IV B. Tech II semester (R-15)

BY

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UNIT-I

INTRODUCTION

Importance And Role Of Avionics

1. Systems Which Interface Directly With Pilot
2. Aircraft State Sensor Systems
3. Navigation Systems
4. External World Sensor Systems
5. Task Automation Systems.

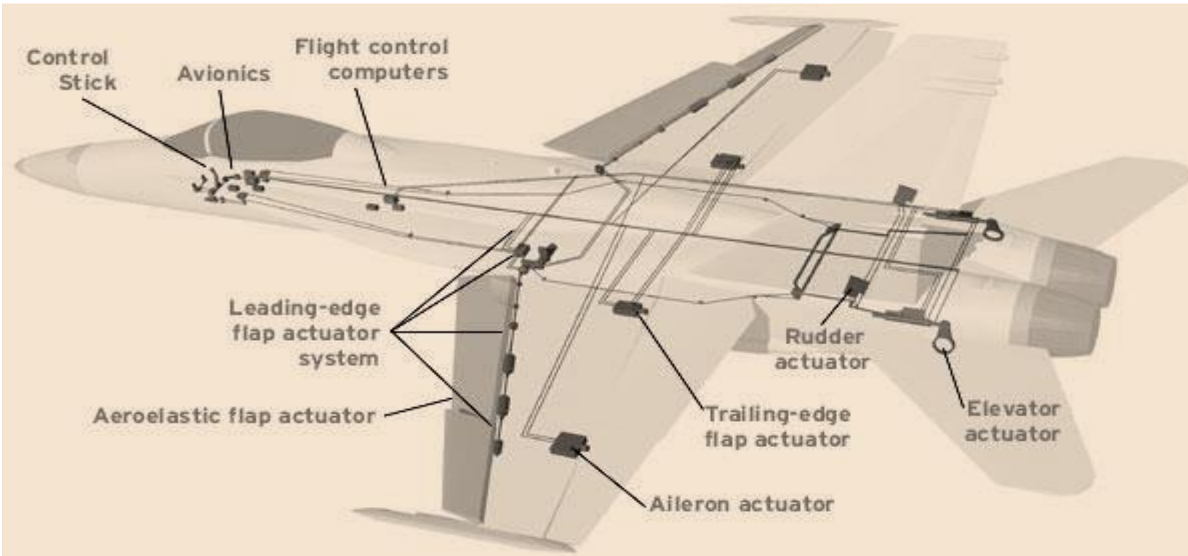
Importantce and Role of Avionics

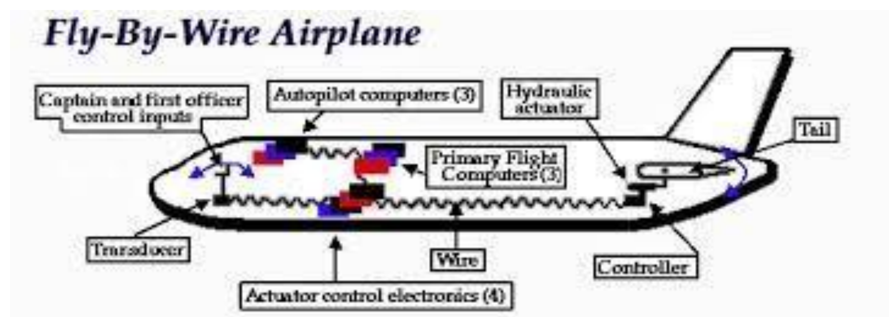
- Avionics = Aviation +Electronics
- Used in USA in early 1950's.
- Avionic System / Avionic subsystem :

  any system in the aircraft which is dependent on electronics for its operation.

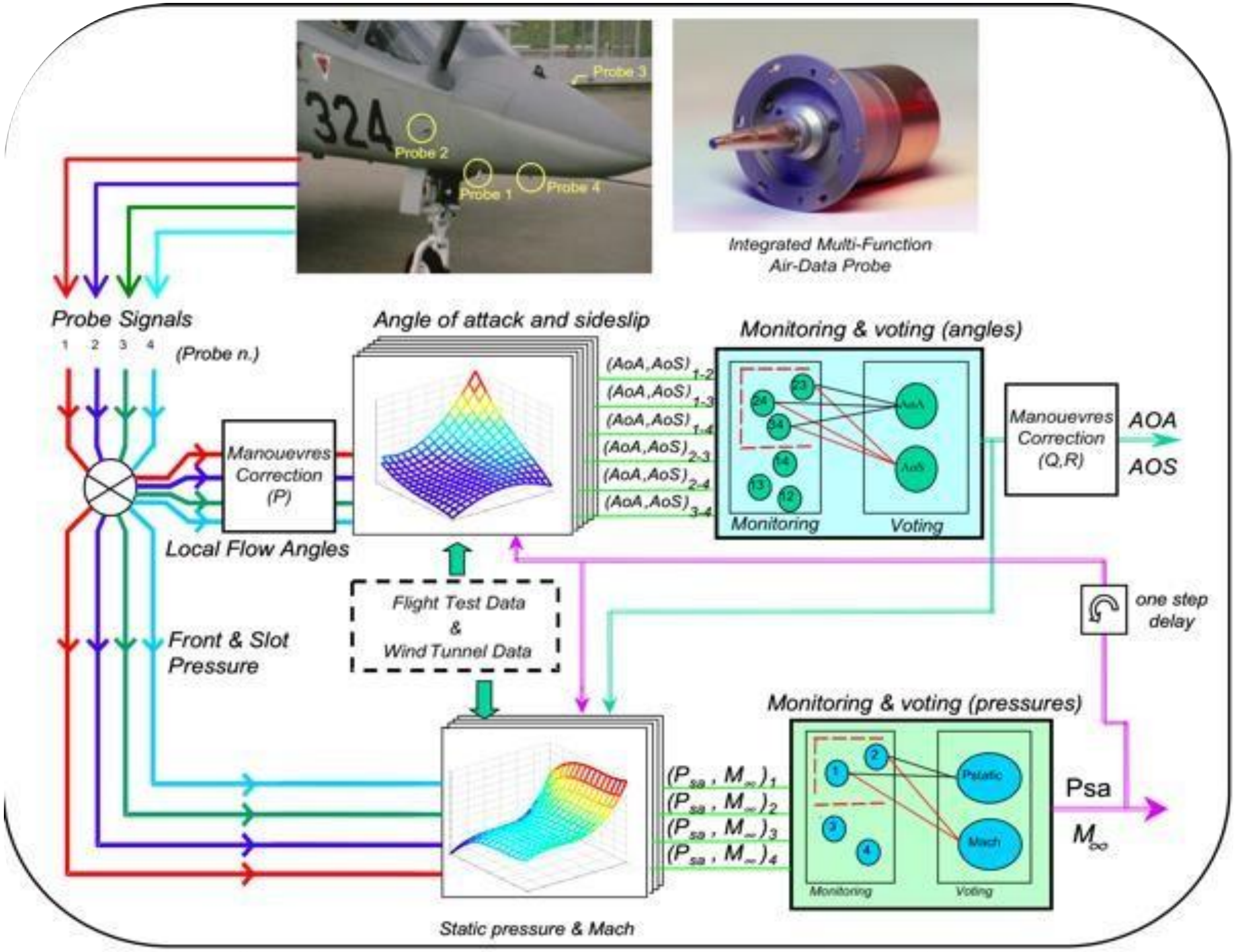
Fly by wire Flight control system:

1. **Fly-by-wire** (FBW) is a system that replaces the conventional manual flight controls of an aircraft with an electronic interface.



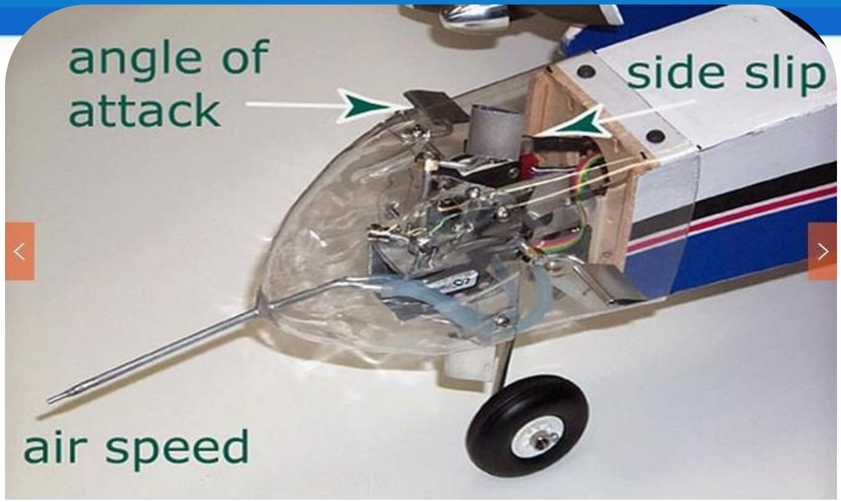


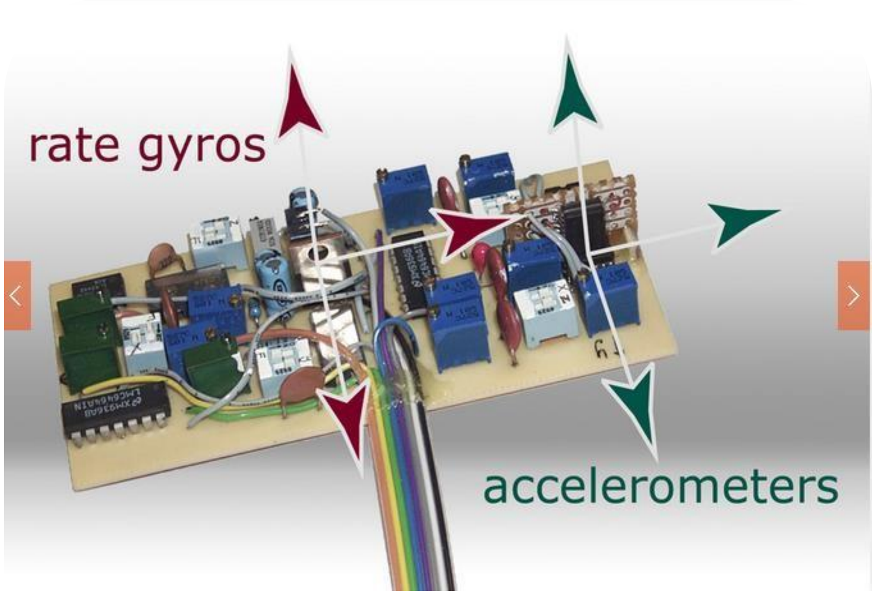
Pilots control stick sensor assembly



Air-Data Elaboration Procedure in a Quadruplex Fly-By-Wire FCS

Air Data Sensors


angle of attack
side slip
air speed


rate gyros
accelerometers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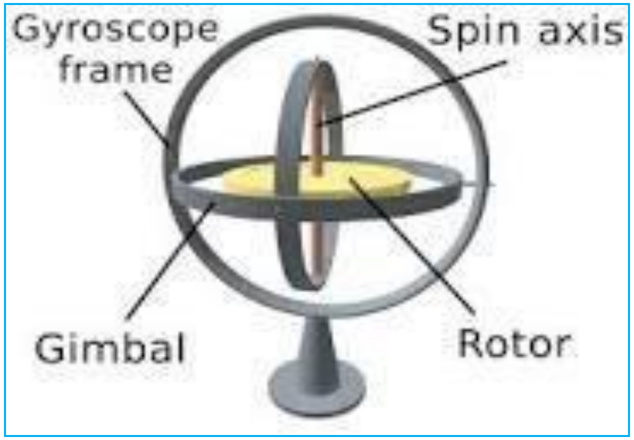


- A gyroscope is a device that uses Earth's gravity to help determine orientation. Its design consists of a freely-rotating disk called a rotor, mounted onto a spinning axis in the center of a larger and more stable wheel.
- As the axis turns, the rotor remains stationary to indicate the central gravitational pull, and thus which way is "down."

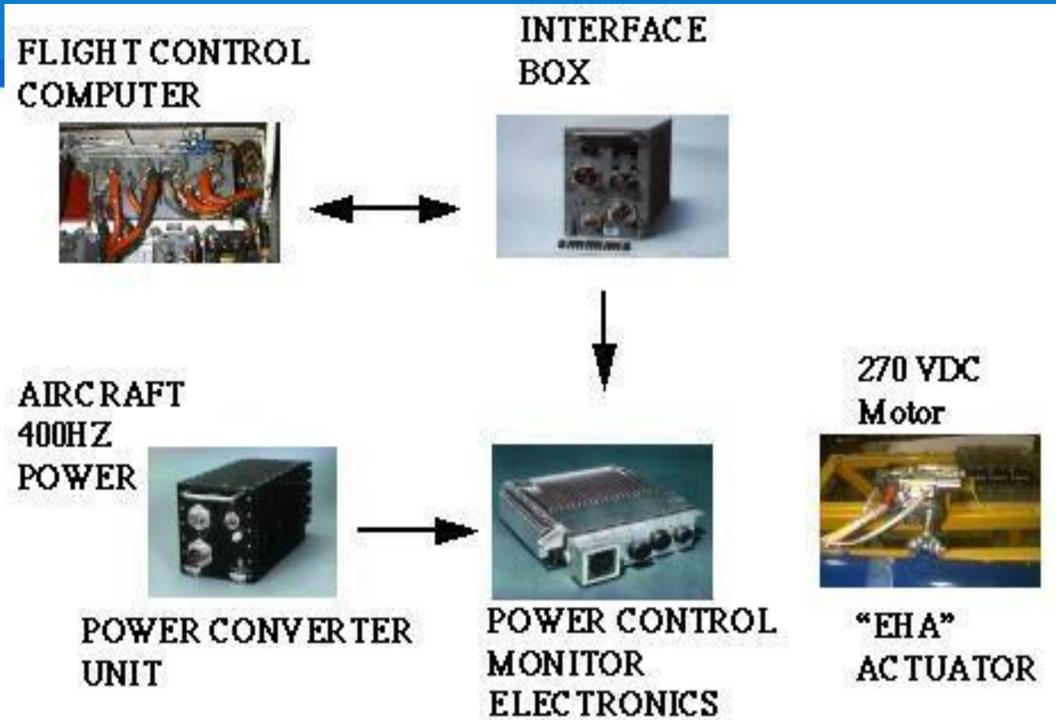
Accelerometer

•An accelerometer is a compact device designed to measure non-gravitational acceleration.

•When the object it's integrated into goes from a standstill to any velocity, the accelerometer is designed to respond to the vibrations associated with such movement.

•It uses microscopic crystals that go under stress when vibrations occur, and from that stress a voltage is generated to create a reading on any acceleration.

•Accelerometers are important components to devices that track fitness and other measurements in the quantified self movement.



Electro Hydraulic Actuators

An **Actuator** is a type of motor that is responsible for moving or controlling a mechanism or

system. It is operated by a source of energy, typically electric current, hydraulic fluid pressure, or

pneumatic pressure, and converts that energy into motion.

Importance And Role Of Avionics Contd.

- Million dollar business
- 30% of total cost of aircraft ---- avionics equipments
- 40% - maritime/patrol/anti submarine aircraft
- 75% - Airborne early warning aircraft.
- The avionic systems are essential to enable the flight crew to carry out the aircraft mission safely and efficiently.

Importance And Role Of Avionics Contd.

- Mission : Carrying the passengers to their destination, intercepting a hostile aircraft, attacking a ground target, reconnaissance or maritime patrol.
- In military operations, reconnaissance is the exploration outside an area occupied by friendly forces to gain information about natural features and enemy presence.

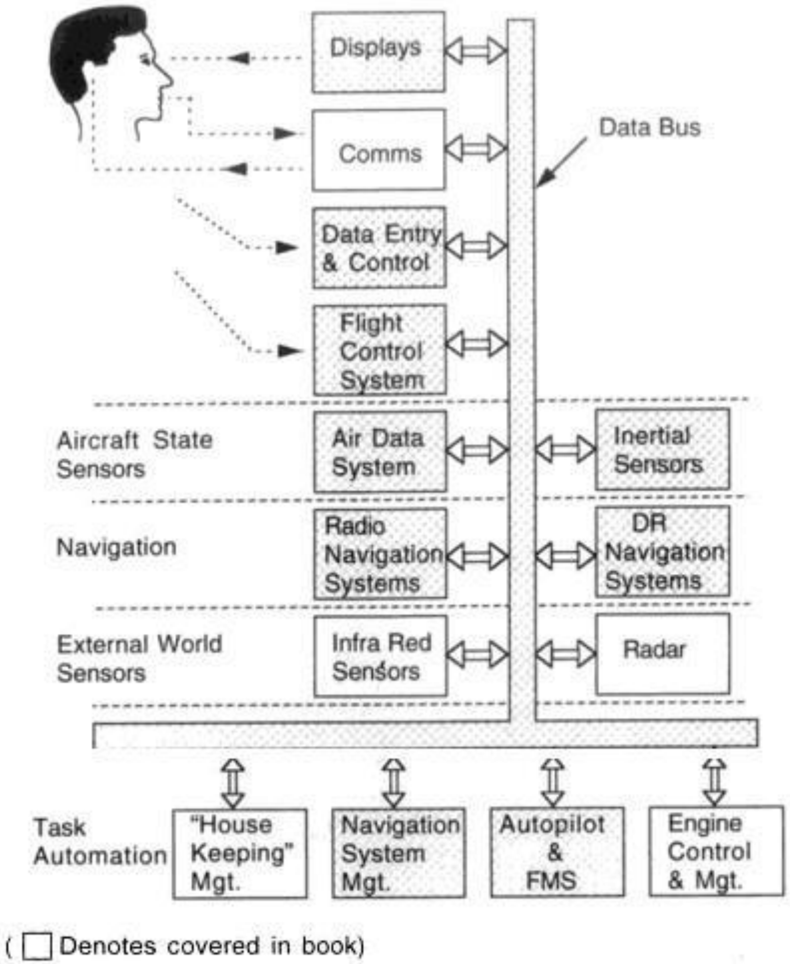
Importance And Role Of Avionics Contd.

- By automation of tasks, the crew s workload can be minimized.
- The reduction in weight is also significant and can be translated into more passengers or longer range on less fuel.
- The crew comprises of two members namely, the first pilot/ captain and the second pilot.
- The elimination of second crew member (navigator/ observer/ radar operator) has also significant benefits in terms of reduction in training costs.

Importance And Role Of Avionics Contd.

Goal Of Avionic Systems Are

- Increased Safety
- Air Traffic Control Requirements
- All Weather Operation
- Reduction In Fuel Consumption
- Improved Aircraft Performance And Control
- Handling And Reduction Of Maintenance Costs



...ic systems.

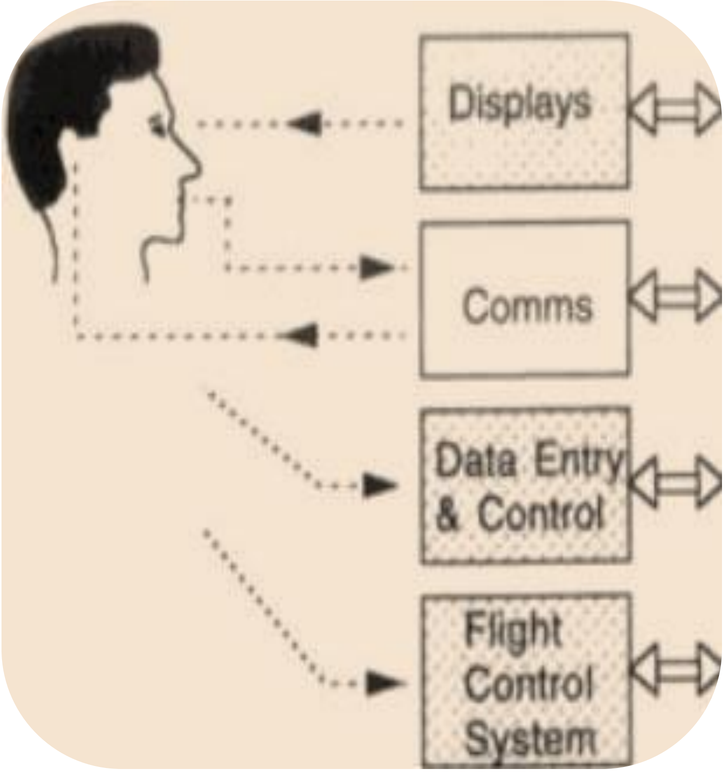
The figure depicts the hierarchical structure comprising layers of specific tasks and avionic system functions.

It shows the prime/core functions which are mainly common to both military and civil aircraft.

Main avionic subsystems can be grouped into five layers according to their role and function.

- Systems Which Interface Directly With The Pilot.
- Aircraft State Sensor Systems
- Navigation Systems
- External World Sensor Systems
- Task Automation Systems

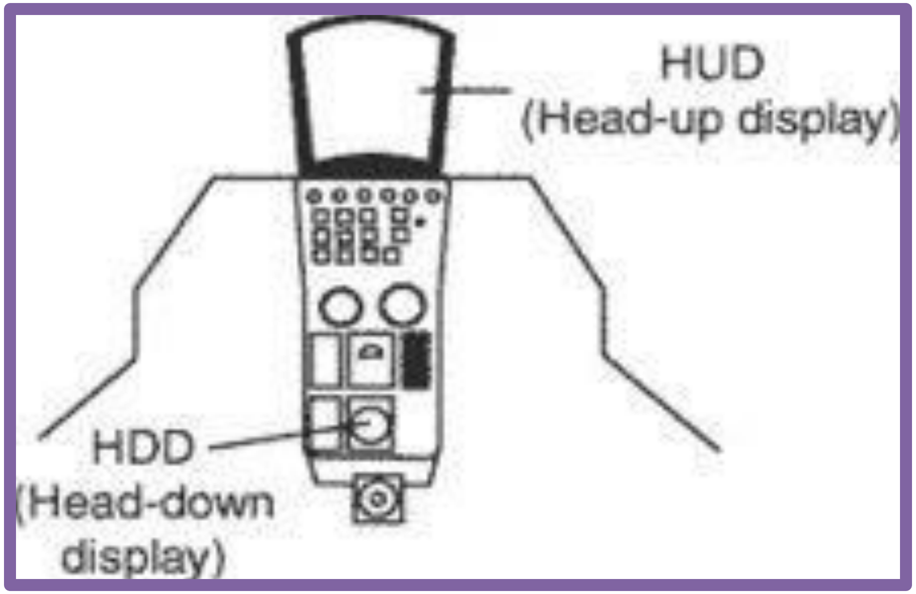
Systems Which Interface Directly With The Pilot



Core avionic systems

Displays: Provide Visual Interface Between Pilot And The Aircraft Systems.
Helmet Mounted Displays (HMDs),
Head Up Displays (HUDs),
Head Down Displays (HDDs).
Combat, civil aircraft – HUD
Modern Combat aircraft, helicopters – HMD
Prime advantage : Project the display information into pilots field of view .

comprise head up displays (HUDs)



helmet mounted displays (HMDs)

Systems Which Interface Directly With The Pilot

- HUD can also display a forward looking infrared (FLIR) video picture one to one with the outside world from a fixed FLIR imaging sensor installed in aircraft.
- HMD --- HUD on the helmet.
- Major advantage --- Information can be presented to the pilot when looking in any direction as opposed to the relatively limited forward field of HUD.
- Night viewing Goggles can also be integrated.

Head Up Displays (HUDs),

Head Down Displays (HDDs)

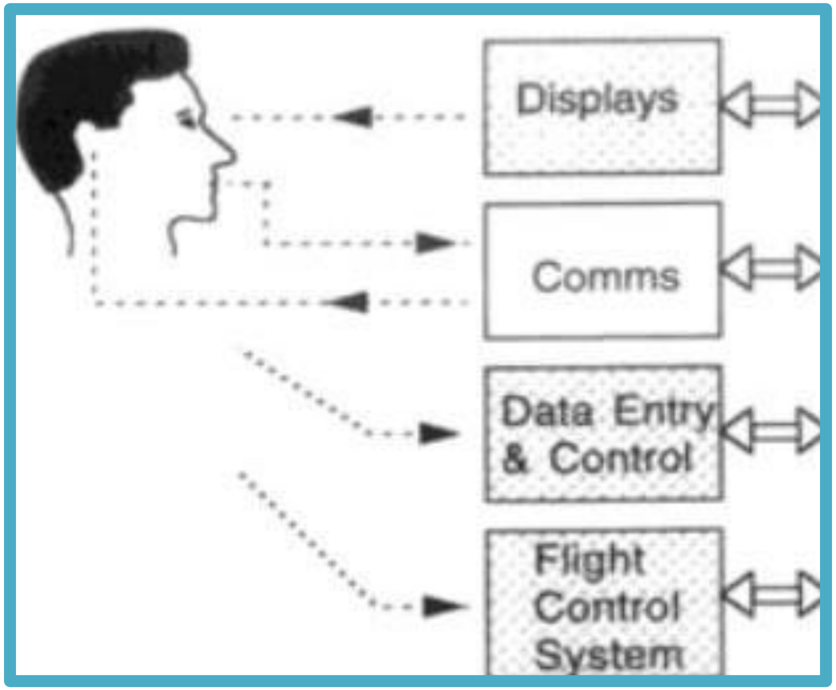
Systems Which Interface Directly With The Pilot

Colour head down displays, multi-function colour displays

- Height, Air Speed, Mach Number, Vertical Speed, Artificial Horizon, Pitch Angle, Bank Angle And Heading And Velocity Vector.
- Navigation Displays,
- Horizontal Situation Indication (HIS) Displays,
- Weather Radar Displays,
- Engine Data ,
- Aircraft Systems --- Electrical Power Supply System, Hydraulic Power Supply System, Cabin Pressurization System And Fuel Management System

Communications :

Two way communication between ground bases and the aircraft or between aircraft - air traffic control.



Communications :

- High Frequency Radios ---- 2 to 30 MHz.
- Very High Frequency -------- 30 to 100 MHz.
- Ultra High Frequency ------ 250 to 400 MHz.
- SATCOM systems

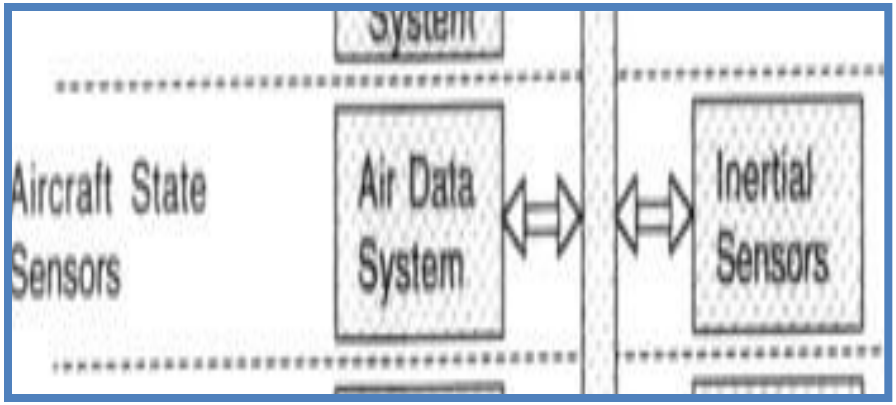
Data Entry And Control :

Crew --- Avionic Systems.

- Keyboards,
- Touch Panels,
- Direct Voice Input Control

Flight control :

- Auto stabilization/ Stability Augmentation.
- FBW flight control system Auto stabilization systems are required for achieving acceptable control and handling motion characteristics across flight envelope.
- FBW flight control systems provides continuous automatic stabilization of the aircraft by computer control of the control surfaces from appropriate motion sensors.



1. Air Data systems
2. Inertial Sensor Systems
3. Accurate information of air data quantities sensed by accurate sensors are computed by air data computing system for control and navigation of aircraft

The use of very high accuracy gyros and accelerometers to measure the aircrafts motion enables an inertial navigation system (INS) to be mechanized which provides very accurate Attitude and Heading Information together with the aircrafts velocity and position data.

Navigation system :

Accurate navigation information, that is the aircraft's position, ground speed and track angle (direction of motion of the aircraft relative to true North) is clearly essential for the aircraft's mission, whether civil or military. Navigation systems can be divided into dead reckoning (DR) systems and position fixing systems; both types are required in the aircraft.

Navigation system :

Dead reckoning Navigation system :

DR navigation derives the vehicles present position by estimating the distance traveled from a known position's speed and direction of motion of vehicle.

3 types:

- Inertial navigation systems,
- Doppler/heading reference system,
- Air Data/heading reference system.

NAVIGATION SYSTEM :

Radio Navigation system :

- ✓The Position fixing systems used at present are mainly radio navigation systems based on satellite or ground based transmitters.
- ✓A suitable receiver in the aircraft with a supporting computer is then used to derive the aircrafts position from the signals received from the transmitters.
- ✓INS, GPS, VOR/DME, ILS, MLS can be included for full navigation.

Outside World Sensor Systems:

These systems, which comprise both radar and infrared sensor, systems enable all weather and night time operation and transform the operational capability of the aircraft (or helicopter).

The *Radar Systems* installed in civil airliners and many general aviation aircraft provide weather warning.
The radar looks ahead of the aircraft and is optimized to detect water droplets and provide warning of storms, cloud turbulence and severe precipitation so that the aircraft can alter course and avoid such conditions, if possible.

Outside World Sensor Systems: (cont…)

- It should be noted that in severe turbulence, the violence of the vertical gusts can subject the aircraft structure to very high loads and stresses.
- These radars can also generally operate in ground mapping and terrain avoidance modes.

Infrared Sensor Systems

- The major advantage of being entirely passive systems.
- Infrared (IR) sensor systems can be used to provide a video picture of the thermal image scene of the outside world either using a fixed FLIR sensor, or alternatively, a gimbaled IR imaging sensor.

Task Automation Systems

These comprise the systems which reduce the crew workload and enable minimum crew operation by automating and managing of tasks.

1. Navigation management system:

operation of all radio navigation aid systems and the combination of the data from all the navigation sources.

2. Autopilots and Flight Management Systems

The tasks carried out by the FMS include:

- Flight planning. Navigation management.
- Engine control to maintain the planned speed or Mach number.
- Control of the aircraft flight path to follow the optimized planned route. Control of the vertical flight profile.
- Ensuring the aircraft is at the planned 3D position at the planned time slot; often referred to as 4D navigation. This is very important for air traffic control.

Task Automation Systems

- Flight envelope monitoring.
- Minimizing fuel consumption.

3. Engine control and Management:

Full Authority Digital Engine System (FADEC)

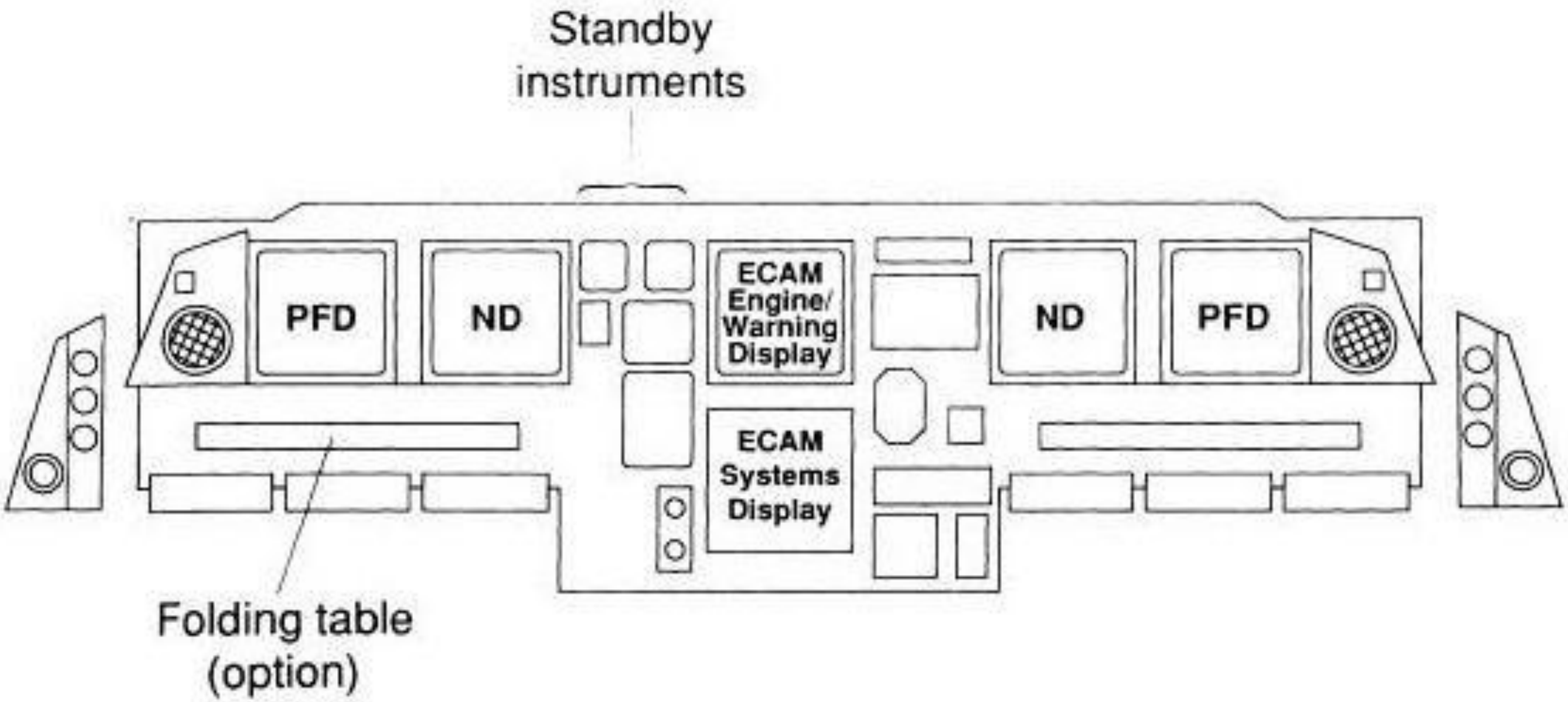
- flow of fuel,
- temperature,
- engine speed,
- acceleration,
- engine health monitoring system- performance deterioration.

4. House Keeping Management:

- Automation of background tasks – aircrafts safe and efficient operation.
- Fuel management. This embraces fuel flow and fuel quantity measurement and control of fuel transfer from the appropriate fuel tanks to minimize changes in the aircraft trim.
- Electrical power supply system management.
- Hydraulic power supply system management.
- Cabin/cockpit pressurization systems.
- Environmental control system.
- Warning systems.
- Maintenance and monitoring systems.

AIRBUS A380 FLIGHT DECK

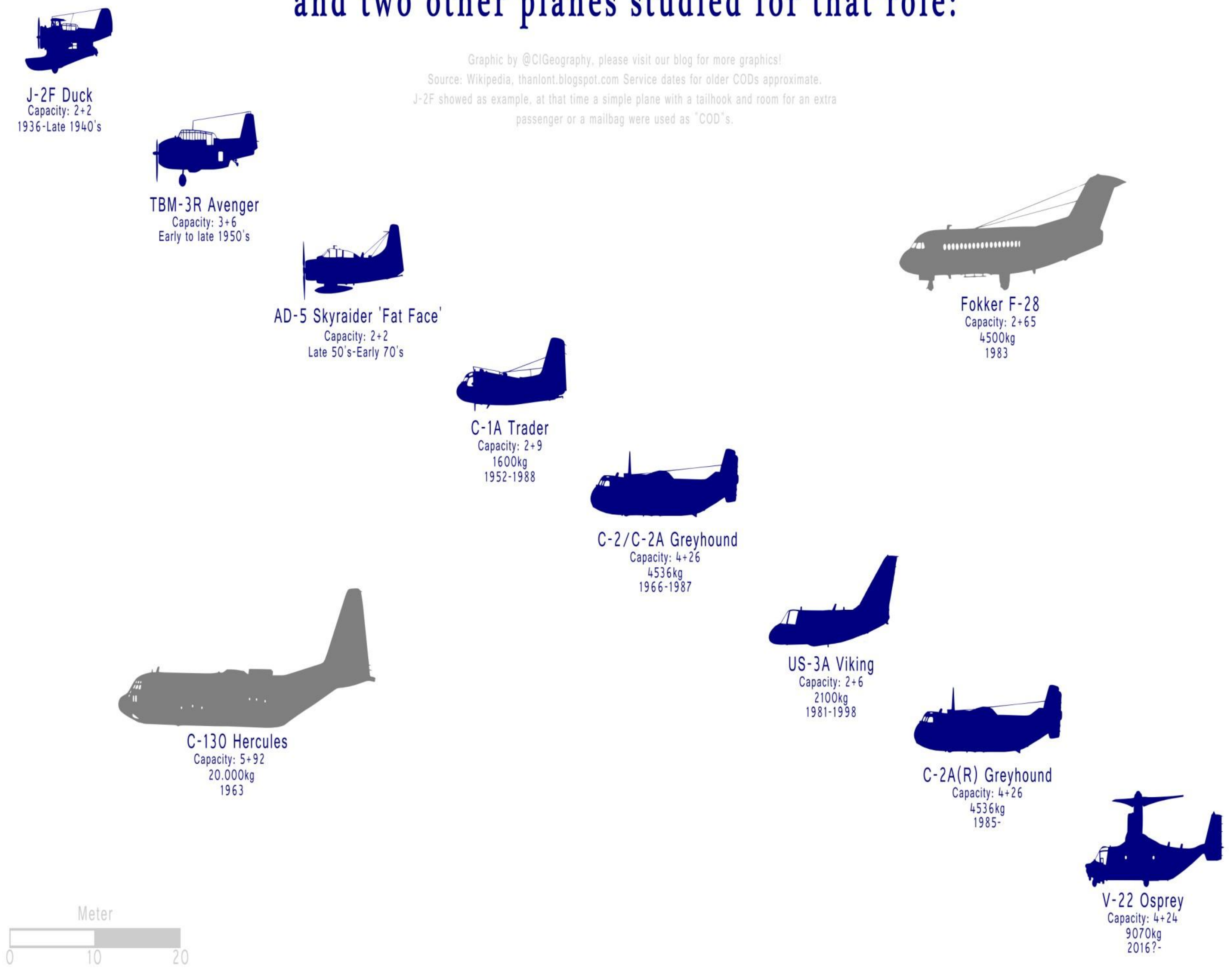
BOEING B777 FLIGHT DECK



Airbus A340 flight deck – main panel (by courtesy of Airbus Industrie).

EUROFIGHTER TYPHOON

United States Navy Carrier Onboard Delivery evolution and two other planes studied for that role:




AIRCRAFT CARRIER EVOLUTION
ÉVOLUTION DES PORTE-AVIONS - ENTWICKLUNG DES FLUGZEUGTRÄGERS - EVOLUCIÓN DEL PORTAAVIONES
Evolution of the USS Intrepid

UNIT II

DISPLAYS AND MAN–MACHINE INTERACTION AND COMMUNICATION SYSTEM

INTRODUCTION

The cockpit display systems provide a visual presentation of the information and data from the aircraft sensors and systems to the pilot (and crew) to enable the pilot to fly the aircraft safely and carry out the mission.

- Primary flight information,
- Navigation information,
- Engine data,
- Airframe data,
- Warning information.

Continuation…

The military pilot has also a wide array of additional information to view, such as:

- Infrared imaging sensors,
- Radar,
- Tactical mission data,
- Weapon aiming,
- Threat warnings.

Continuation…

Examples of these developments are:

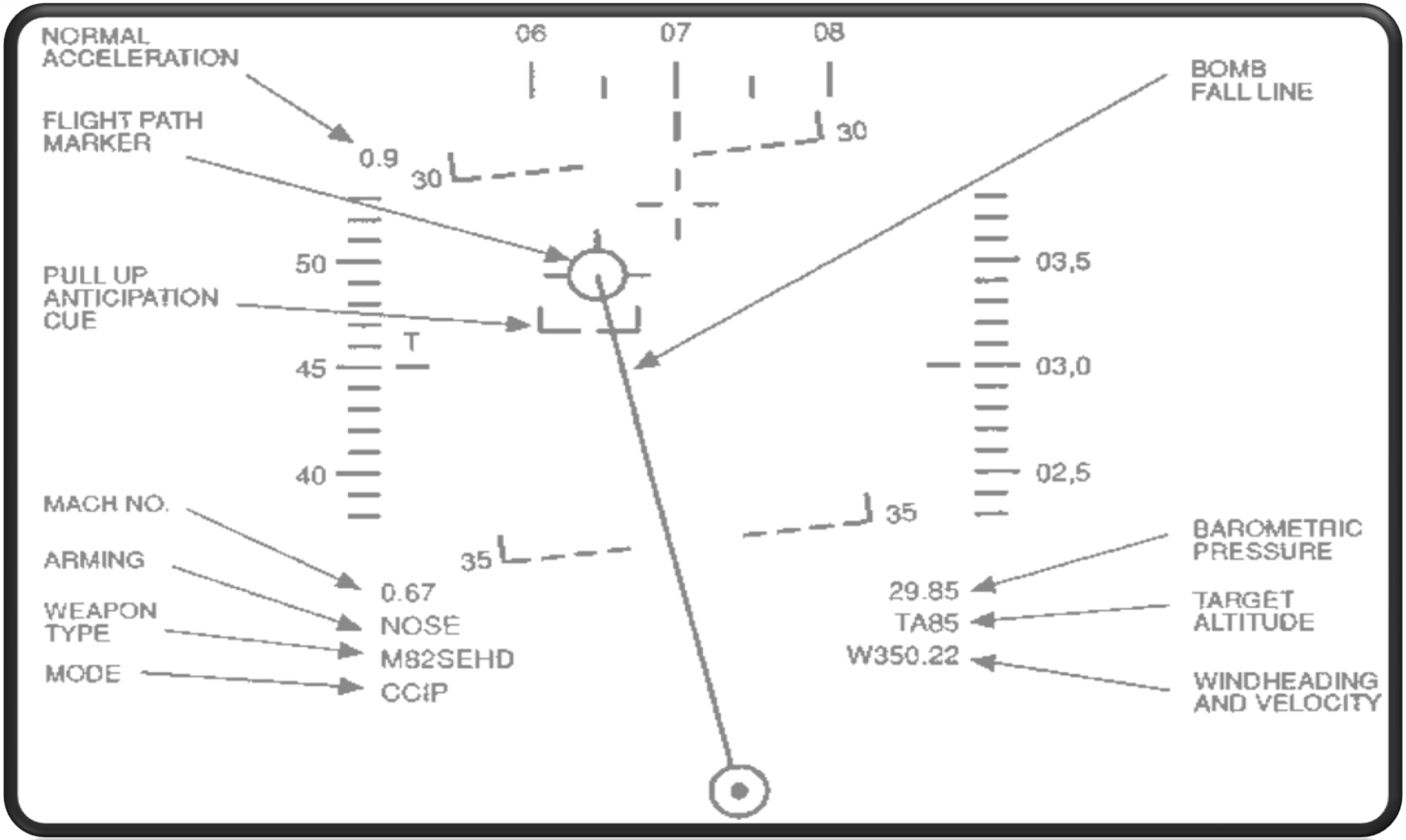
- Head up displays,
- Helmet mounted displays,
- Multi-function color displays,
- Digitally generated color moving map displays,
- Synthetic pictorial imagery,
- Displays management using intelligent knowledge based system (IKBS) technology,
- Improved understanding of human factors and involvement of human factors specialists from the initial cockpit design stage.

Continuation…

The basic principles involved in the following topics:

- Head up displays
- Helmet mounted displays
- Computer aided optical design
- Discussion of HUDs versus HMDs
- Head down displays
- Data fusion
- Intelligent displays management
- Display technology
- Control and data entry

The HUD has enabled a major improvement in man–machine interaction (MMI) to be achieved as the pilot is able to view and assimilate the essential flight data generated by the sensors and systems in the aircraft whilst head up and maintaining full visual concentration on the outside world scene.



Typical weapon aiming display

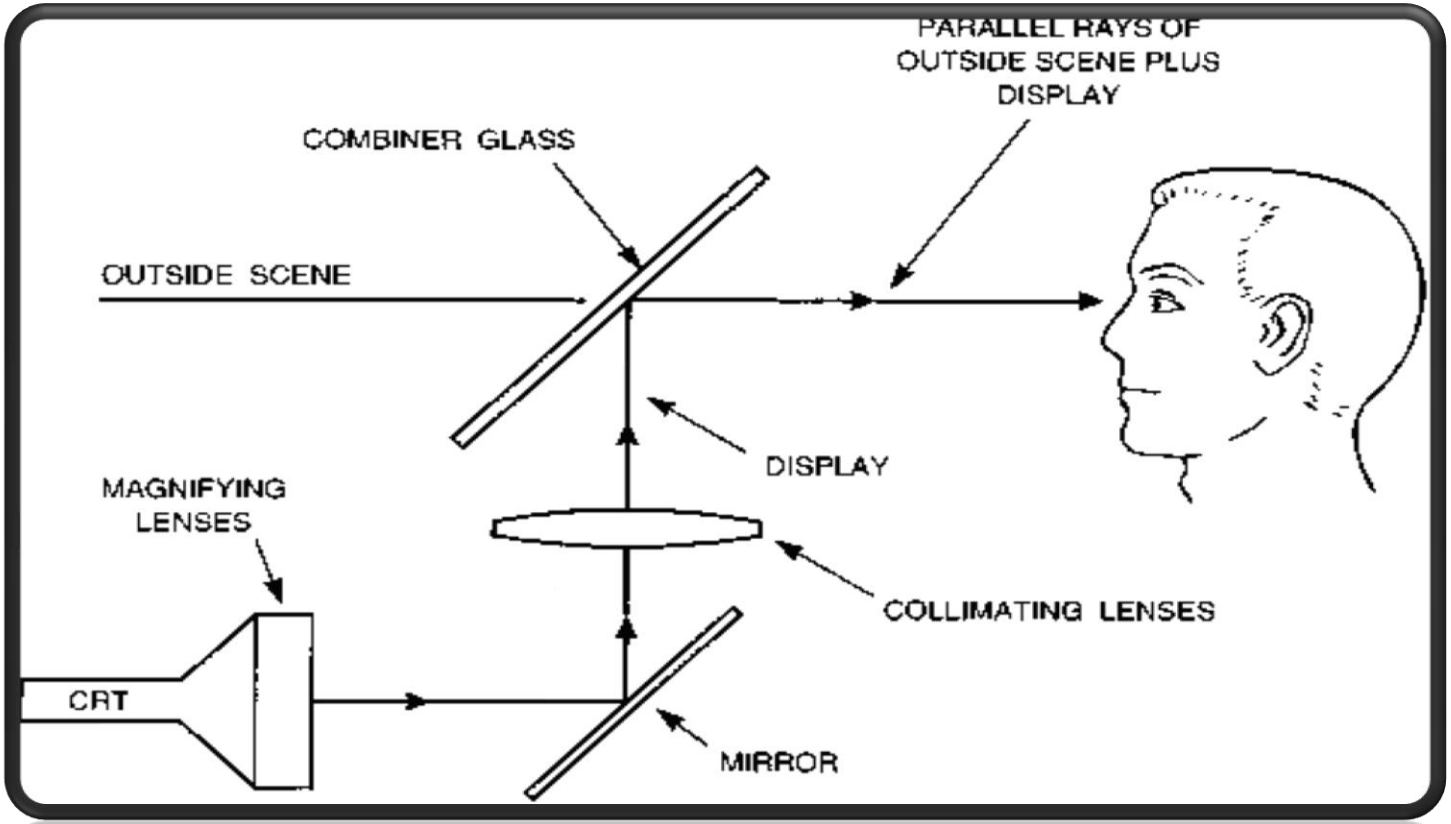
HUDs are now being installed in civil aircraft for reasons such as:

Civil HUD installation

Cont…

- Inherent advantages of head-up presentation of primary flight information including depiction of the aircraft’s flight path vector, resulting in improved situational awareness and increased safety in circumstances such as wind shear or terrain/traffic avoidance maneuvers.
- To display automatic landing guidance to enable the pilot to land the aircraft safely in conditions of very low visibility due to fog, as a back up and monitor for the automatic landing system. The display of taxi-way guidance is also being considered.
- Enhanced vision using a raster mode HUD to project a FLIR video picture of the outside world from a FLIR sensor installed in the aircraft, or, a synthetic picture of the outside world generated from a forward looking mill metric radar sensor

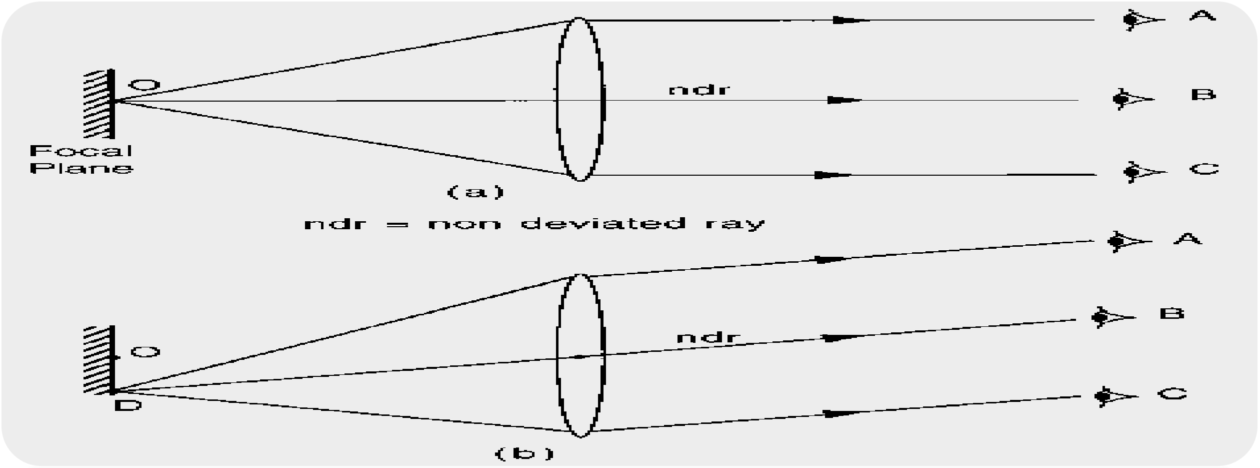
Basic Principles

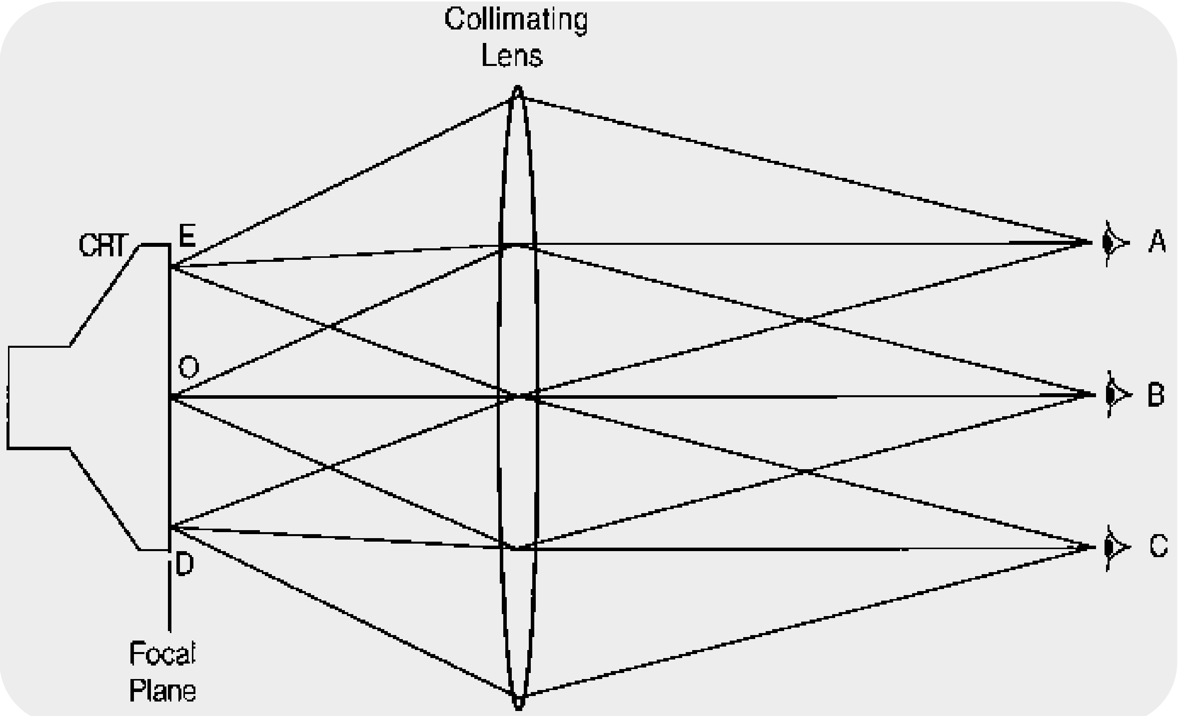


HUD schematic.

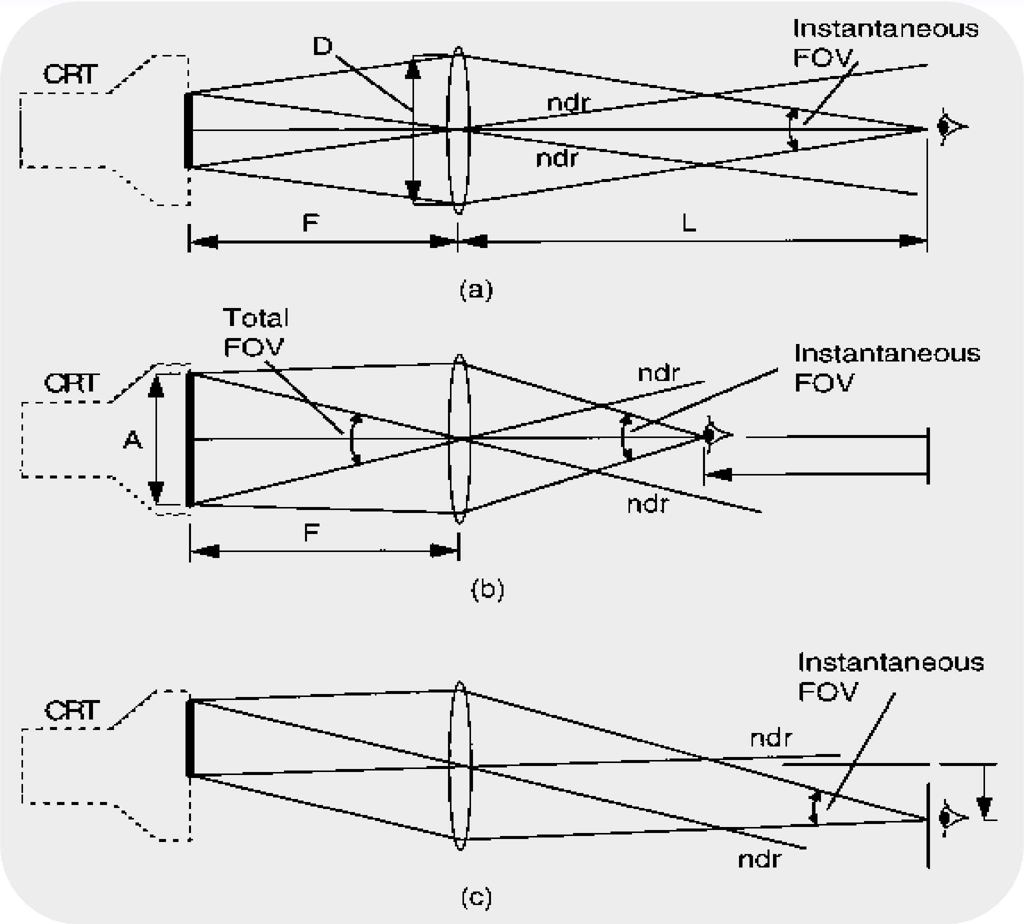
Simple optical collimator

A collimator is defined as an optical system of finite focal length with an image source at the focal plane. Rays of light emanating from a particular point on the focal plane exit from the collimating system as a parallel bunch of rays, as if they came from a source at infinity.

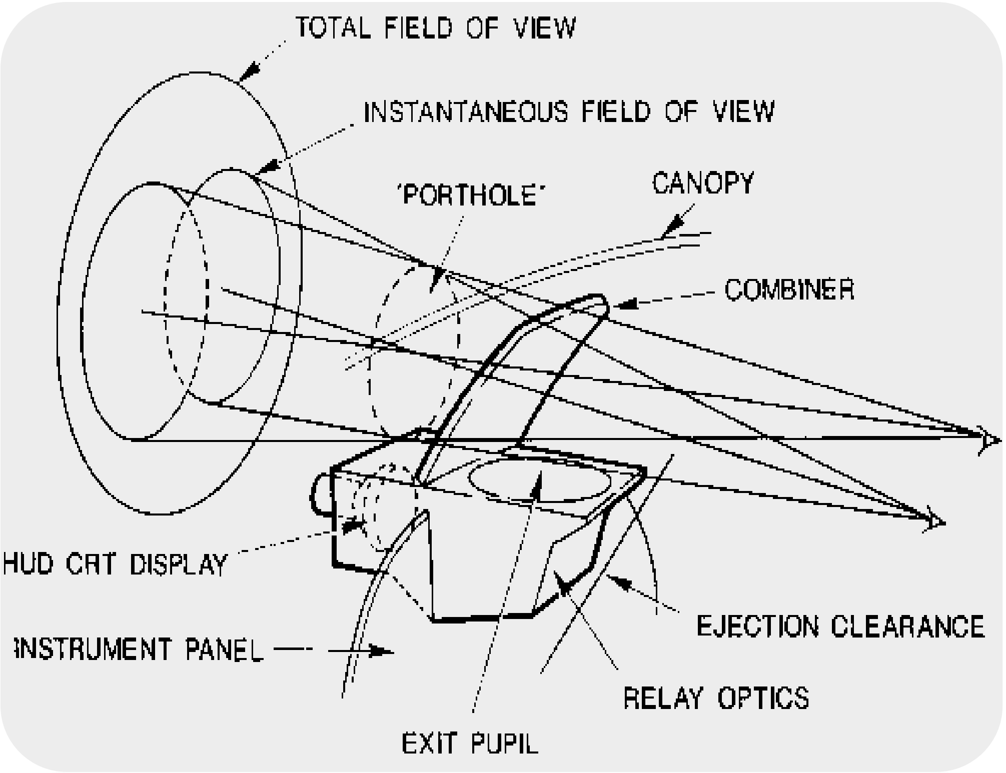




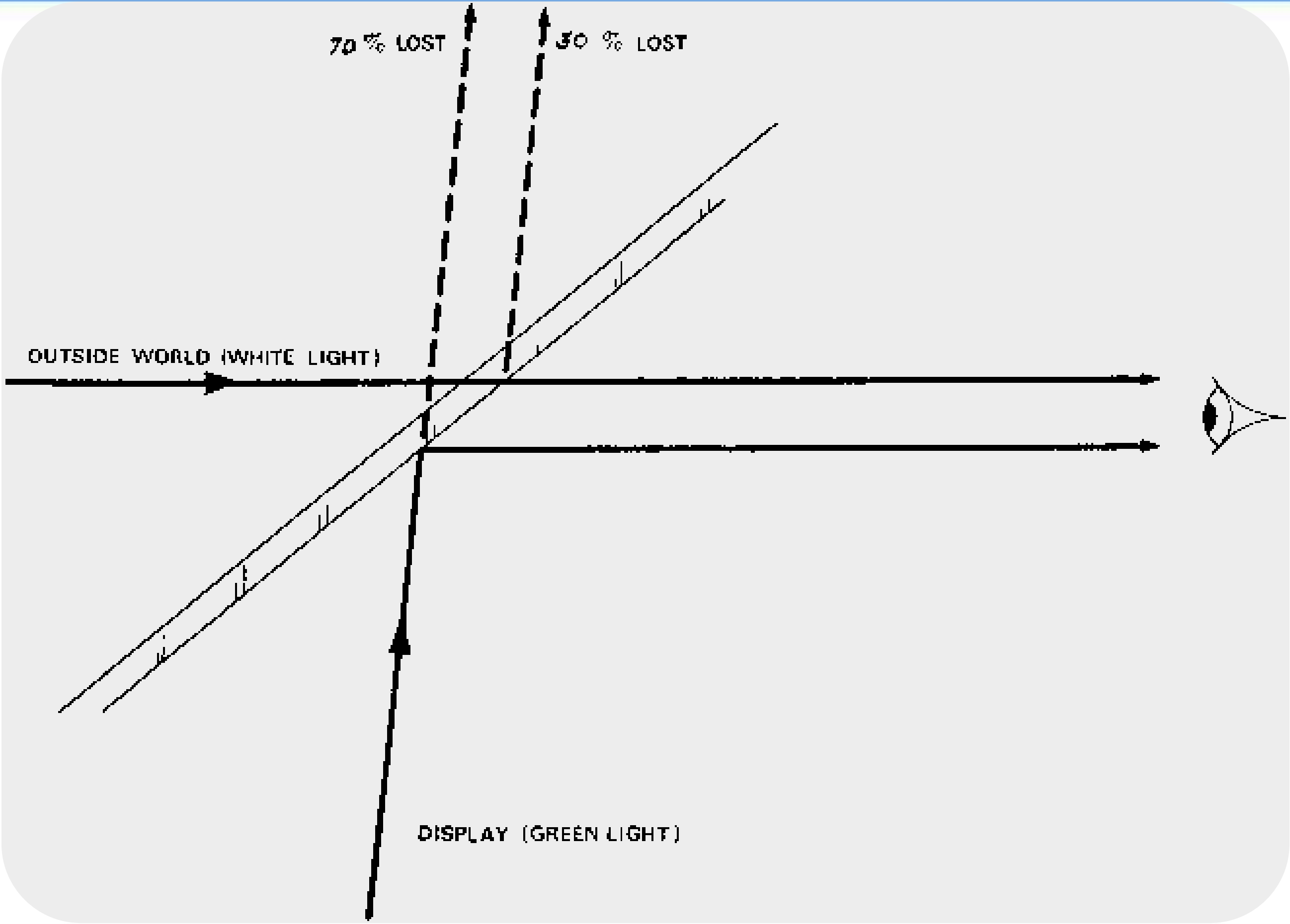
Simple optical collimator ray trace



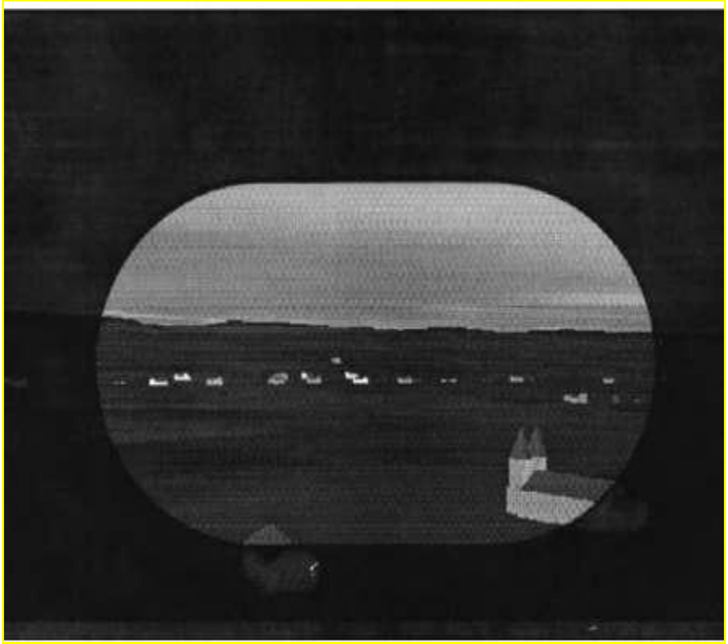
INSTANTANEOUS AND TOTAL FOV



HUD installation constraints and field of view



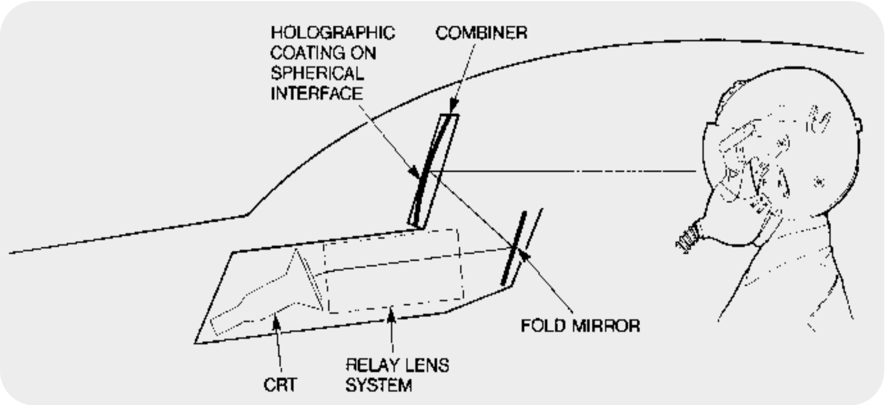
CONVENTIONAL REFRACTIVE HUD COMBINER OPERATION



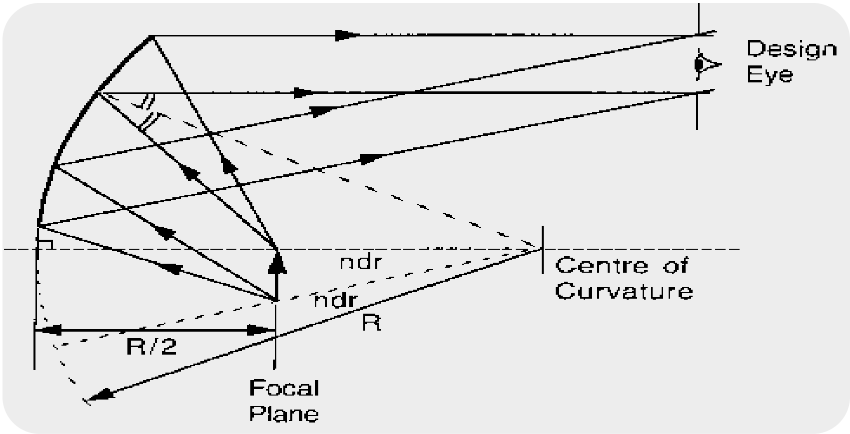
Instantaneous FOV of conventional HUD.

Instantaneous FOV of holographic HUD.

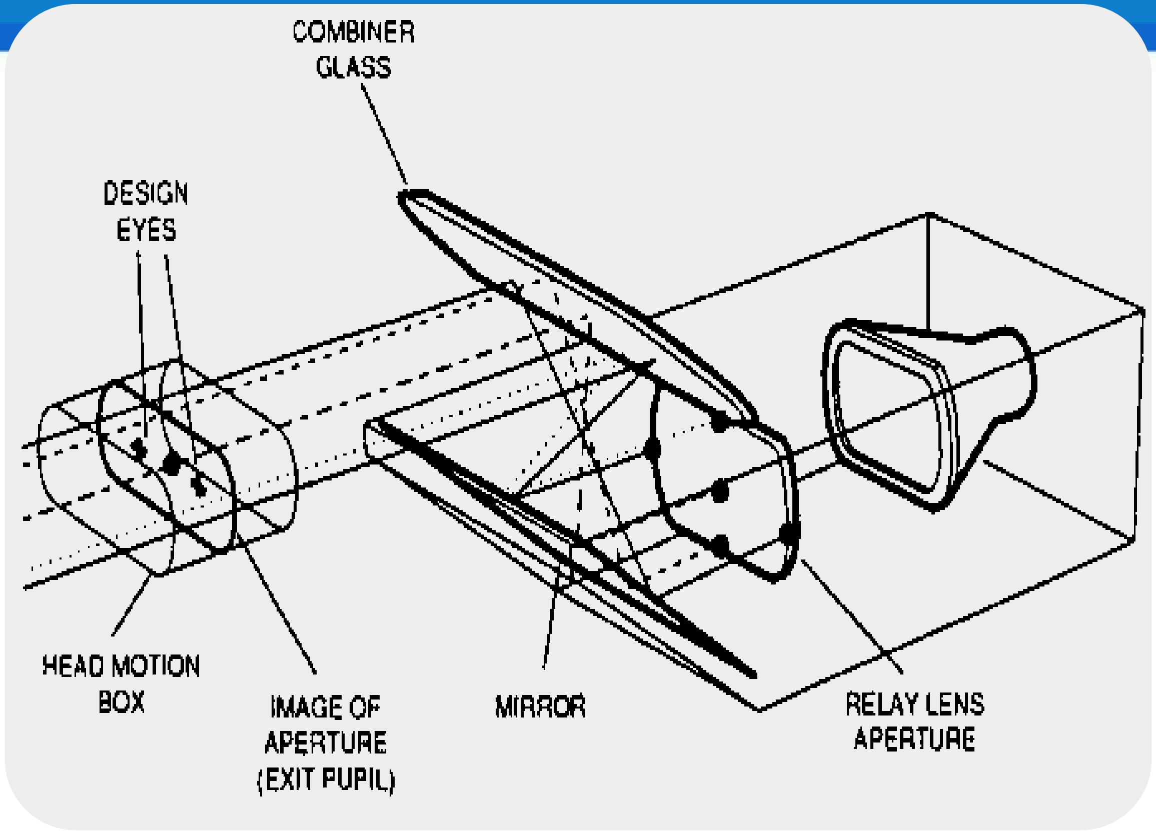
Holographic HUDs



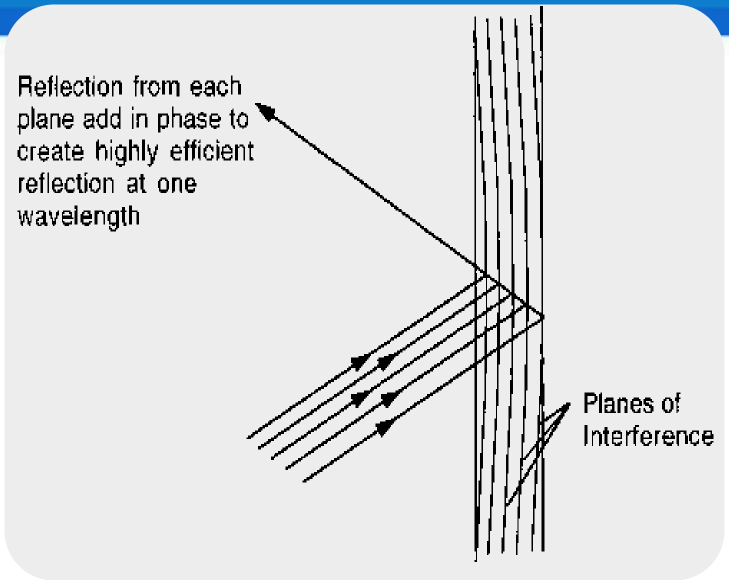
Off-axis holographic combiner HUD configuration.



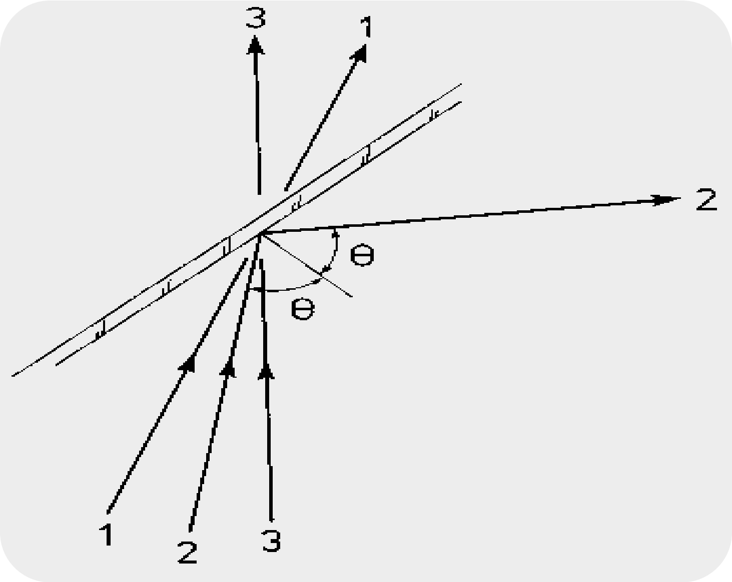
Collimation by a spherical reflecting surface.



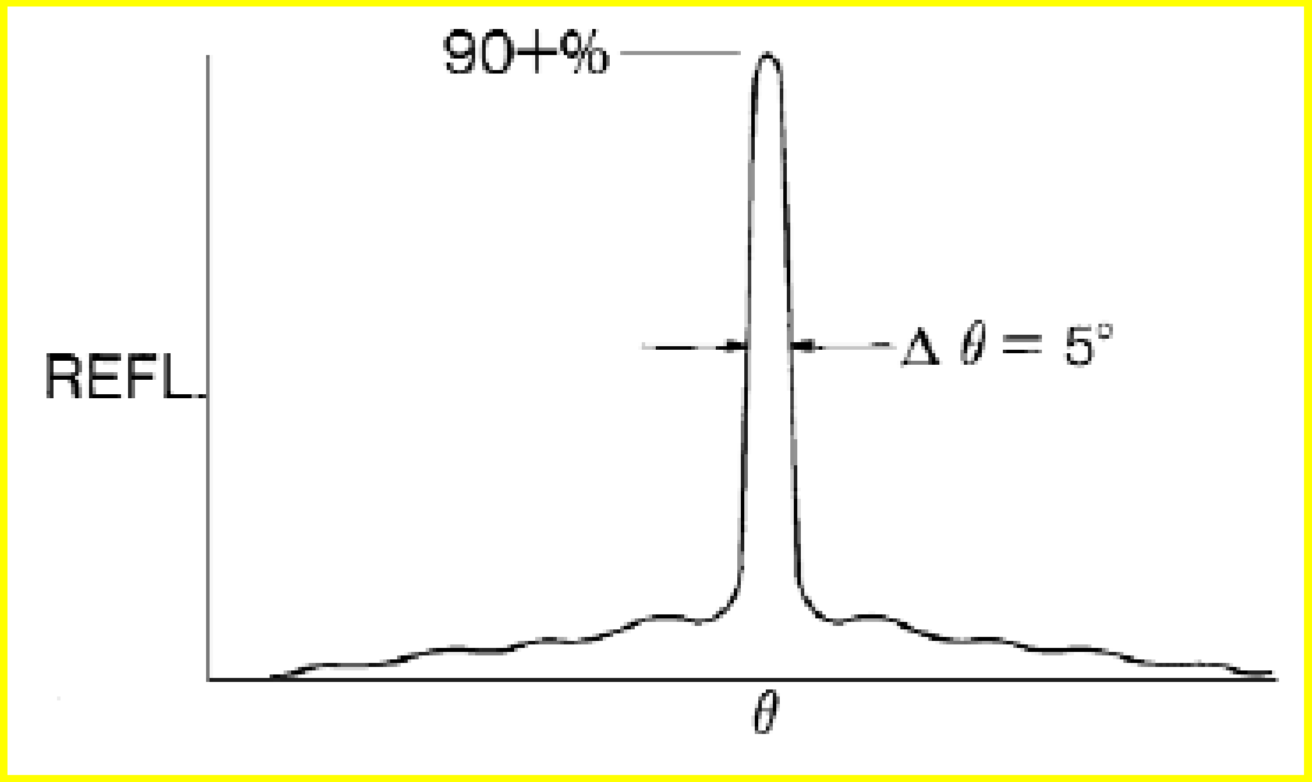
The head motion box concept.



Holographic coating.



Angularly selective reflection of monochromatic rays.



Holographic coating performance.

Holographic Combiner

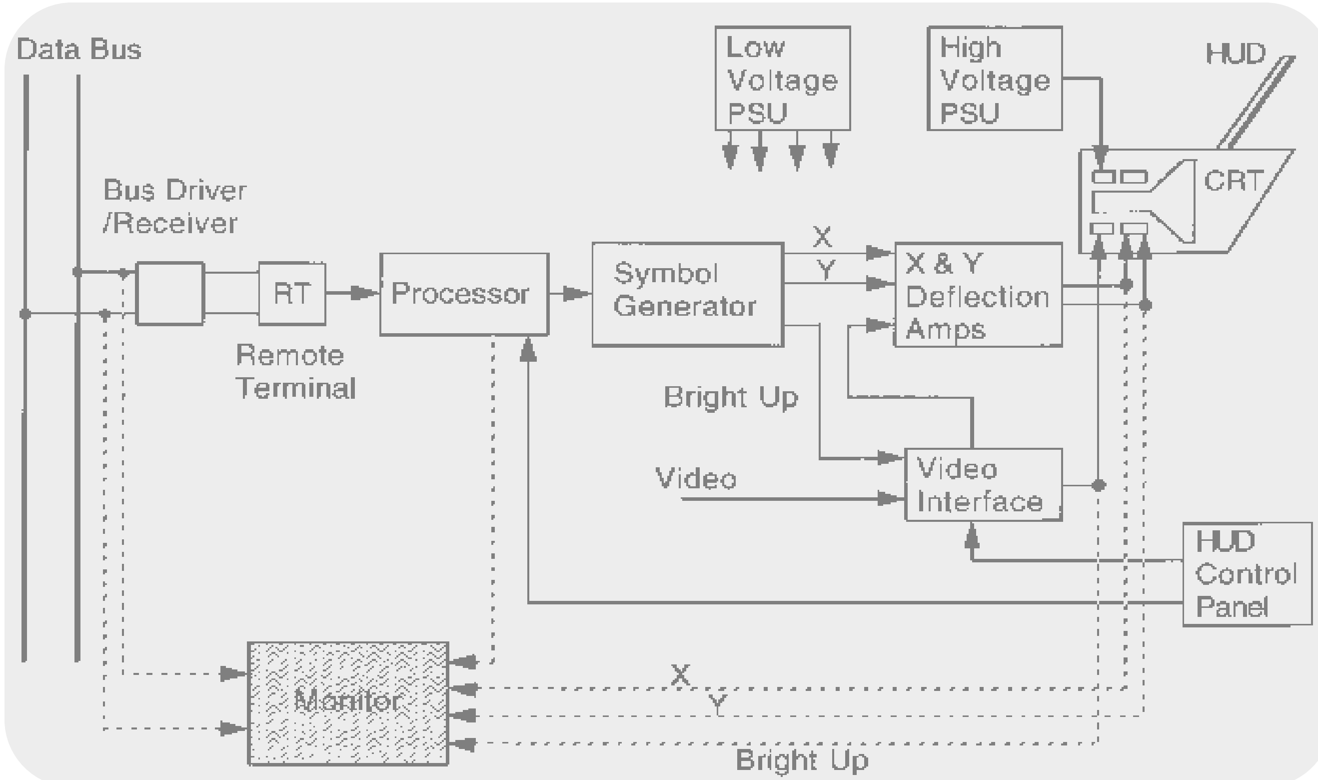
The process for producing the powered holographic combiner is very briefly out- lined below.

The process has three key stages:

- Design and fabricate the Computer Generated Hologram (CGH).
- Produce master hologram.
- Replicate copies for the holographic combiner elements.

Wide FOV holographic HUD installed in Euro fighter Typhoon (by courtesy of BAE Systems).

HUD Electronics



Continuation…

The display processor processes this input data to derive the appropriate display formats, carrying out tasks such as axis conversion, parameter conversion and format management. In addition the processor also controls the following functions:

- Self test,
- Brightness control (especially important at low brightness levels),
- Mode sequencing,
- Calibration,Power supply control

Unit-III

INERTIAL SENSORS AND GLOBAL POSITIONING SYSTEMS

Introduction

Gyros and Accelerometers

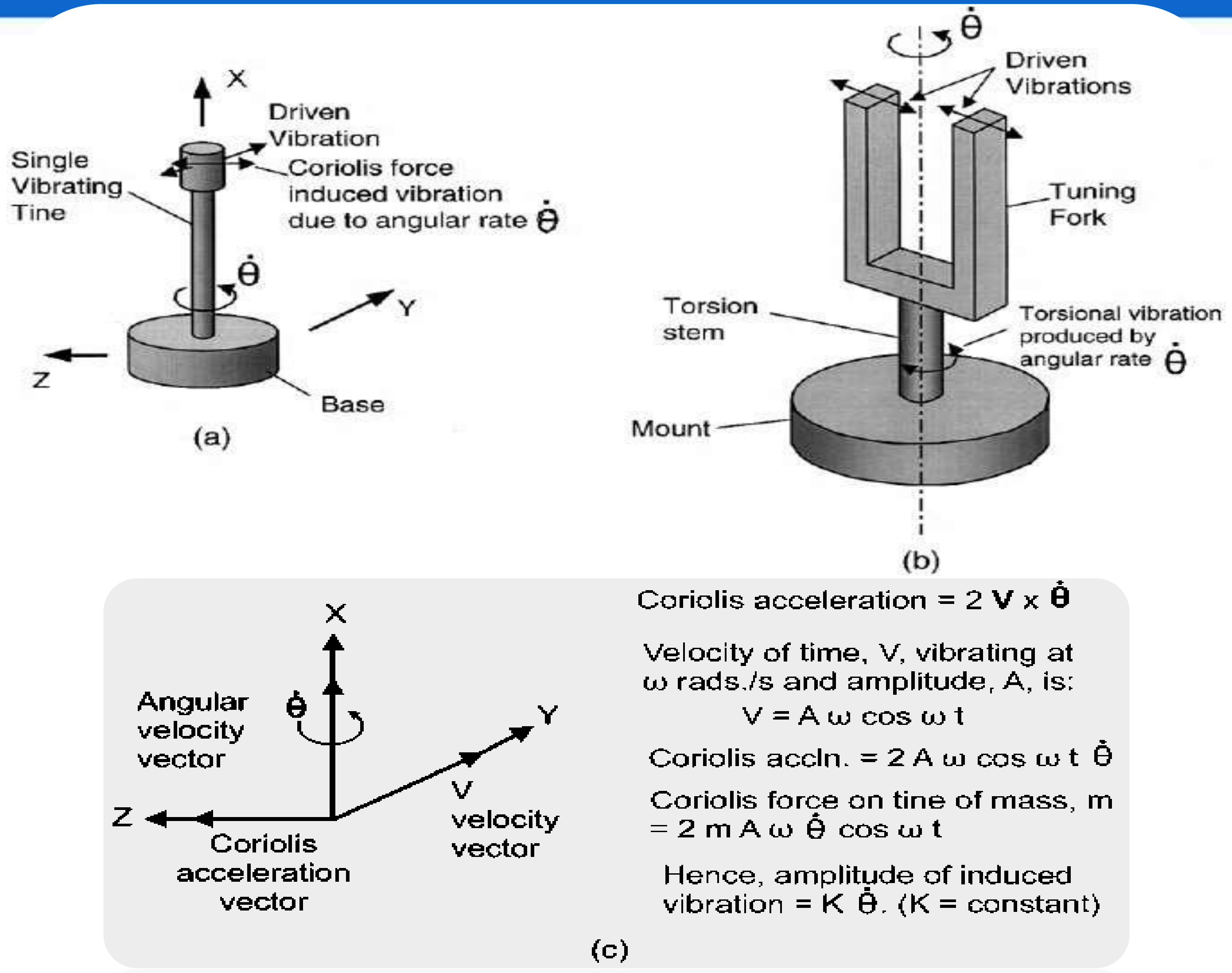
•The accuracy requirements for gyros and Accelerometers can differ by several orders of magnitude depending on the application

Micro Electro-Mechanical Systems (MEMS) Technology Rate Gyros

•These gyros exploit the effects of the Coriolis forces which are experienced when a vibrating mass is subjected to a rate of rotation about an axis in the plane of vibration.

• There are two basic configurations which are being exploited; a tuning fork configuration and a vibrating cylinder configuration.

Cont…



Tuning fork rate gyro

General Rules

Don’t open instrument

- Any internal problem, send it in for repair
- Can paint the outside
- Can make markings on the outside
- A white slippage mark must be place on glass/case
- Can repair outside wires, tubes and connectors
- Must be repaired by a certificated repair station approved for a specific class instrument

Label inoperable instruments

- Place label on instrument
- Document with a trouble ticket

General Rules

- **Markings and graduations are made according to the Aircraft Manufacturer**
  - Aircraft Specification or Type Certificate Data Sheet
  - Maintenance manual
  - Flight manual
- **Marks**
  - Red radial line – minimum or maximum
  - Green – normal
  - Yellow – caution
  - Not specified by Title 14

Instrument Case

- FAA say – “Cases for electrically operated instruments are made of iron or steel; these materials provide a path for stray magnetic force fields that would otherwise interfere with radio and electronic devices.
- Case usually made of iron/steel
  - Protect against magnetic and electrical fields
- Mounting
  - Flanges

Mounting

- Flanges
  - Mount from the front
- Flangeless
  - Uses a expanding type of clamp secured to the rear face of the panel
- Slide in cases
  - Almost all radios

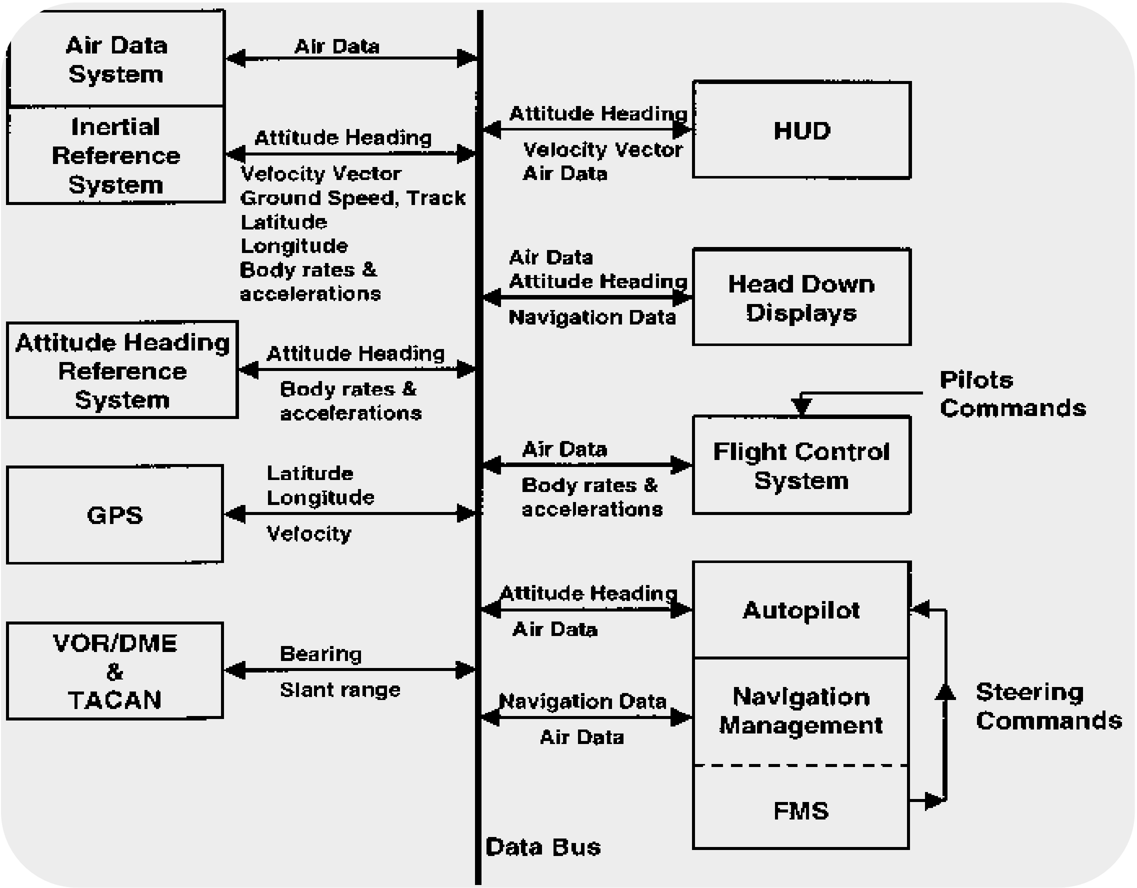
Unit IV

Navigation Systems and Landing Systems

INTRODUCTION AND BASIC PRINCIPLES

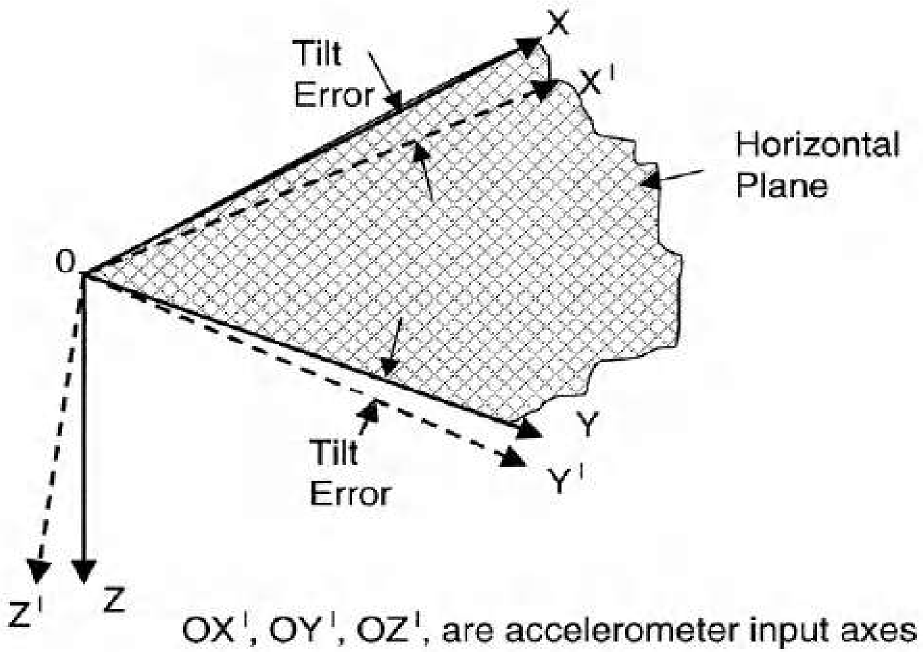
Navigation – The act, science or art of directing the movement of a ship or aircraft.

1. Air data based DR navigation.
2. Doppler/heading reference systems.
3. Inertial navigation systems.
4. Doppler inertial navigation systems

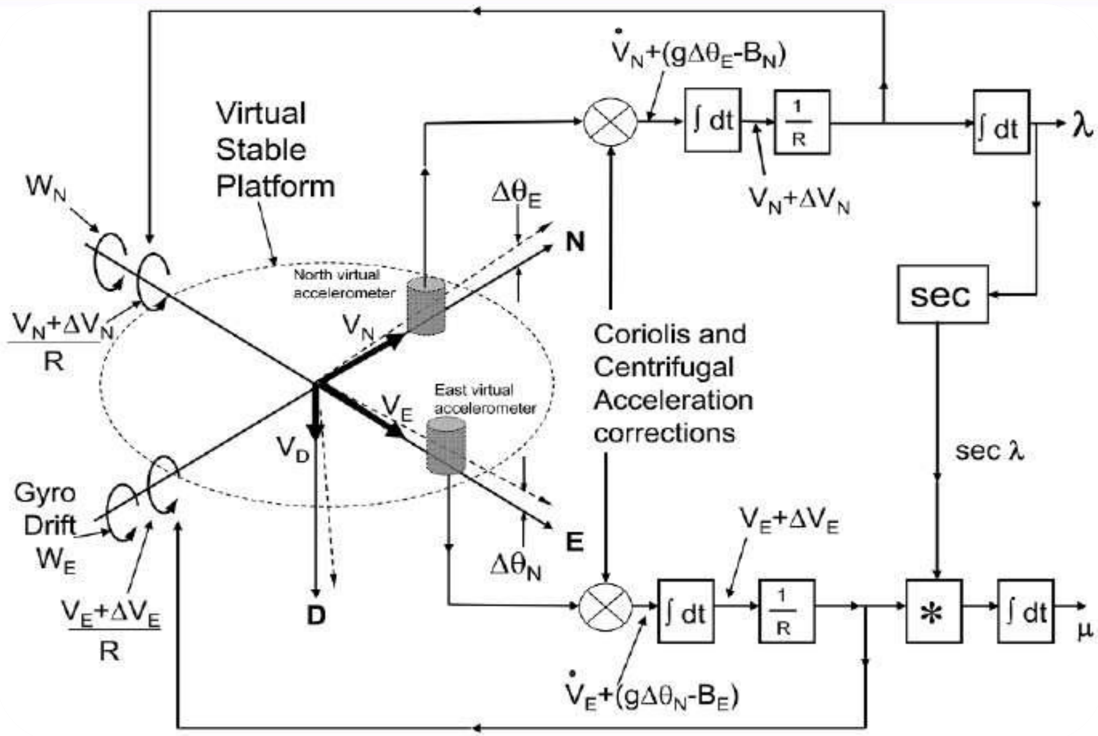


Navigation system information flow to user systems

Basic Principles and Schuler Tuning



Tilt errors

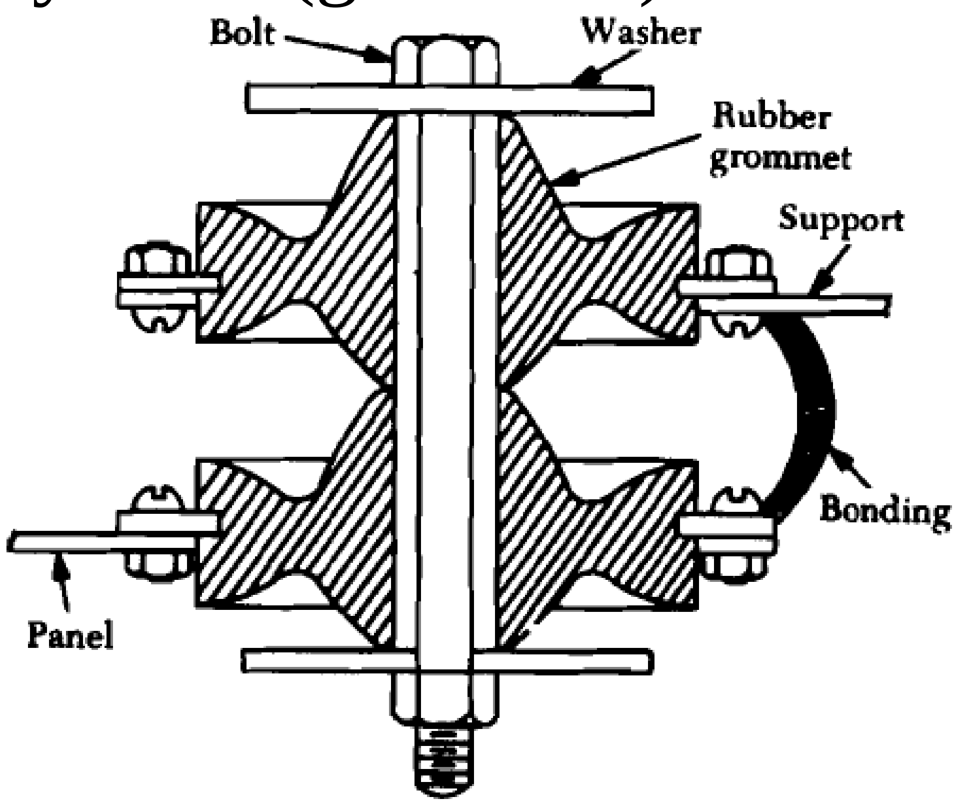


Schuler tuned strap-down INS (note: The Earth rotation rates about the North and East axes are left out for clarity).

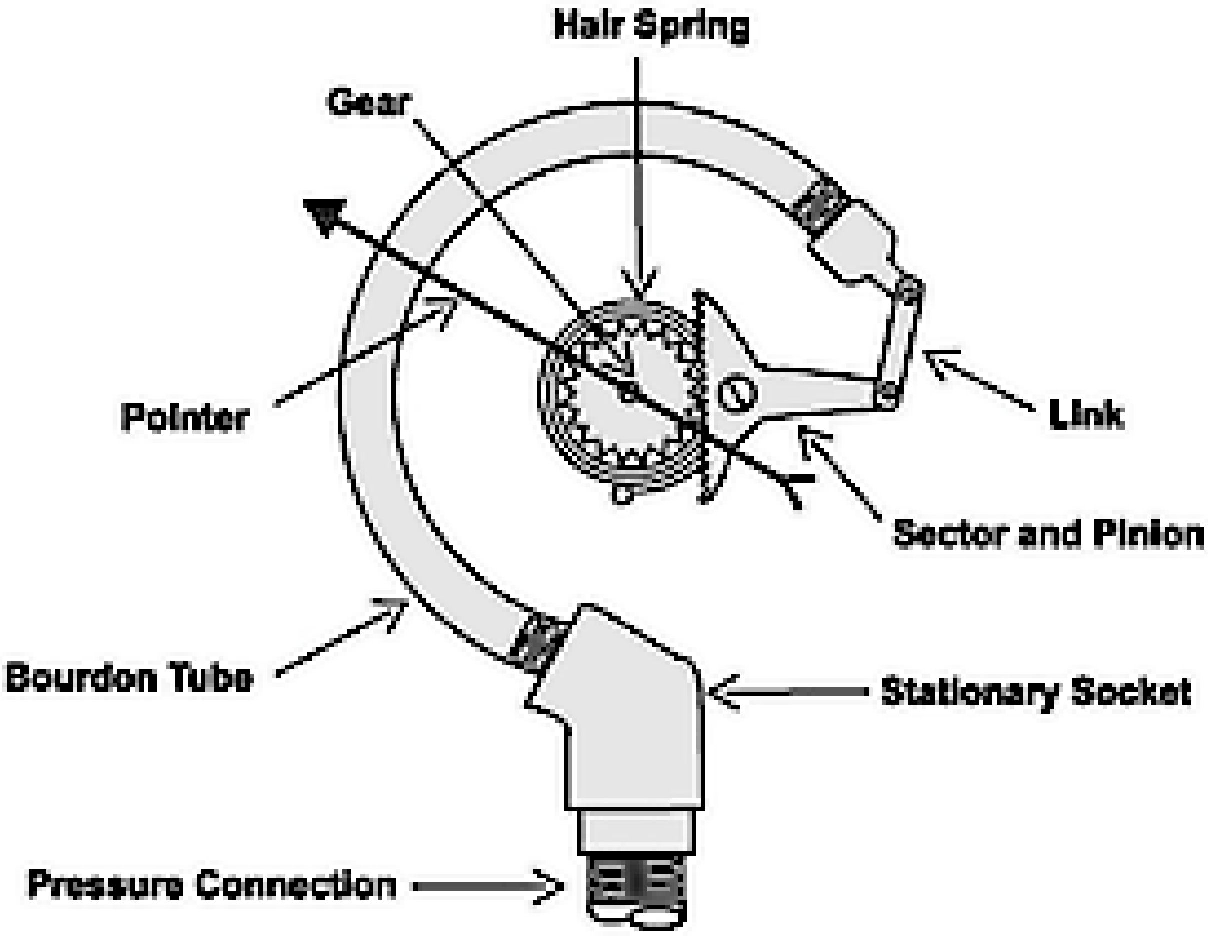
Instrument Panel

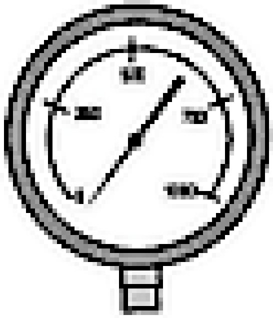
Instrument Panel Mounts

- Shock mounted
  - Absorb low-frequency, amplitude (strength) shocks
- Electrically bond (grounded) with bonding strap



BOURDON TUBE PRESSURE GAGE



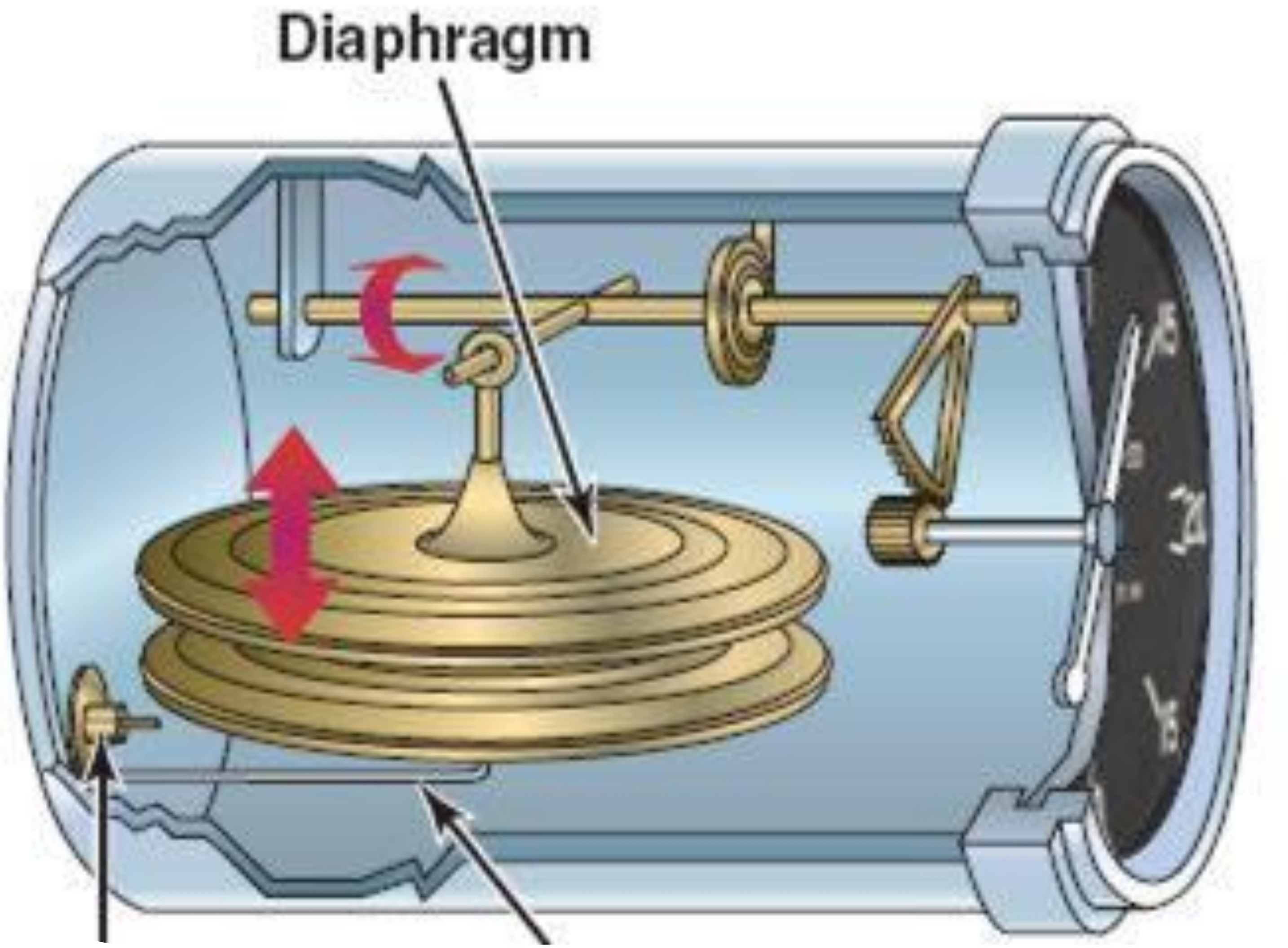


BOURDON TUBE PRESSURE GAGE

BOURDON TUBE PRESSURE GAGE

- Used for higher pressures
- Oil pressure
  - Restrictor on input line to limit leaks
  - Kerosene to improve movement
- Kerosene is thinner than oil
- Hydraulic pressure
- Oil temperature
  - Capillary tube senses temperature
  - Volatile fluid vaporizes at higher temperatures and increases pressure

Diaphragm-Type Pressure Gage

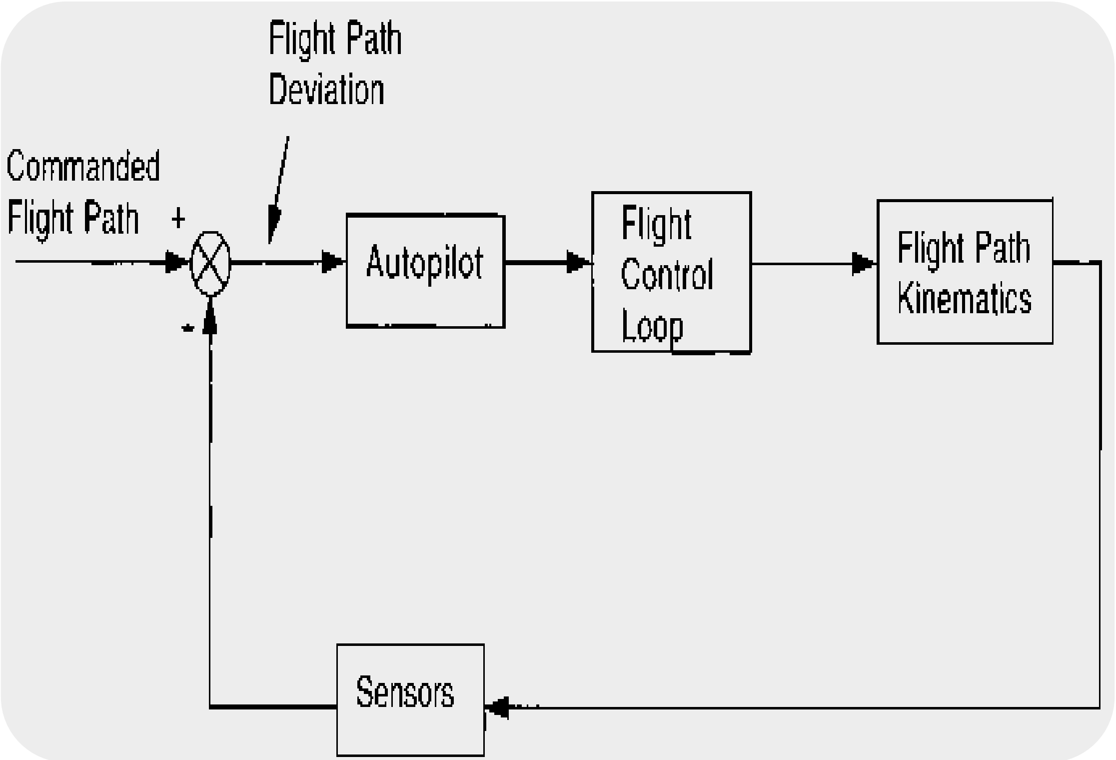


DIAPHRAGM TYPE PRESSURE GAGE

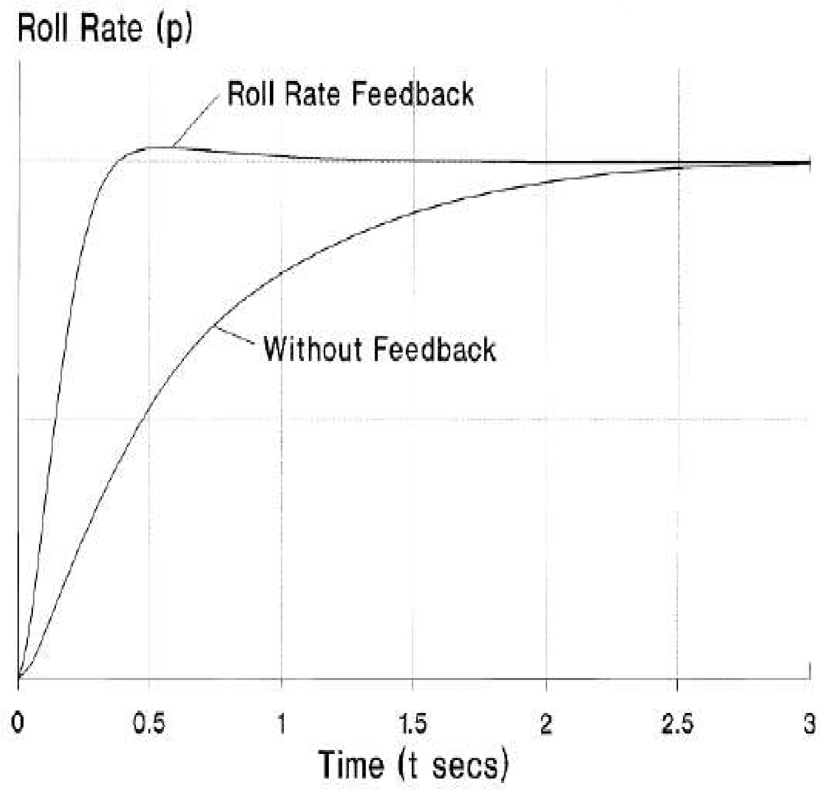
- Vacuum system Suction Gage
- Manifold Pressure Gage
  – Measures absolute pressure
  – If leaks or engine not running, measures atmosphere pressure

Unit V

Surveillance System and Autopilot System



Autopilot loop

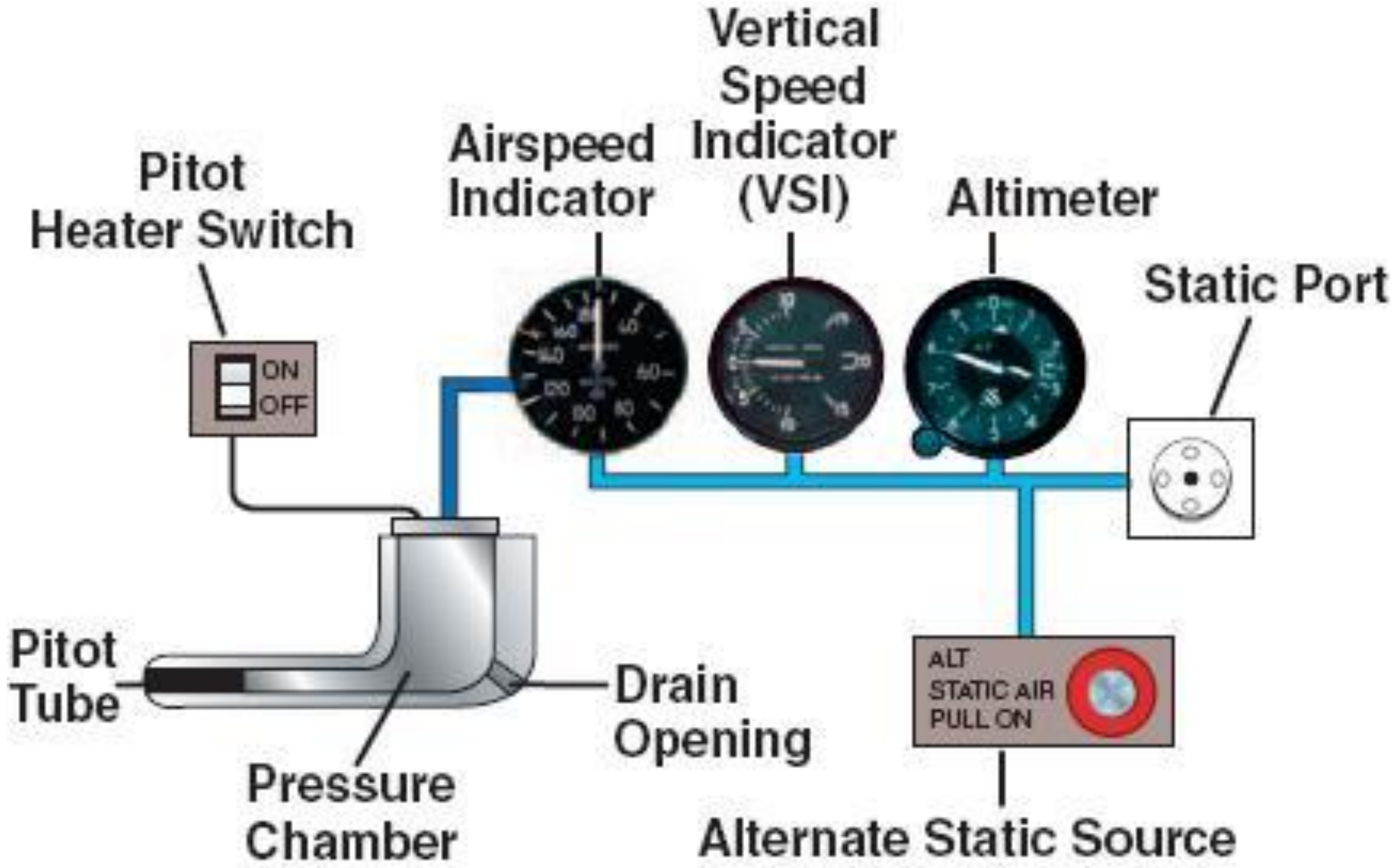


Roll rate response.

FAR Sec. 91.411

- (a) No person may operate an airplane, or helicopter, in controlled airspace under IFR unless--
  - (1) Within the preceding 24 calendar months, each static pressure system, each altimeter instrument, and each automatic pressure altitude reporting system has been tested and inspected and found to comply with appendix E of part 43 of this chapter;
  - (2) Except for the use of system drain and alternate static pressure valves, following any opening and closing of the static pressure system, that system has been tested and inspected and found to comply with paragraph (a), appendices E and F, of part 43 of this chapter; and
  - (3) Following installation or maintenance on the automatic pressure altitude reporting system of the ATC transponder where data correspondence error could be introduced, the integrated system has been tested, inspected, and found to comply with paragraph (c), appendix E, of part 43 of this chapter.

Pitot-Static System



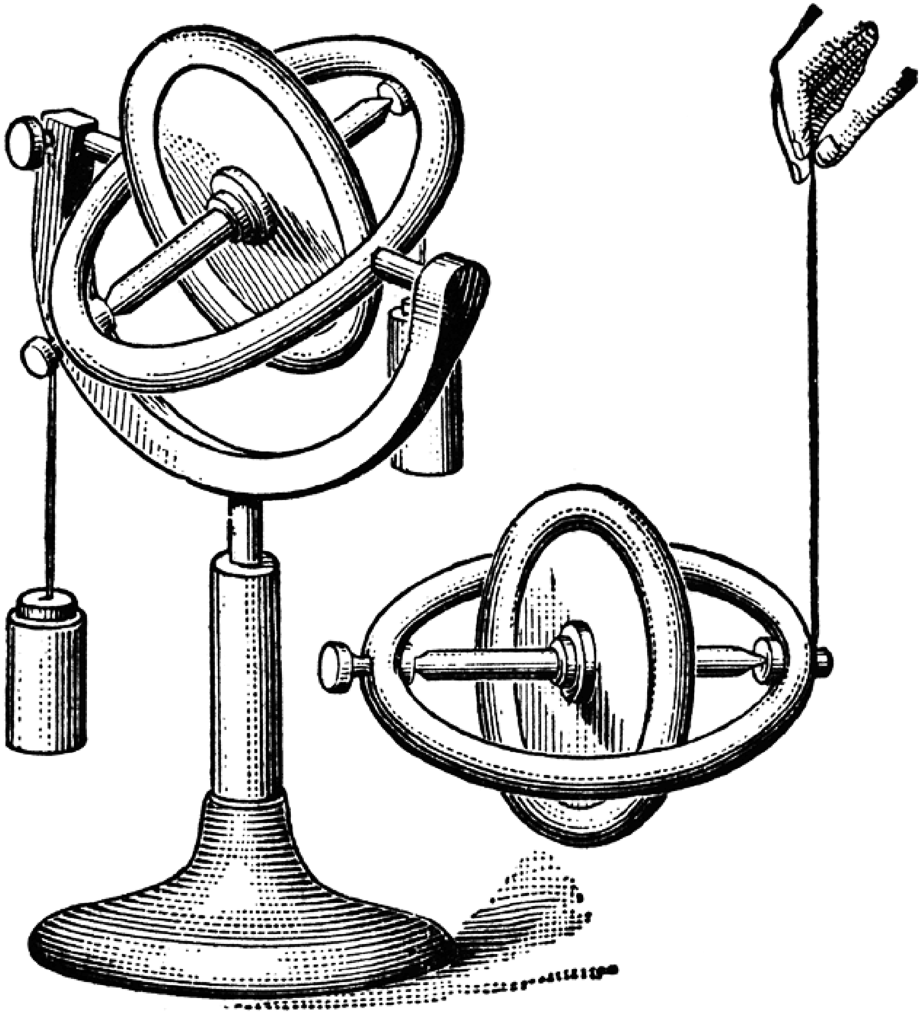
PITOT-STATIC SYSTEM

- Altimeter – Static source
  - Set to 29.92" Hg and it will read pressure altitude
- Rate of Climb – Static source
  - Measures change in pressure
- Airspeed Indicator – Static and Pitot sources
  - Also Mach meter
  - Measure the difference between static pressure and static pressure (impact pressure)
  - Blue (best climb rate); White (Flap extension)
  - May have maximum allowable speed – static source
- Must a have alternate static source

Pitot-Static System Maintenance

- Pressure Test
  - Apply vacuum to equivalent altitude of 1,000 feet
  - No more than 100 feet loss in 1 minute
  - Altimeter may be used to make test
- Clean entry holes, drain holes and static ports
- Check Pitot Heater
  - Look at electric drain and temperature
- Trouble shoot by isolating sections
- A static leak will cause low readings on altimeter and airspeed indicator

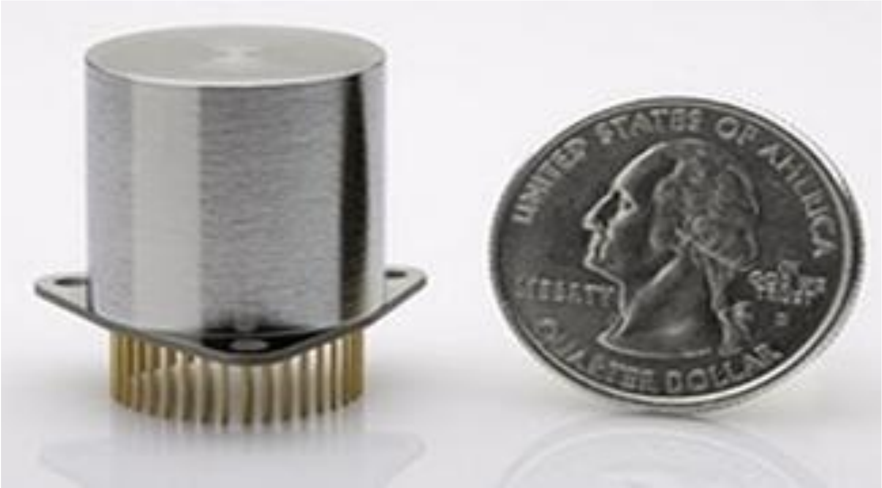
Gyroscope

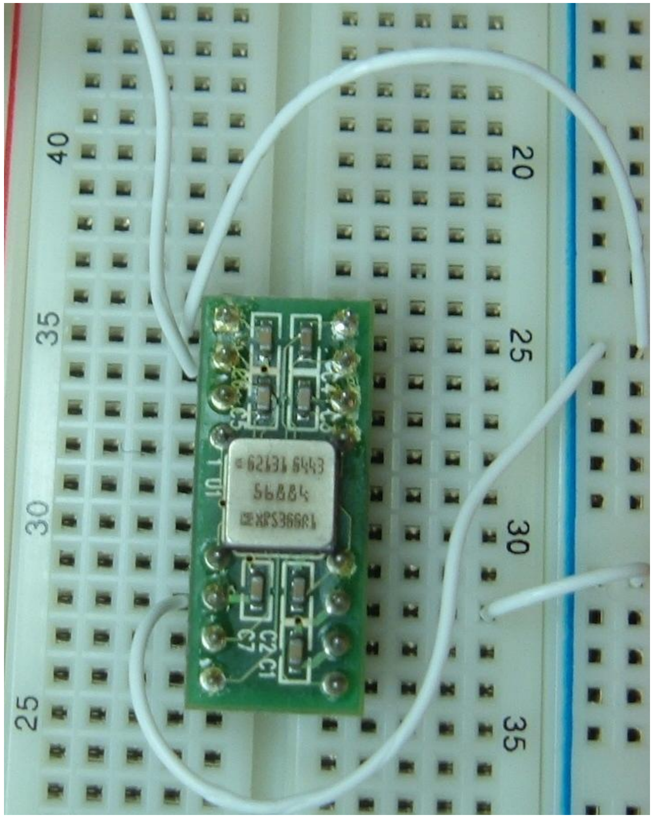


Gyroscope

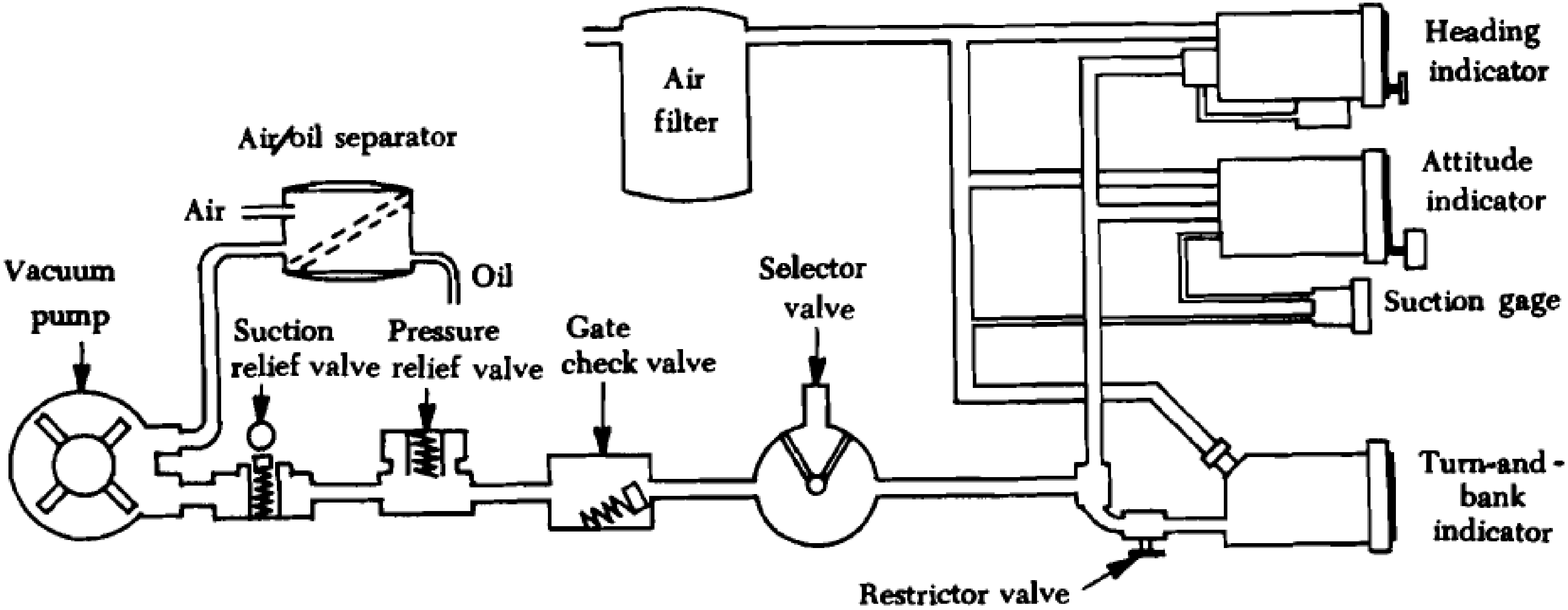
- Measures movement
- Vacuum powered
- Electric powered

Solid State Gyroscope





Vacuum System for Gyro



VACUUM SYSTEM FOR GYRO

- Vacuum pump – usually engine driven
  - Dirt is it’s enemy
  - Time limited – usually 5 years
  - No lubrication

Vacuum System for Gyro

- Air-Oil Separator
- Suction Relief Valve/Vacuum Regulator Valve
  - Adjust vacuum
  - Error in adjust can cause excess vacuum
- Suction Gage – pilot must monitor
- Air Filter
  - Usually single central filter
  - Regularly changed

Instrument Panel

Turn Coordinator

- Usually electrically driven
  - As a backup to vacuum system
- Measures both bank and yaw

Synchro-Type Remote Indicator

- A Synchro system is an electrical system used from transmitting information from one point to another.
  - Autosyn
    - Electric magnet
  - Selsyn
  - Magnesyn
    - Permanent magnet
- Synchro receiver is connected synchro transmitter by wires

D.C. Selsyn System

- Shows the position and movement of:
  - Landing gear
  - Wing flaps
  - Cowl flaps
  - Oil cooler doors
- A resistor can be added to the circuit to indicate end points like gear lock

D.C. Selsyn System

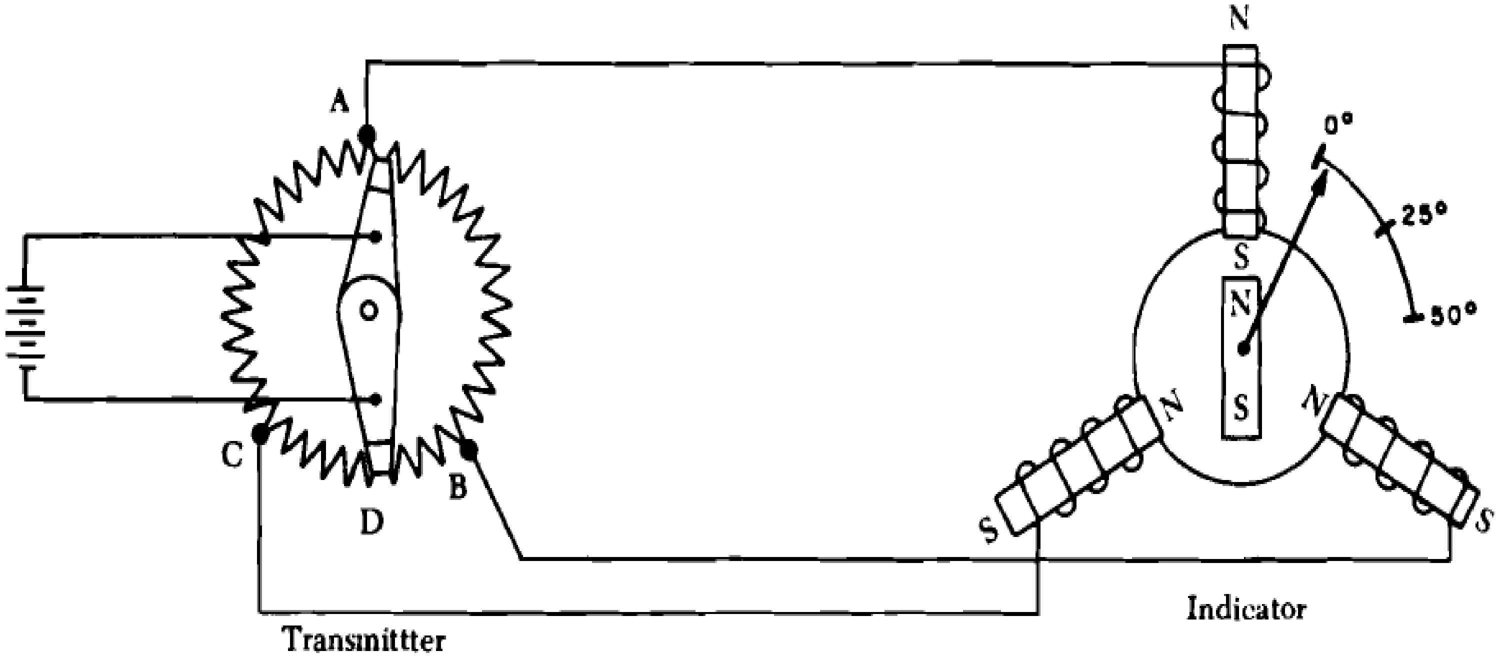
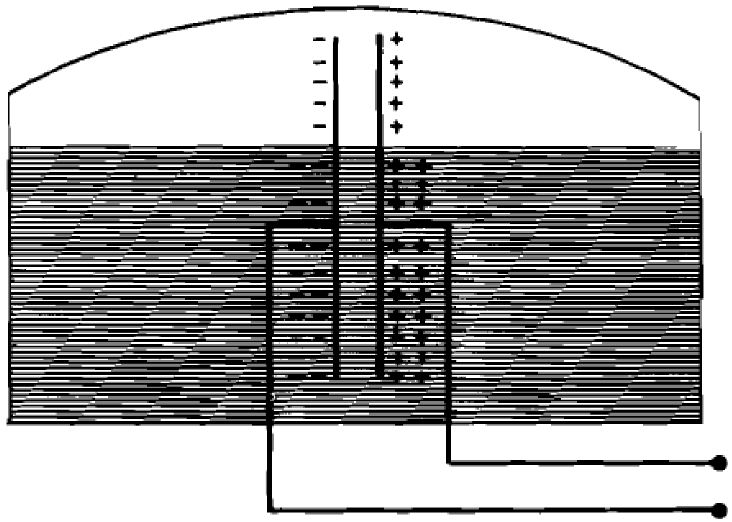


FIGURE 12–23. Schematic diagram of a d.c. selsyn system.

Capacitor-Type Fuel Quantity System

- A capacitor formed with fuel and air acting as a dielectric
- No moving parts
- Measures weight of fuel
  - Important for jets



Angle-Of-Attack

- Helps alert a pilot of stall and the amount of lift
  - Better than a stall warning
- Measures a differential pressure at the point the airstream flows in a direction not parallel to the true angle of attack of the aircraft

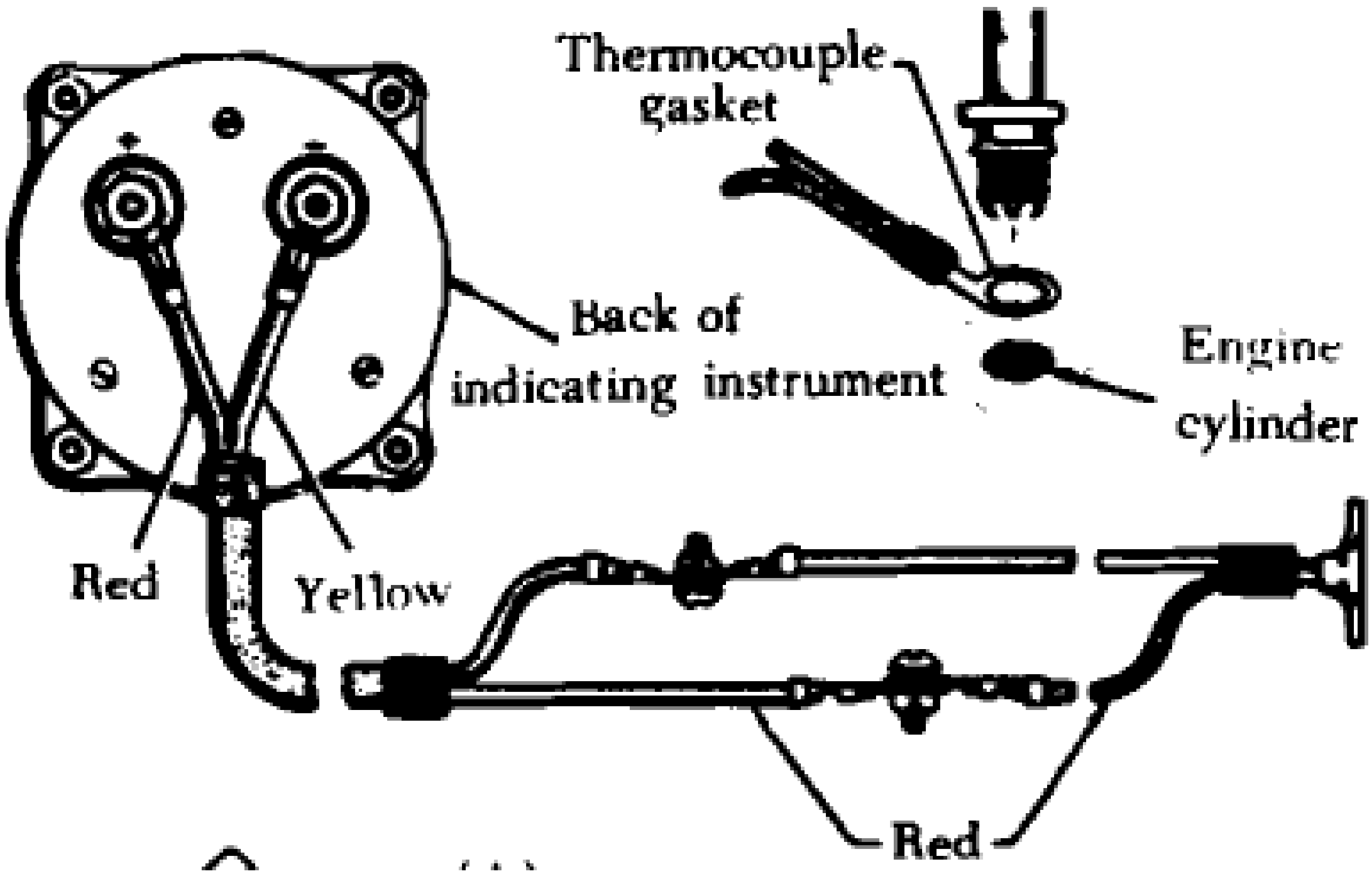
Electrical Resistance Thermometer

- Components
  - Heat-sensitive element or bulb
    - Changes resistance with heat
  - Indicator
  - Wheatstone bridge metering circuit
- Measures: free air; carburetor air; coolant (engine) and oil temperature
  - No really hot temperatures – exhaust and cylinder head

Thermocouple Thermometer Indicator

- Thermocouple generates electricity when it gets hot
  - No external power need
  - Made with two different metals
  - Iron/Constantan; Copper/Constantan or Chromel/Alumel are common combinations
  - Chromel/Alumel used on jet engines
- Don’t alter or repair thermocouple

Thermocouple Thermometer Indicator



Thermocouple Thermometer Indicator

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  - ❖Made with two different metals
  - ❖Iron/Constantan; Copper/Constantan or Chromel/Alumel are common combinations
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