift is directly proportional to the aircraft velocity (groundspeed) and can be expressed by the mathematical formula:

Doppler Shift= FV/C

- ✓ Where:

F = frequency transmitted

V = velocity of aircraft (ground speed)

➢ DOPPLER NAVIGATION

○ THE DOPPLER RADAR

- ✓ The Doppler shift is upward ("Up-Doppler") on a beam transmitted forward of a moving aircraft and downward ("Down-Doppler") on a beam transmitted aft.
- ✓ Two other factors must be considered when the Doppler shift is measured by a radar set in an aircraft.
- ✓ First, since both the transmitter and receiver are located in the aircraft, two Doppler shifts are created.
- ✓ One when the wave is transmitted and the second as it is reflected back to the aircraft.
- ✓ A factor of two must now be added to the Doppler formula.

$$\text{Doppler Shift} = 2\,FV/C$$

➢ DOPPLER NAVIGATION

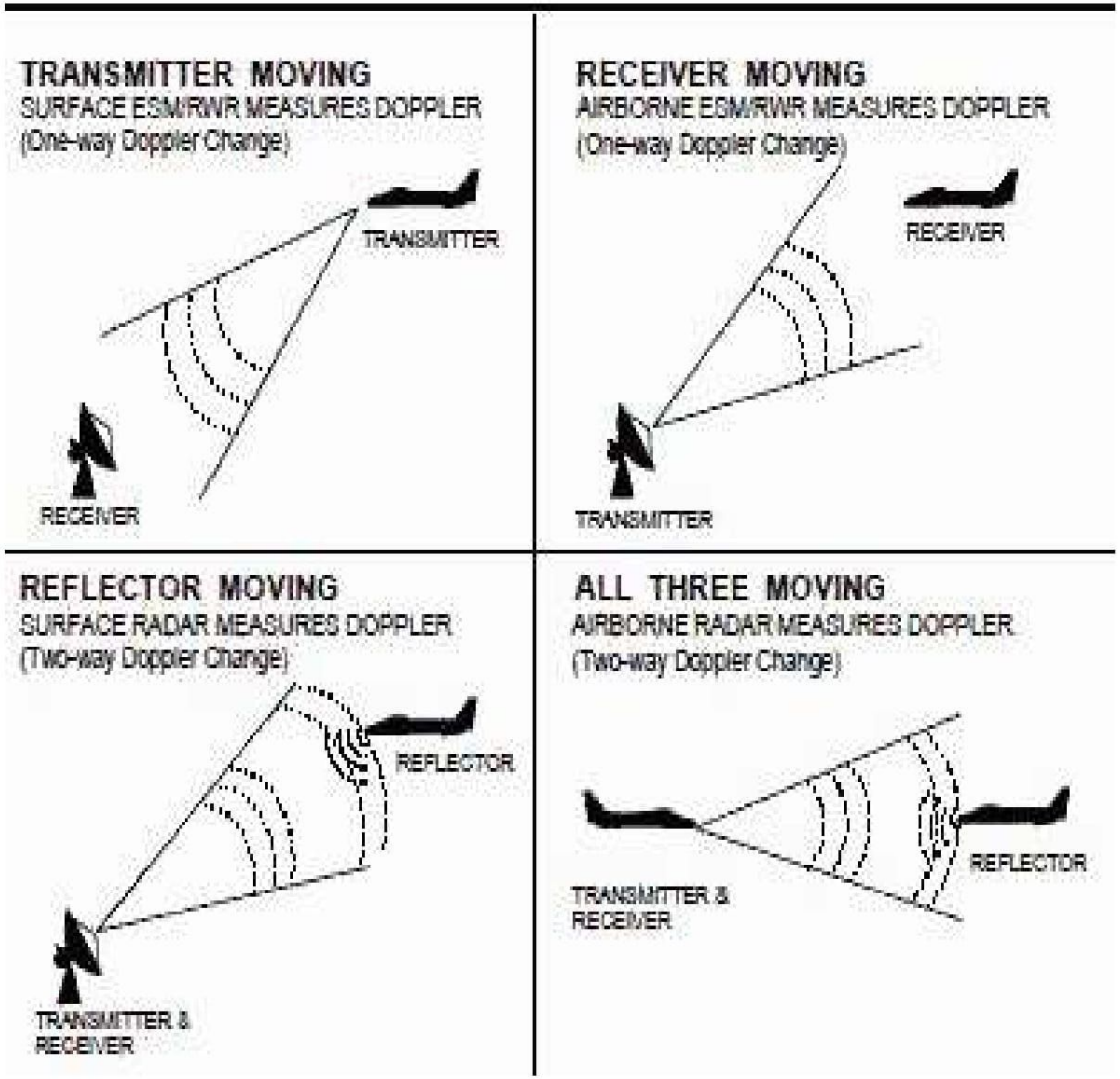
○ THE DOPPLER RADAR

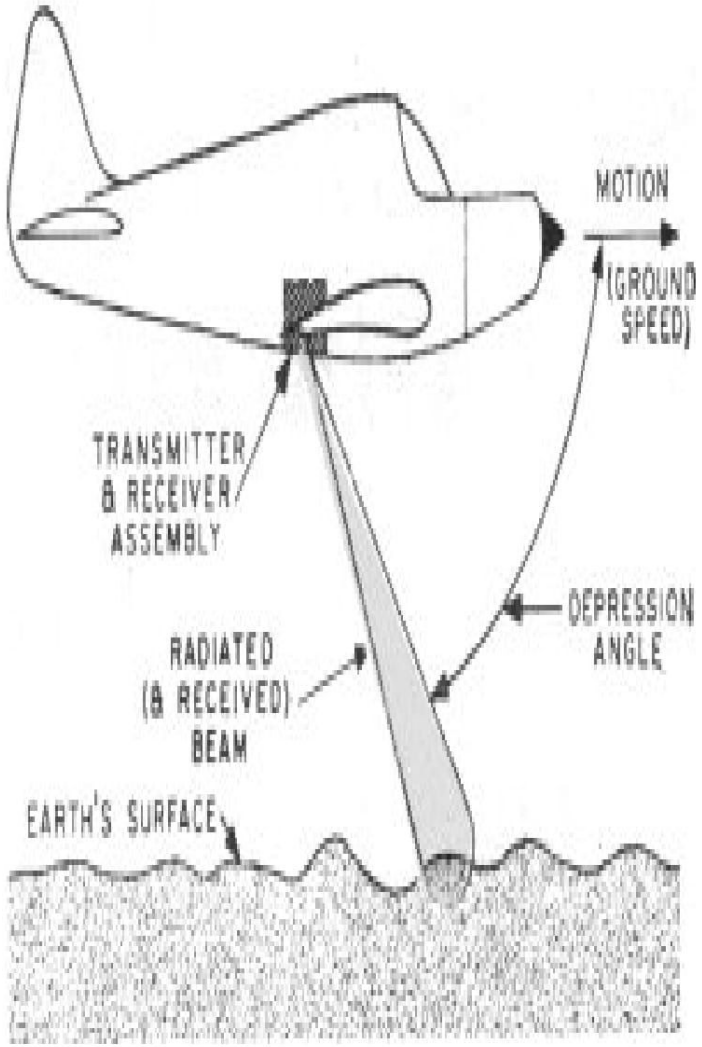
- ✓ The second factor that must be considered is the angle of antenna radiation. Maximum Doppler shift would be received if the antenna beam was transmitted dead ahead.
- ✓ If the beam was directed straight down at the earth, the Doppler shift would be minimum.
- ✓ Since in the aircraft the beam is directed to the ground at an angle between dead ahead (0 degrees) and straight down (90 degrees), we introduce a factor to compensate for this.
- ✓ The factor used is the cosine of the radiating angle (θ). The complete Doppler formula then becomes:

$$\text{Doppler Shift} = 2\,FV\cos\theta/C$$

➢ DOPPLER NAVIGATION

○ THE DOPPLER RADAR





➢ DOPPLER NAVIGATION

○ THE DOPPLER RADAR

- ✓ The Doppler shifts incurred, above and below the transmitted frequency, are detected and converted into an audio signal within the Doppler system at the nominal frequency of 10.33 Hz per knot of groundspeed.
- ✓ The audio signal is used for groundspeed and drift angle computations.
- ✓ The Doppler system transmits one shaped beam forward and one aft.
- ✓ Generally, these beams are angled below the aircraft, fore and aft at a 70˚degree depression angle.
- ✓ This creates an RF energy pattern on the ground much like the illumination pattern of a flashlight beamed at· an angle onto a tabletop.

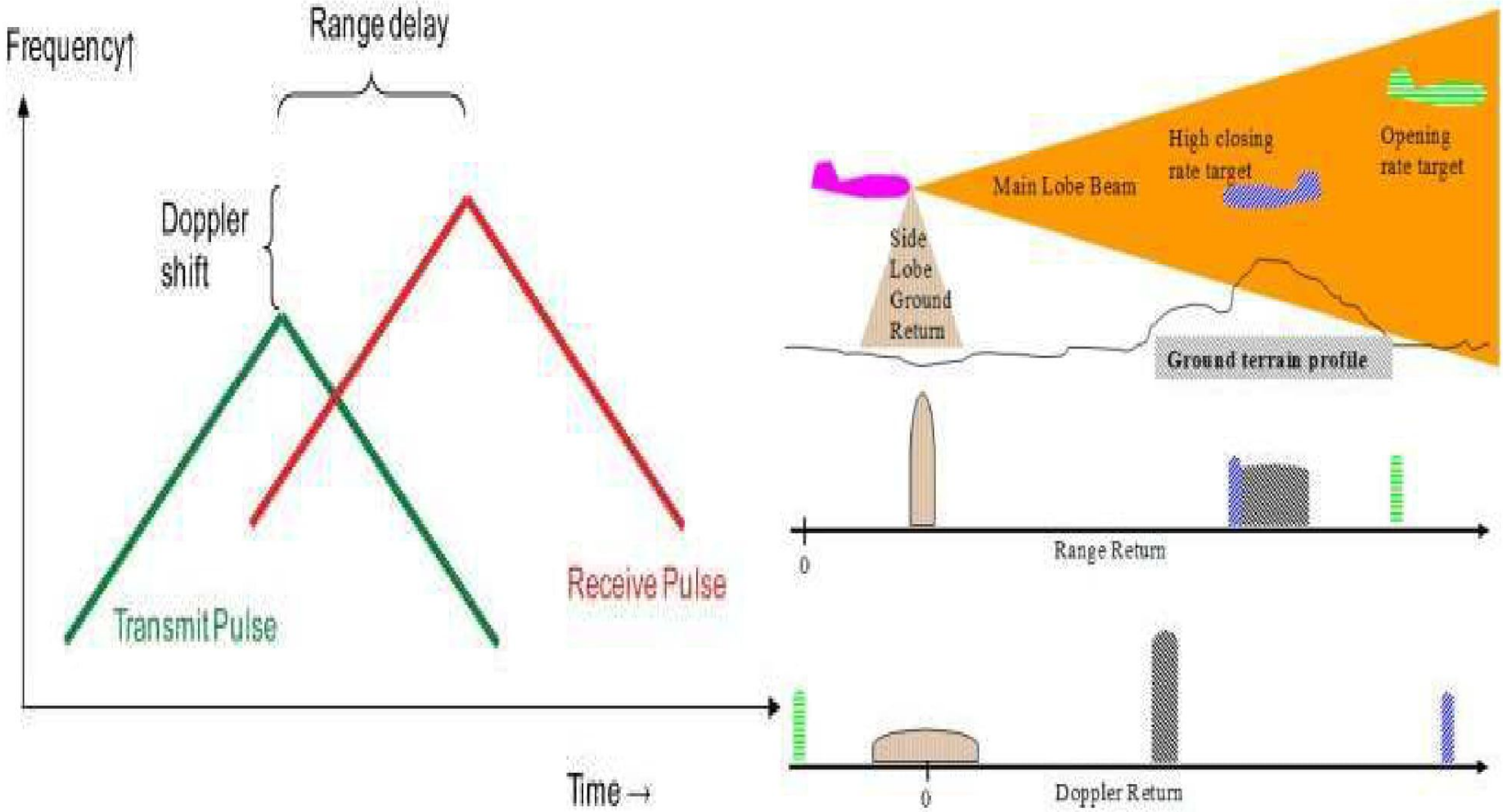
➢ DOPPLER NAVIGATION

○ THE DOPPLER RADAR

- ✓ Two receiver beams are utilized simultaneously, one looking forward, the other looking aft.
- ✓ This ability of a radar set to look in two directions at once is called "Janus" operation.
- ✓ The fore and aft beams are offset from the centerline of the aircraft and are switched from side to side at a specified rate, for example at 3/4 second rate.
- ✓ During the first 3/4 second period, the beams cover the right forward and left aft segments of the transmitted patterns.
- ✓ In the following 3/4 second period, the beams cover the left forward and right aft segments.

➢ DOPPLER NAVIGATION

○ THE DOPPLER RADAR



➢ DOPPLER NAVIGATION

- **THE DOPPLER RADAR**
- The tracker circuits measure ground speed by determining (frequency tracking) the Doppler shift.
- The difference between the Up Doppler and Down-Doppler frequencies is detected to produce a Janus Doppler audio signal which is the sum of the two Doppler shifts and is representative of ground speed.
- In older analogue instrument systems, the Janus Doppler signal was used to drive a servo.
- The rotation of the servo shaft, was analogous to the ground speed, which in turn controlled a servo loop responsible for positioning the digital ground speed readout on the indicator.

FLIGHT MANAGEMENT SYSTEM (FMS)

A Flight Management System (FMS) is an on-board multi-purpose navigation, performance, and aircraft operations computer designed to provide virtual data and operational harmony between closed and open elements associated with a flight from pre-engine start and take-off, to landing and engine shut-down.

FLIGHT MANAGEMENT SYSTEM

- An FMS comprises four main components:-
- The Flight Management Computer (FMC).
- The Automatic Flight Control or Automatic Flight Guidance System (AFCS or AFGS).
- The Aircraft Navigation System.
- An Electronic Flight Instrument System (EFIS) or equivalent electromechanical instrumentation.

➢ FLIGHT MANAGEMENT SYSTEM (FMS)

- ✓ Flight Management Systems, which became popular in the mid-1980s, automates a wide variety of in-light tasks previously performed by a human navigator; thereby, reducing the workload on the light crew.
- ✓ Not only can it define a desired route from the aircraft's current position to any point in the world, but the route will be based on the aircraft's operating characteristics to manage overall light performance.
- ✓ On-time take-offs and landings, fuel conservation, and long engine and component life all contribute to airline profitability.
- ✓ The FMS helps achieve these results by operating the aircraft with much greater precision than humanly possible.

➢ FLIGHT MANAGEMENT SYSTEM (FMS)

- ✓ The FMS consists of dual redundant Flight Management Computers (FMC) and Control Display Units (CDU).
- ✓ During normal operation, the computers crosstalk with each other to share and compare information.
- ✓ Each FMC is capable of operating independently in the event the other FMC fails. However, only one FMC is provides commands to the other aircraft systems at any one time.
- ✓ Prior to take-off, the flight crew inputs their initial geographic location (latitude and longitude) and light plans on one of the CD Us located in the center console.
- ✓ The FMC receives navigation and guidance information from the air data, inertial navigation, and global positioning system, in addition to ground-based radio

➢ FLIGHT MANAGEMENT SYSTEM (FMS)

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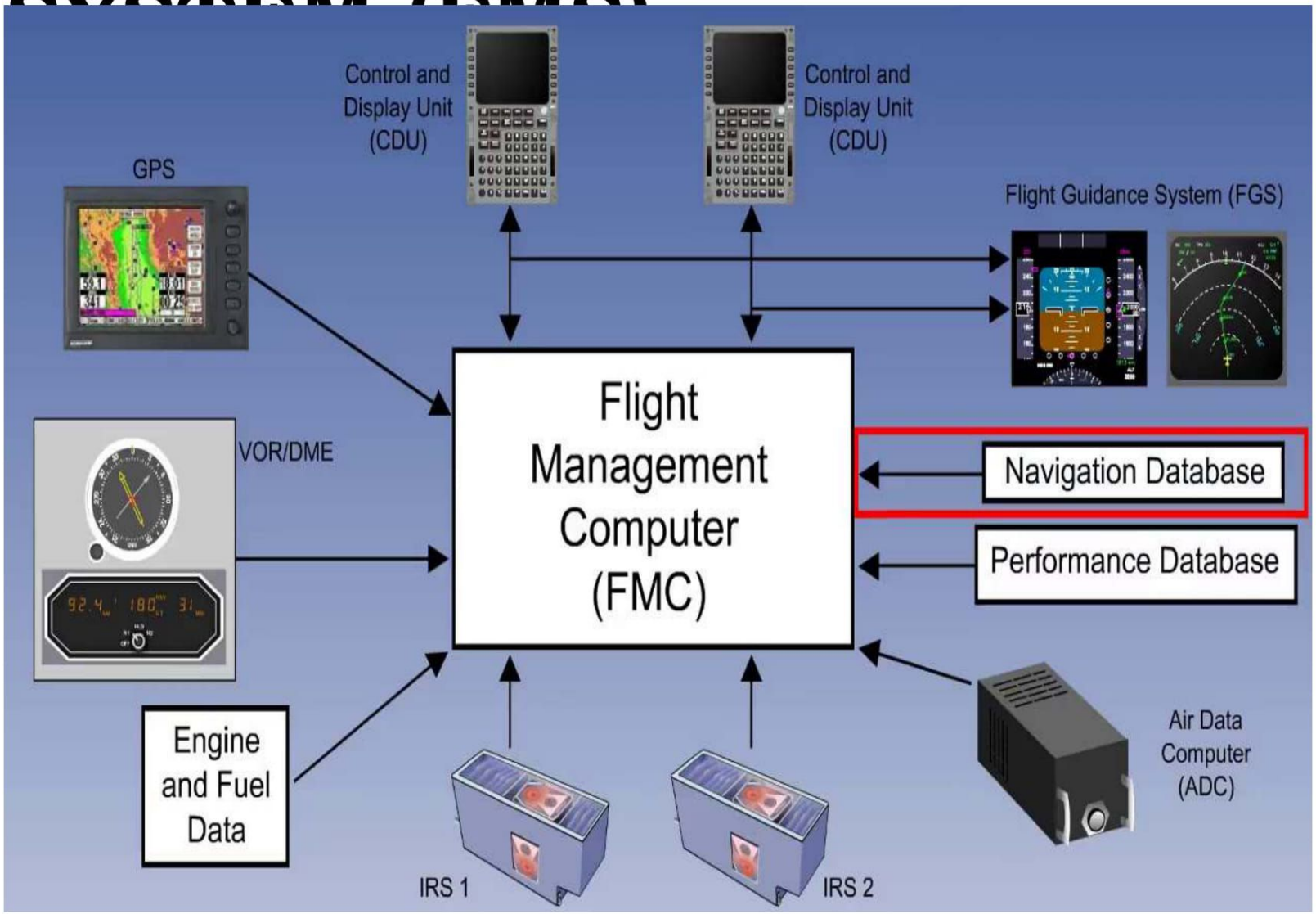

➢ FLIGHT MANAGEMENT SYSTEM (FMS)

- ✓ The FMC then computes the optimum light path, using a stored digital map terrain data base, to guide the aircraft to its final destination.
- ✓ The FMC provides waypoints along the intended route on the EFIS Navigation Display and drives the light director steering command bars on the EFIS Primary Flight Display.
- ✓ The FMC communicates with the Thrust Management System (TMS) that drives the auto-throttle to control aircraft speed, and the automatic Flight Control System (FCS or AFCAS), that drives the actuators that move the control surfaces for lateral and vertical control along the computed light path.
- ✓ The FMC continually optimizes the light path as variables, such as wind speed and direction, change