Lecture 1: Introduction to Avionics Systems

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Avionics Systems AVE 402/V

Fall Semester I

Week number :3

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Tishk International University
Engineering Faculty
Avionics Engineering Department

Avionics Systems

AVE 402/V

TOPIC: Introduction to Avionics Systems

Week1_Lecture1

4th Grade- Fall Semester 2024-2025

Instructor: Prof.Dr. Qaysar Salih Mahdi

Objectives :

To introduce the students with functioning and principle of operation of various avionics systems including sensors installed on a modern passenger and fighter aircraft.

UNIT I: INTRODUCTION TO AVIONICS

Importance and role of Avionics in modern aircraft- systems which interface directly with pilot,aircraft state sensor systems, outside world sensor systems, task automation systems. The avionics equipment and system requirement, environmental, weight, reliability. Standardization and specification of avionics equipment and systems, ARINC and MIL specification. Electrical and optical data bus systems. Integrated modular avionics architectures.

UNIT II: DISPLAY &MAN- MACHINE INTERACTION AND COMMUNICATION SYSTEM

Introduction to displays- head- up displays(HUD)- basic principles, Helmet mounted displays, Head tracking systems. Head down displays- Civil cockpit, Military cockpit, Solid state standby display systems, Data fusion in displays- Intelligent display systems. Introduction to voice and data communication systems- HF,VHF,UHF and Satellite communications, Flight data recorders.

UNIT III: INERTIAL SENSORS, ATTITUDE DERIVATION AND AIR DATA SYSTEMS

Basic principles of gyroscope and accelerometers. Introduction to optical gyroscope, ring laser gyros, principles. Stable platform system, strap down systems, error in inertial systems and corrections. Air data Information and its use, derivation of Air Data Laws and relationship, altitude static pressure relationship, variation of ground pressure, Speed of sound, Mach Number, CAS, TAS, Pressure error. Air data sensors and computing

UNIT IV: NAVIGATION (INS AND GPS) AND LANDING SYSTEM

Principles of Navigation, Types of Navigation systems, Inertial Navigation System, Initial alignment and Gyro compassing, Strap down INS computing. Landing System, localizer and glide slope, marker systems. Categories of ILS. Global navigation satellite systems, GPS, description and basic principles. Integration of GPS and INS, Differential GPS.

UNIT V: SURVEILLANCE AND AUTO FLIGHT SYSTEMS

Traffic alert and collision avoidance systems(TCAS),Enhanced ground proximity warning system. Weather radar. Autopilots, Basic principle, height control, heading control, ILS coupled autopilot control, satellite

landing system, speed control and auto throttle. Flight management systems, principles, flight planning, navigation and Guidance, performance prediction and flight path optimization.

TEXT BOOKS

1.Collinson, R.P.G., Introduction to Avionics Systems, second edition, Springer,2003,ISBN 978- 81- 8489- 795- 1

2.Moir, I. and Seabridge, A., Civil Avionics Systems, AIAA education Series, AIAA, 2002, ISBN 1- 56347589- 8

REFERENCE BOOKS

1. Kayton, M., & Fried, W.R, Avionics Navigation Systems, Wiley, 1997,ISBN 0- 471- 54795- 6Z

Outcomes:

1. The student would gain understanding of the basic principles of avionics system

INTRODUCTION TO AVIONICS

Need for Avionics in civil and military aircraft and space systems

- Integrated Avionics system
- Typical avionics sub systems
- Design approaches and recent advances
- Application Technologies.

UNIT 1: INTRODUCTION TO AVIONICS

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

- **Definition of Avionics**
- **Avionics is a combination of aviation and electronics. Avionics system or Avionics sub-system depends on electronics. Avionics grew in 1950‟s and 1960 as electronic devices which replaces the mechanical or analog equipment in the aircraft.**

- **Avionics equipment on a modern military or civil aircraft**

- **account for around;**
  - **30% of the total cost of the aircraft**
  - **40% in the case of a maritime patrol/anti-submarine aircraft or helicopter.**
  - **Over 75% of the total cost in the case of an airborne early warning aircraft (AWACS).**

NEED FOR AVIONICS

To enable the flight crew to carry out the aircraft mission safely and efficiently. For civil airliner the mission is carrying passengers to their destination. For military aircraft the mission is intercepting a hostile aircraft, attacking a ground target, reconnaissance or maritime patrol.

Advantages

- Increased safety
- Air traffic control requirements
- All weather operation
- Reduction in fuel consumption
- Improved aircraft performance and control and handling and reduction in maintenance costs

CORE AVIONICS SYSTEMS

A hierarchical structure comprising layers of specific task and avionics system function for enabling the crew to carry out the aircraft mission.

The core avionics system is depicted in figure 1.1. In the core avionics system, the systems which directly interface with pilot are given below:

Display System

It provides the visual interface between the pilot and the aircraft systems.

Types

- HUD - Head Up Displays
- HMD - Helmet Mounted Displays
- HDD – Head Down Displays

Communication System

It provides the two way communication between the ground bases and the aircraft or between aircrafts. A Radio Transmitter and Receiver was the first avionics system installed in an aircraft. The different types of frequencies used for several ranges are given below.

Long Range Communication – High Frequency (2 – 30 MHz)

Medium Range Communication – Very High Frequency (30 – 100 MHz)

Military Aircraft – Ultra High Frequency (250 – 400 MHz)

Now a days satellite communication systems are used to provide very reliable communication.

UNIT 1: INTRODUCTION TO AVIONICS

Very important video for Introduction to Avionics

https://youtu.be/4XkpCFwGQXE?list=PLRVQZqWI54ibJ2olipObPnCq1PjdVzEqp

Advanced Avionics Systems

- **Advanced avionics systems can automatically perform many tasks that pilots and navigators previously did by hand. For example,**
- **an area navigation (RNAV)** or
- **flight management system (FMS)** unit accepts a list of points that define **a flight route, and automatically performs most of the course, distance, time, and fuel calculations**. Once en route, the FMS or RNAV unit **can continually track the position of the aircraft with respect to the flight route, and display the course, time, and distance remaining to each point along the planned route.**
- **An autopilot is capable of automatically steering the aircraft along the route that has been entered in the FMS or RNAV system.**

- ***UNIT 1: INTRODUCTION TO AVIONICS***

- **The FMS or RNAV unit and autopilot offer** the pilot a variety of methods of aircraft operation. Pilots can perform the navigational tasks themselves and manually control the aircraft, or choose to automate both of these tasks and assume a managerial role as the systems perform their duties. Similarly, information systems now available in the cockpit provide many options for obtaining data relevant to the flight. Advanced avionics systems present three important learning challenges as you develop proficiency.

Advanced avionics systems present three important learning challenges as you develop proficiency:

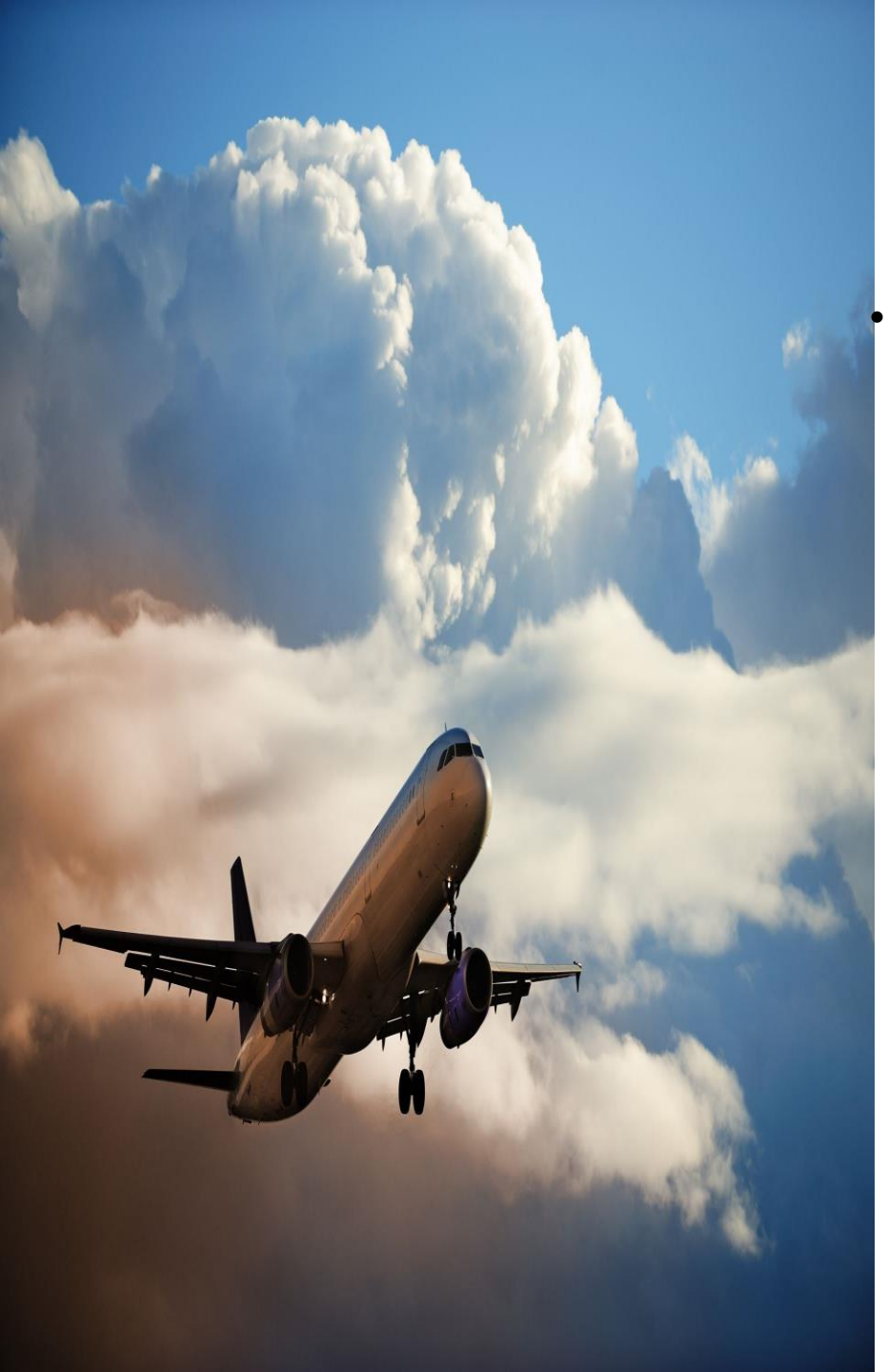
1.How to operate advanced avionics systems

2.Which advanced avionics systems to use and when

3.How advanced avionics systems affect the pilot and the way the pilot flies How To Operate Advanced Avionics Systems.

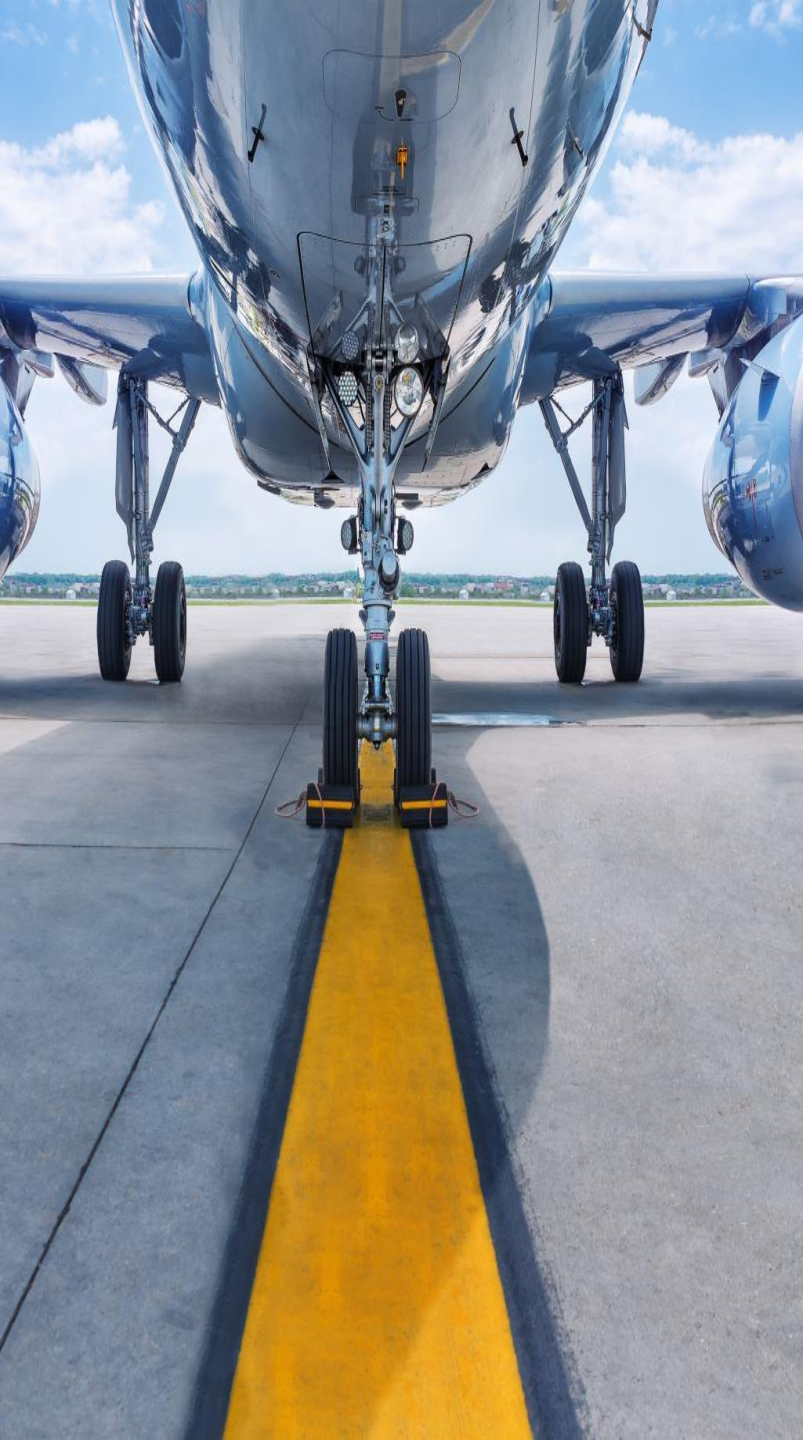
The first challenge is to acquire the "how-to" knowledge needed to operate advanced avionics systems.

This course describes the purpose of each kind of system, overviews the basic procedures required to use it, explains some of the logic the system uses to perform its function, and discusses each system's general limitations



UNIT 1: INTRODUCTION TO AVIONICS

- **Importance and role of Avionics**
  - **Systems which interface directly with pilot**
  - **Aircraft state sensor systems**
  - **Navigation systems**
  - **External world sensor systems**
  - **Task automation systems.**
  - **Million dollar business ,**
  - **30% of total cost of aircraft --- avionics equipment**
  - **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.**



- **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.

- **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.**

Goal of Avionic systems

- Goal of Avionic systems is
  - increased safety
  - Air traffic control requirements
  - All weather operation
  - Reduction in fuel consumption
  - Improved aircraft performance and control
  - Handling and reduction of maintenance costs

Main Avionic Subsystems

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

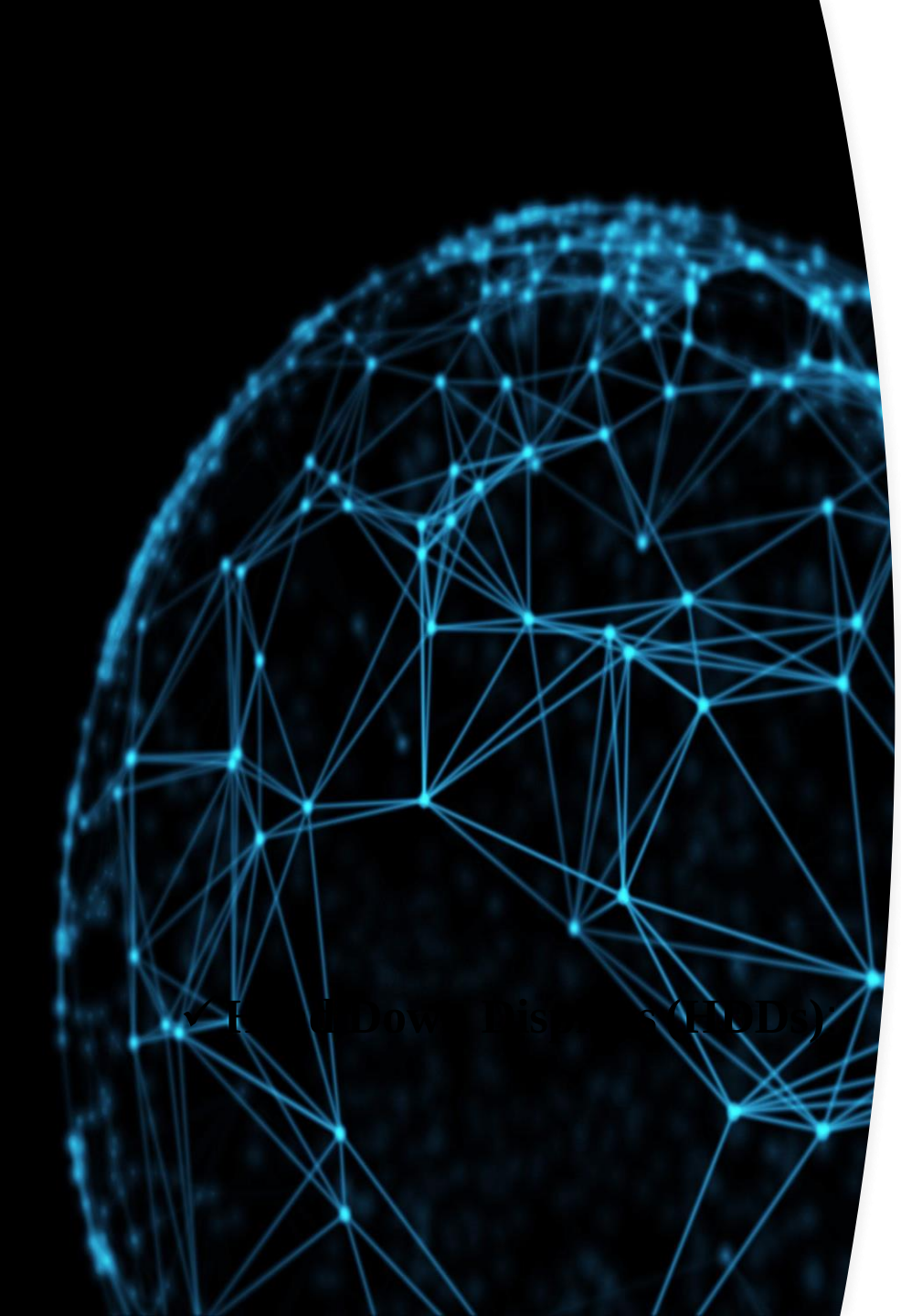
-Systems which interface directly with the pilot.

-Aircraft state sensor systems

-Navigation systems

-External world sensor systems

-Task automation systems



Systems which interface directly with the pilot

✓ **Head up Displays (HUDs)**: 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.

- **Systems which interface directly with the pilot**
  - **Displays:** Provide visual interface between pilot and the aircraft systems.
    - **Helmet Mounted Displays (HMDs)**: - 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.

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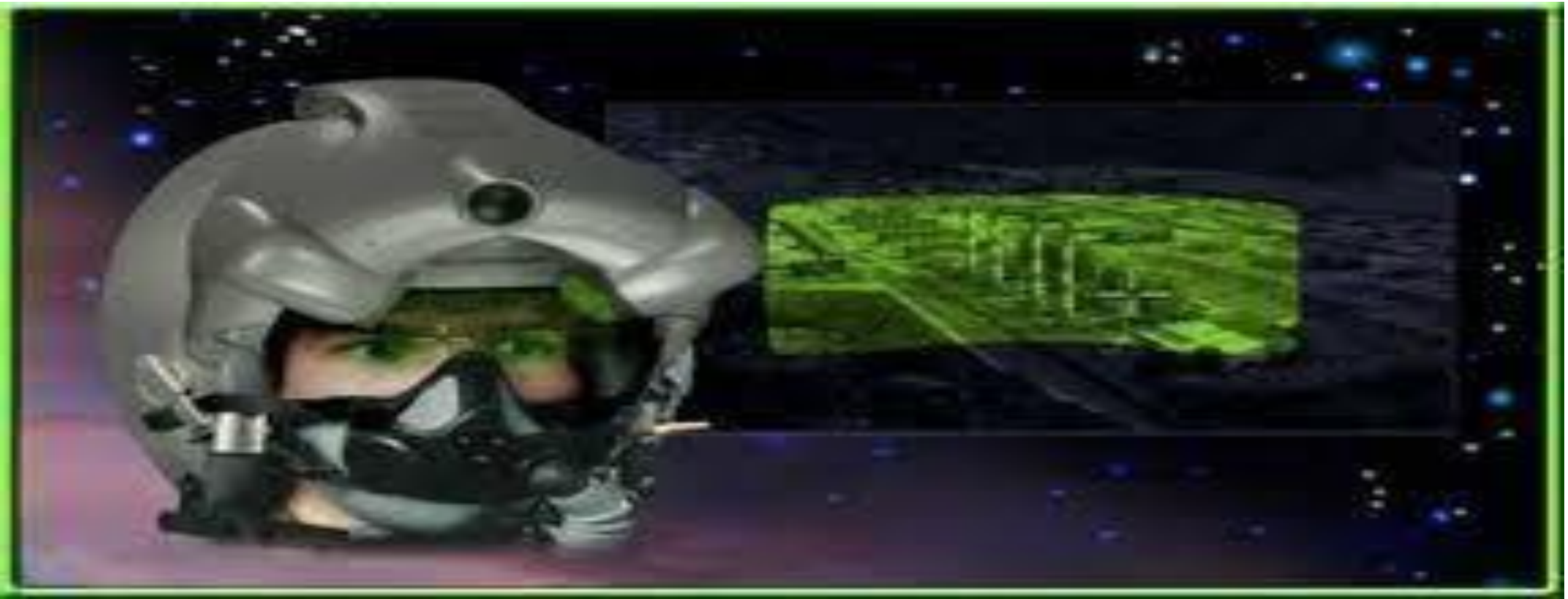


- ✓ **Head up Displays (HUDs): HUD can also display a forward looking infrared (FLIR) video picture one to one with the outside world from a fixed FLIR imaging sensor installed in aircraft.**

✓Head Down Displays (HDDs):

- ***UNIT 1: INTRODUCTION TO AVIONICS***

- **Advantages**

- Give information about 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

Communication Systems

- **Communication Systems :** Two-way communication between ground bases and the aircraft or between aircraft - air traffic control.
  - **High frequency radios ----2 to 30 MHz.**
  - **Very high frequency----- 30 to 100 MHz.**
  - **Ultra high frequency ---- 250 to 400 MHz.**

  - **SATCOM systems** -------- Short for **Satellite Communications** and used frequently in the context of **VSAT (Very Small Aperture Terminal) Communications satellites or comsats. Satcom(satellite), a fleet of early geostationary communications satellites.**

- **Data entry and control:**
  - Crew avionic systems.
  - Keyboards, touch panels, direct voice input control.

- **Flight Control System**

- **It uses the electronic system in two areas.**

  - **Auto Stabilization**
    - **Roll Auto Stabilizer System**
    - **Pitch Auto Stabilizer System**

  - **FBW Flight Control Systems**

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

Core Avionics System

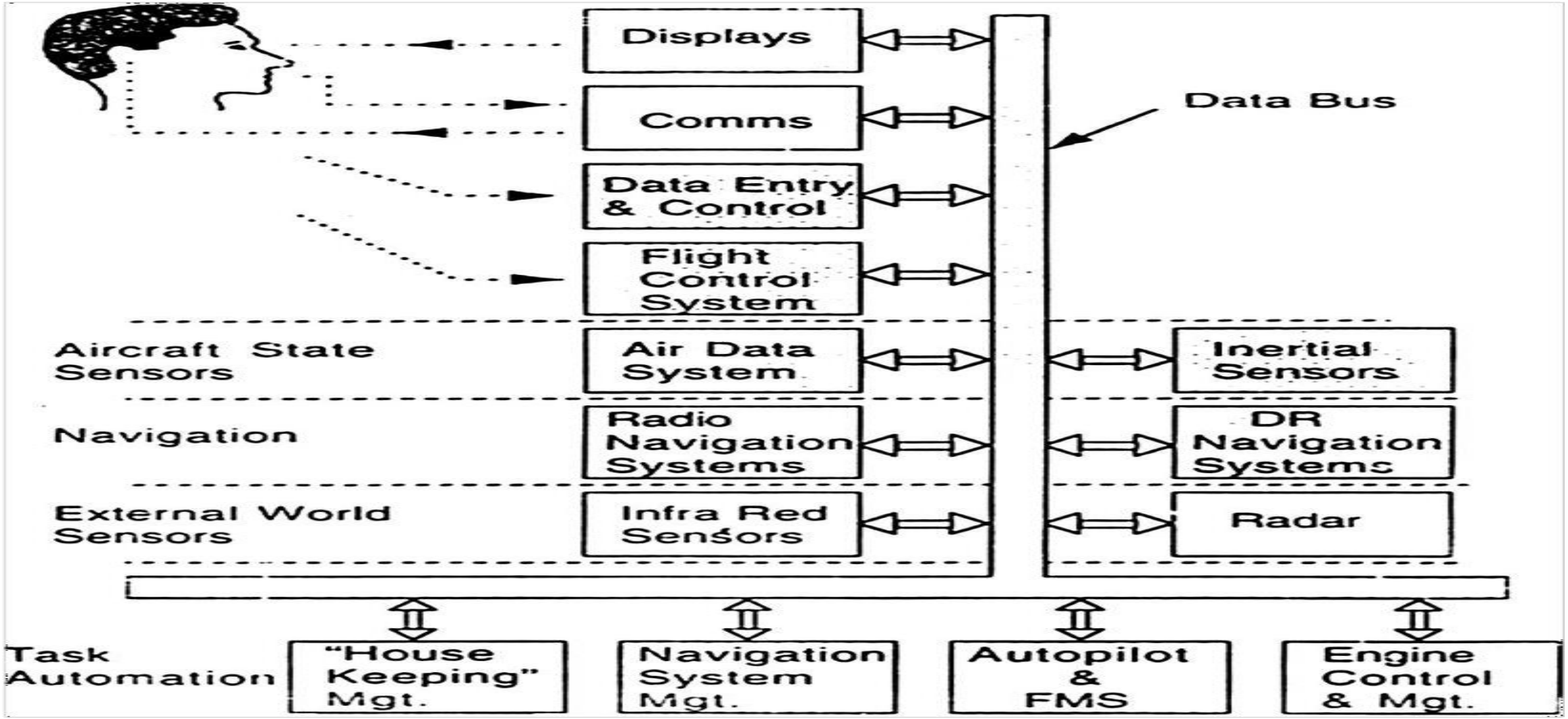
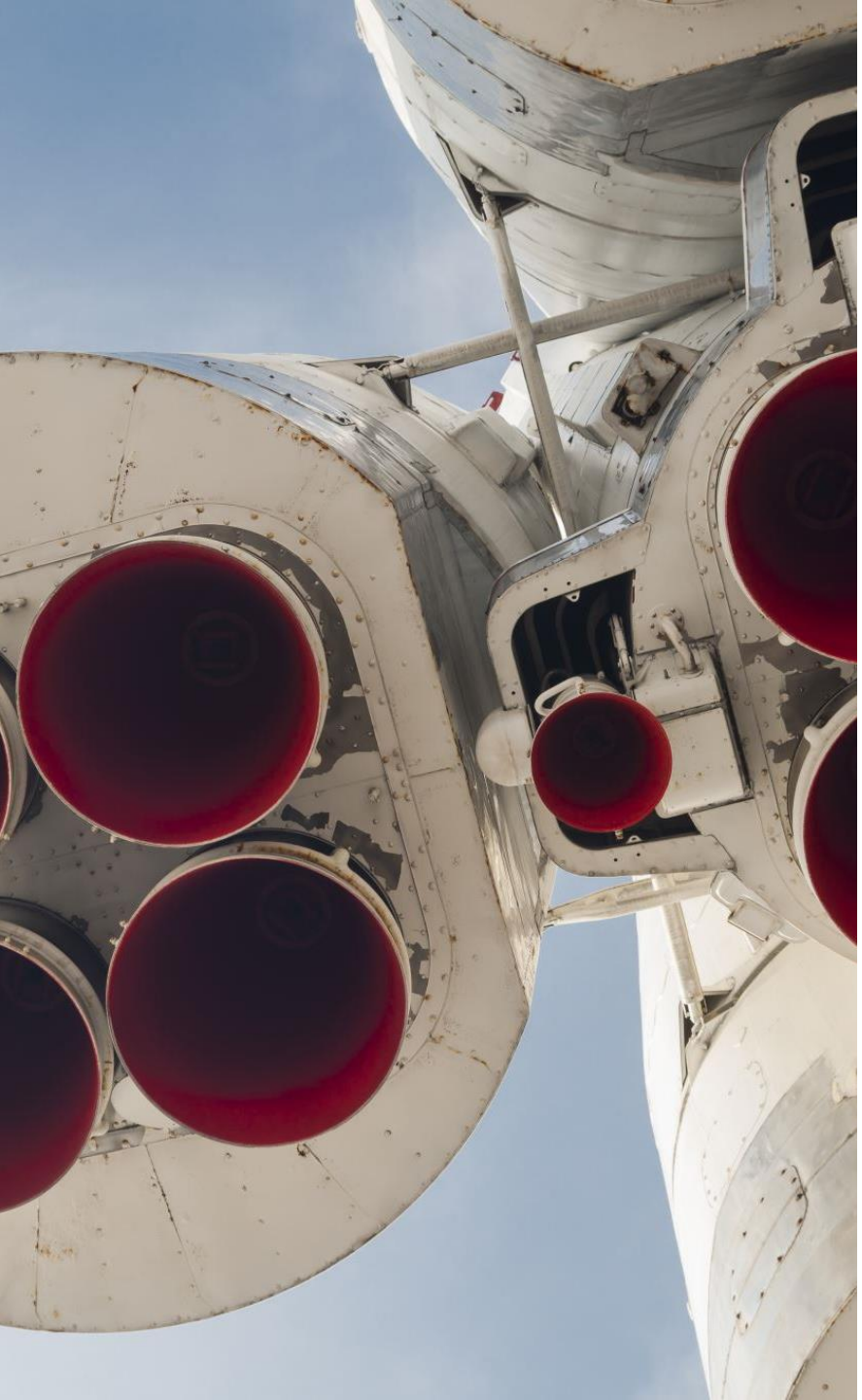


Figure 1.1 Core Avionics System

QUESTIONS

Part A

1.What is meant by avionics and write short notes on need for avionics in space system?
2.List out the advantage of using avionics in civil aircraft.
3.Give the advantages of using avionics in military aircraft.
4.Give the general advantage of Avionics over the conventional aircraft system.
5.Discuss the usage of avionics in space systems.
6.Give few examples of integrated avionics system used in weapon system.
7.Give few examples of integrated avionics system used in civil airlines.
8.Provide the “illities” of Avionics system.
9.Give various systems where the avionics used in aircrafts.
10.Bestow the steps involved in design of avionics system.



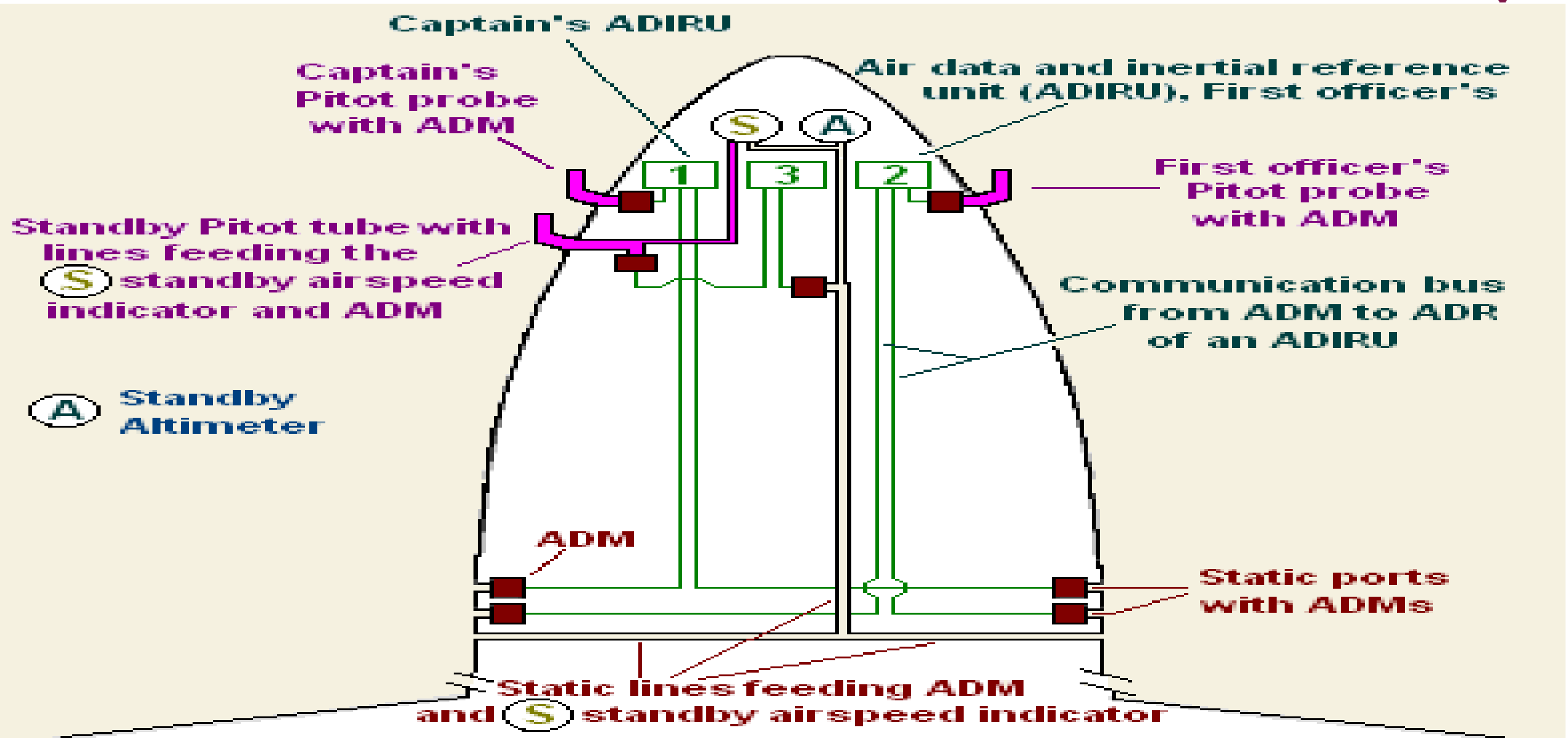
- **Introduction to Avionics**

- **Part B**

- Explain the need of avionics in Civil and military aircrafts.
- Explain few Integrated Avionics system and weapon system.
- What are the major design drivers for avionics system and also describe the various „illities“ in Avionics systems.
- With a neat block diagram explain the integration of different avionics system.
- Explain clearly the top down design procedure that is adopted in Avionics system design and also list the factor on which Avionics design is evaluated and explain each factor in brief.
- Explain the various layers of Avionics systems used in a typical airplane with a neat sketch.
- Explain the design and technologies involved in avionics system and the standards used for it.

- **Aircraft State Sensor Systems:**
  - **Air Data systems:** Accurate information of air data quantities sensed by accurate sensors are computed by air data computing system for control and navigation of aircraft.

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



Inertial Sensor Systems

2. Inertial Sensor Systems: 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 systems

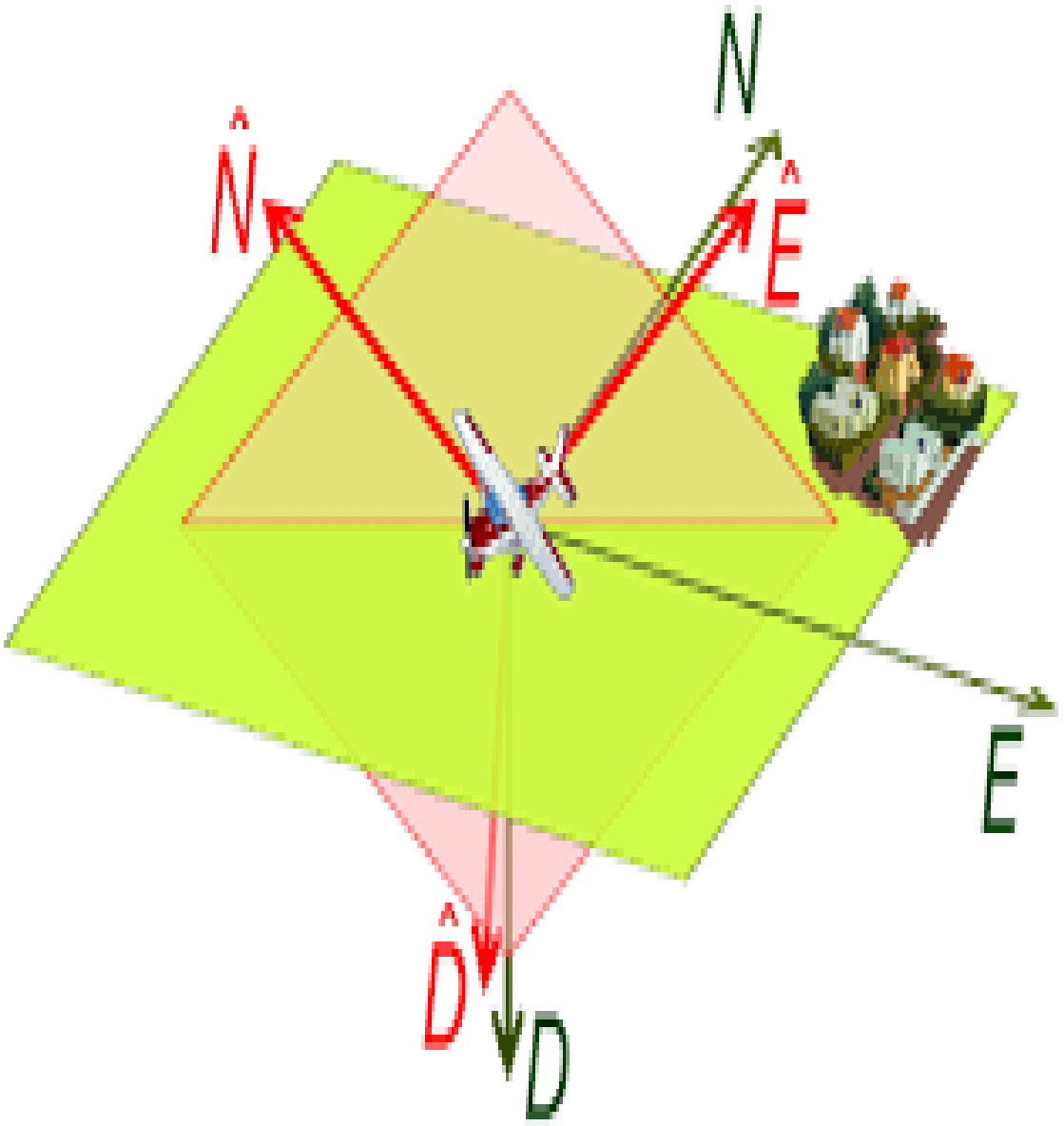
Navigation systems: Accurate navigation information like aircraft position, ground speed and track angle (direction of motion of the aircraft to true North) is essential for the aircraft's mission whether civil or military. Navigation systems are divided into

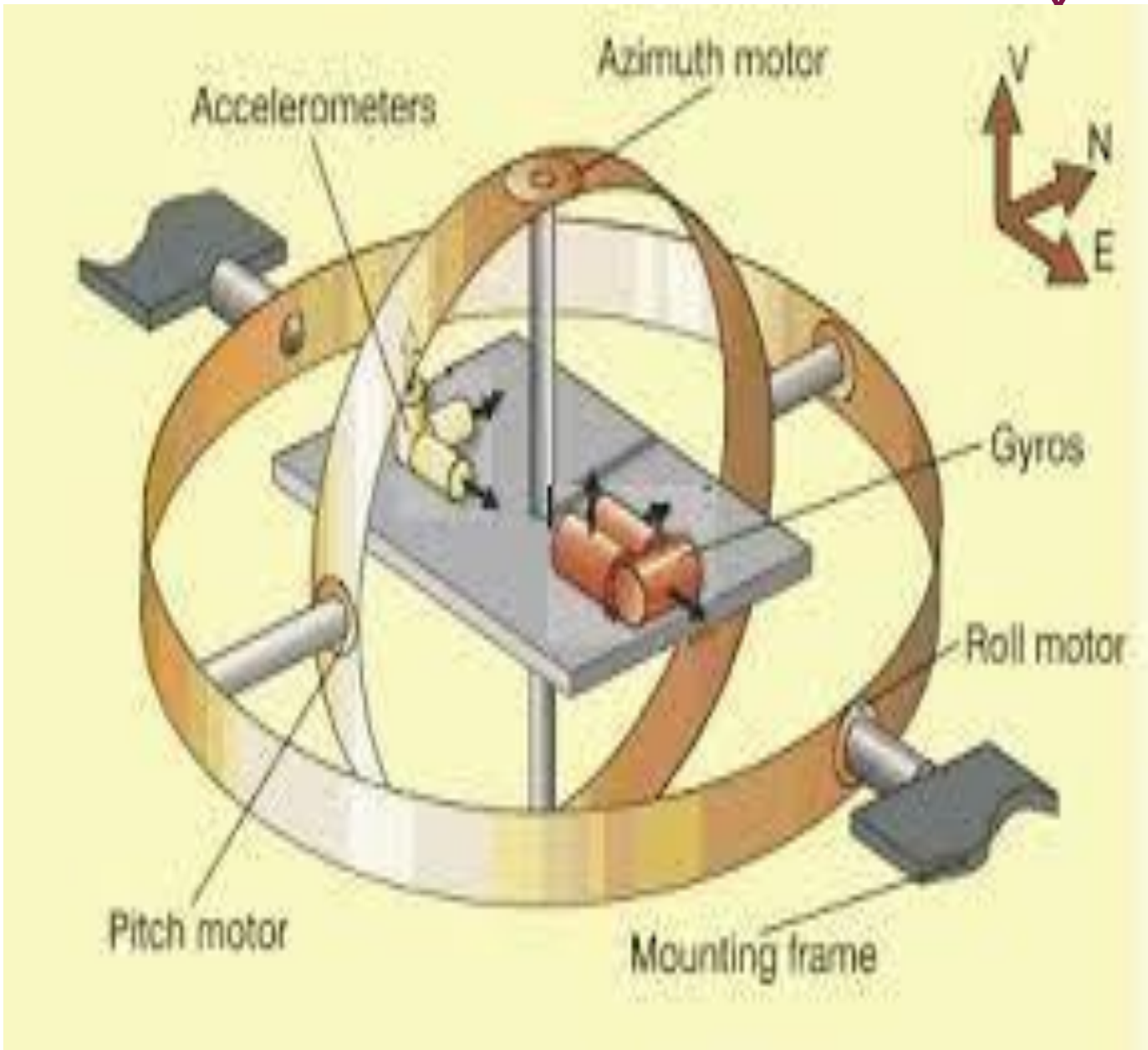
- **Dead Reckoning system:** DR navigation derives the vehicles present position by estimating the distance traveled from a known position's speed and direction of motion of vehicle.

They are of 3 types

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

Navigation systems





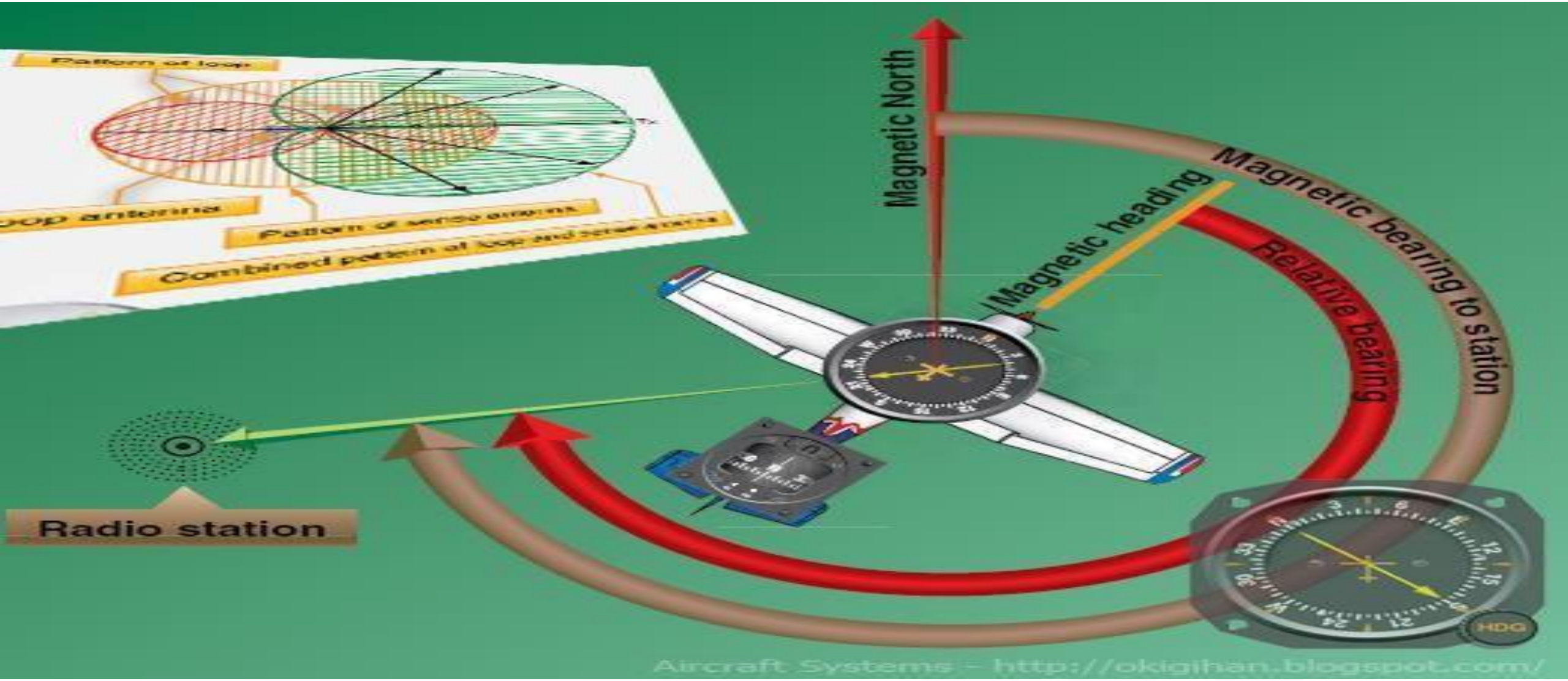
Position Fixed Systems or Radio Navigation System

- **Position Fixed Systems or Radio Navigation System:**
- The Position fixing systems usedat present are mainly **Radio Navigation Systems based on satellite or ground based transmitters.**

A suitable receiver in the aircraft witha supporting computer is then used to derive the aircrafts position from the signals received from **the transmitters.**

Ex: INS,GPS, VOR/DME, ILS MLS can be included for full navigation.

Position Fixed Systems or Radio Navigation System



Avionic equipment

Hence in the above example, the avionic equipment fit would comprise:

- **Radar – target acquisition in all weather conditions.**
- **Doppler – accurate ((4 knots) velocity sensor for DR navigation. (Note: IN systems capable of accurate initial alignment at sea on a moving carrier were still under development in the early 1960s.)**
- **Attitude heading reference system (or master reference gyro system – UK terminology) – attitude and heading information for pilot's displays, navigation computer, weapon aiming computer, autopilot.**
- **Air data computer – height, calibrated airspeed, true airspeed, Mach number information for pilot's displays, weapon aiming, reversionary DR navigation, autopilot.**
- **Radio altimeter – very low level flight profile during attack phase and all weather operation.**
- **Navigation computer – essential for mission.**
- **Autopilot – essential for reduction of pilot work load.**
- **Weapon aiming computer – essential for mission.**
- **HUD – all the advantages of the HUD plus weapon aiming for low level attack; for example, 'toss' bombing.**
- **Stores management system – control and release of the weapons.**
- **Electronic warfare (EW) systems – radar warning receivers, radar jamming equipment. Essential for survivability in hostile environment**

External World Sensor Systems:

External world sensor systems:

These comprise both radar and infrared sensor. Systems enable all weather and night time operations and transform the operational capability of the aircraft.

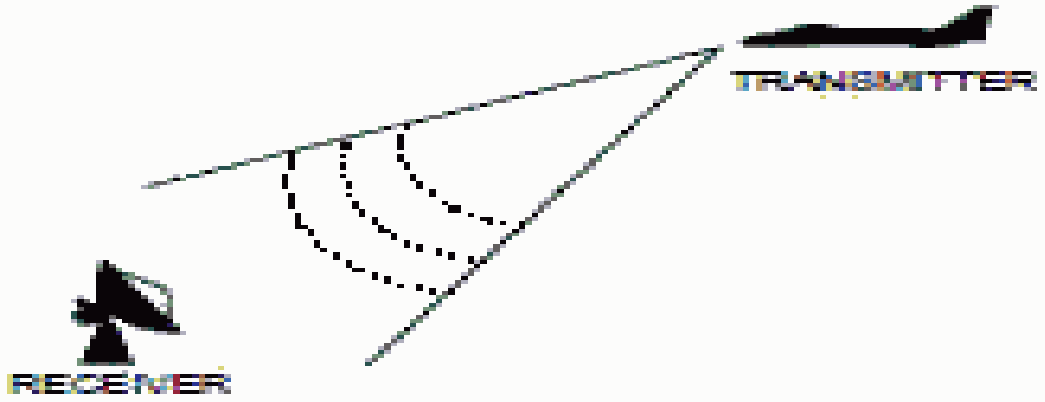
- **Radar Systems: Weather radar** is installed in all civil airliners and also in many general aviation aircraft.

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 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.**

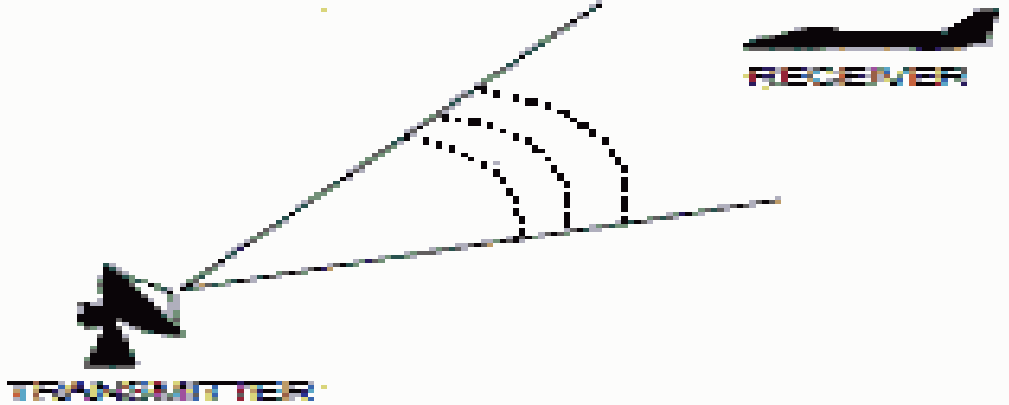
- **Infrared Sensor Systems:** Have major advantage of **being entirely passive systems**.
- Used to provide video picture of **the thermal image scene of the outside world** either using
- **fixed FLIR sensor, or**
- **alternatively gimbaled IR imaging sensor**.

Radar Systems: Weather Radar

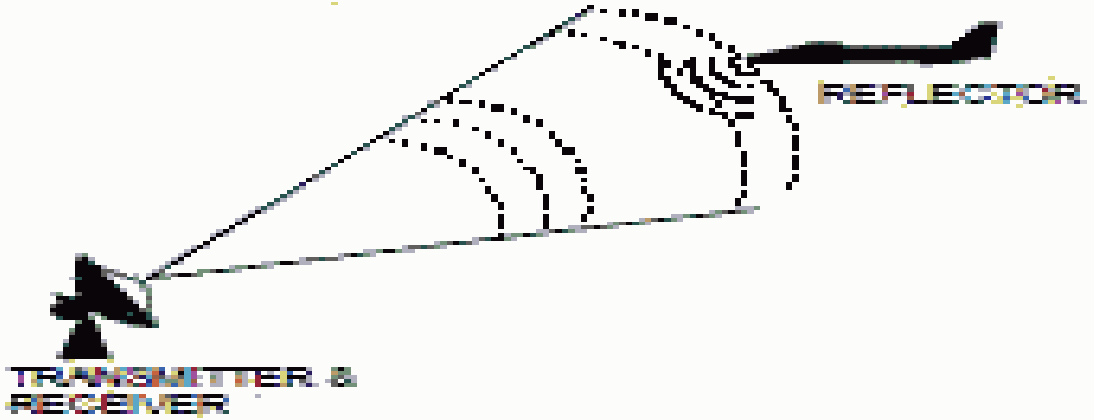
TRANSMITTER MOVING
SURFACE ESM/RWR MEASURES DOPPLER
(One-way Doppler Change)



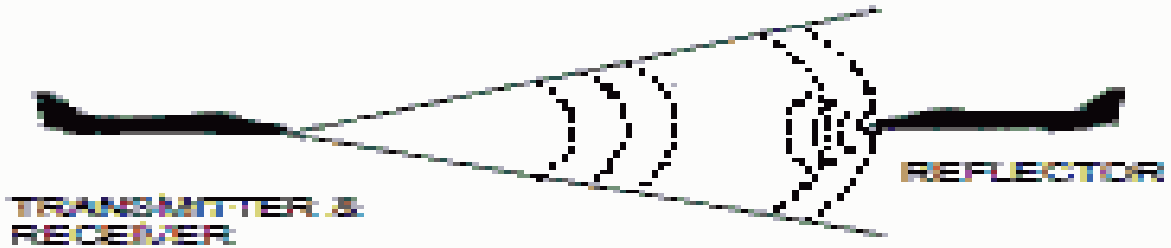
RECEIVER MOVING
AIRBORNE ESM/RWR MEASURES DOPPLER
(One-way Doppler Change)



REFLECTOR MOVING
SURFACE RADAR MEASURES DOPPLER
(Two-way Doppler Change)



ALL THREE MOVING
AIRBORNE RADAR MEASURES DOPPLER
(Two-way Doppler Change)



Task Automation Systems

v. **Task Automation Systems**: These comprise the systems which reduce the crew workload and enable minimum crew operation by automating and managing of tasks.

- ✓**Navigation management system:** operation of all radio navigation aid systems and the combination of the data from all the navigation sources.
- ✓**Autopilots and Flight Management Systems:**

Autopilots and Flight Management Systems

i. Flight planning,
ii. Navigation management,
iii. Engine control to maintain the planned speed or mach number,
iv. Control of the aircraft path to follow the optimized planned route,
v. Control of the vertical flight profile,
vi. Ensuring the aircraft is at the planned 3D position at planned time slot: often referred as 4D navigation.

Very important for ATC (Air Traffic Control) Flight envelop monitoring
Minimizing fuel consumption

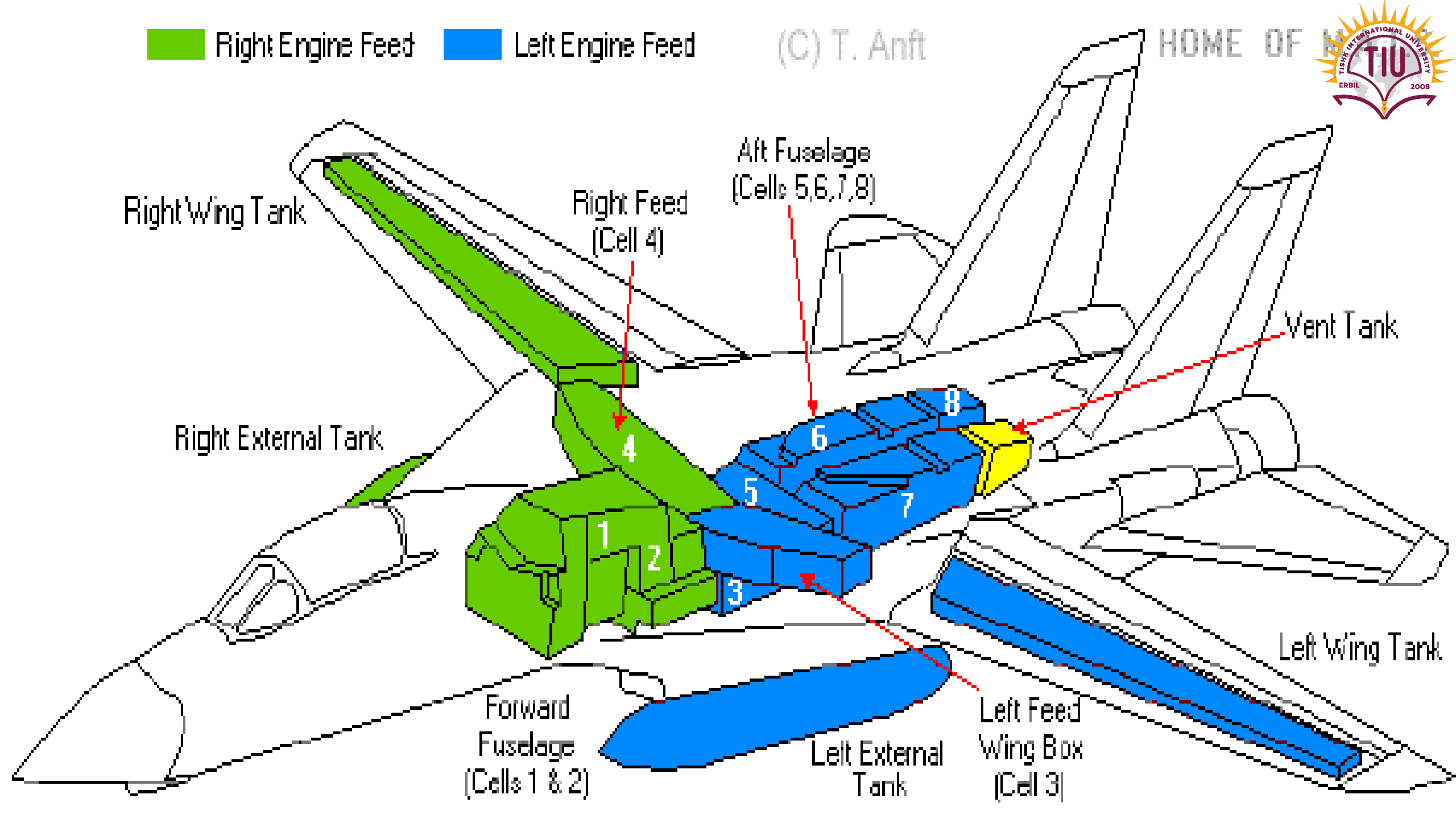
✓**Engine control and Management: Full Authority Digital Engine Control System (FADEC) -**

-- **flow of fuel, temperature, engine speed, acceleration, engine health monitoring system**

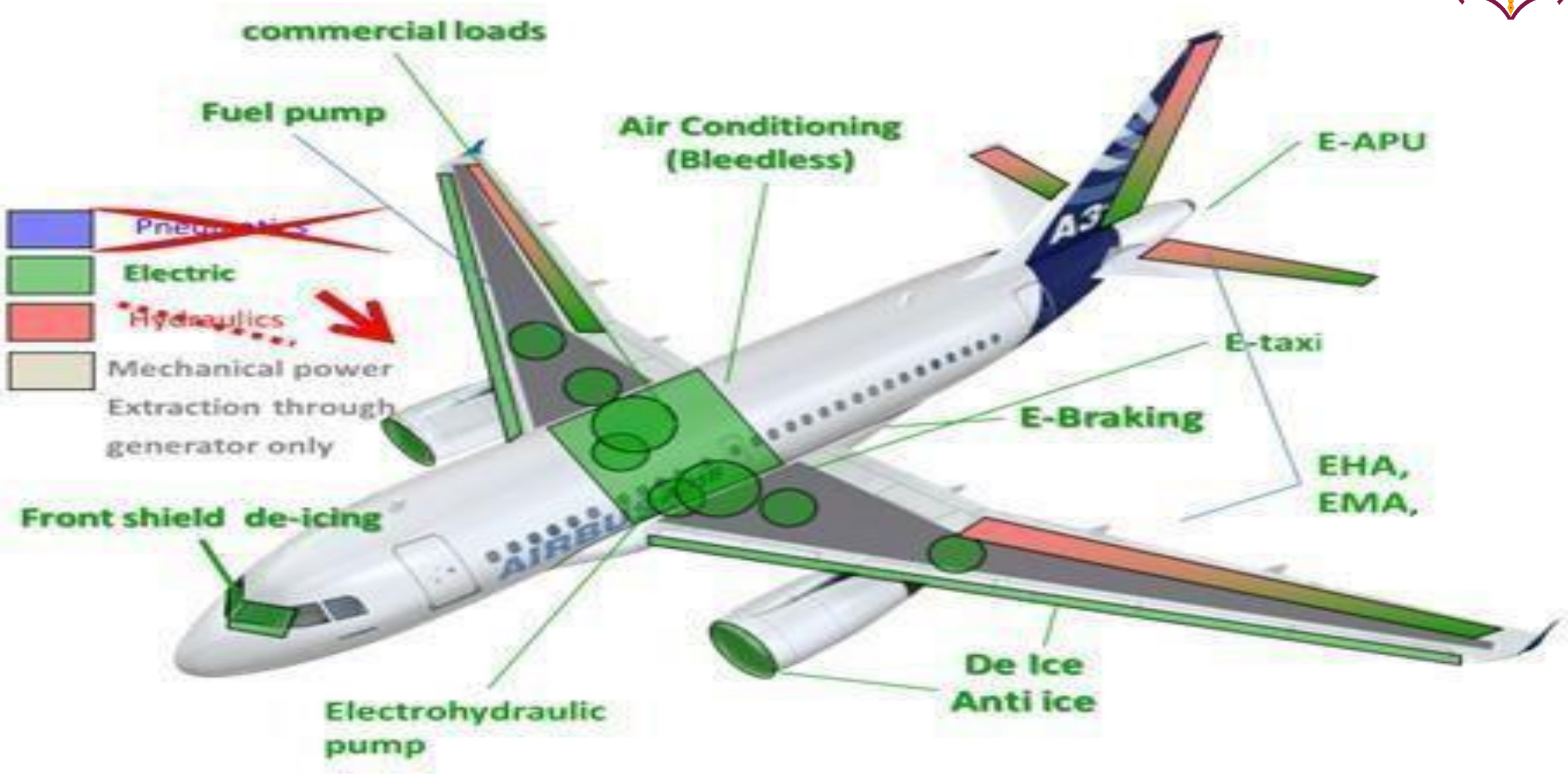
– **Performance deterioration.**

✓**House Keeping Management:** automation of background tasks – aircrafts safe and efficient operation.

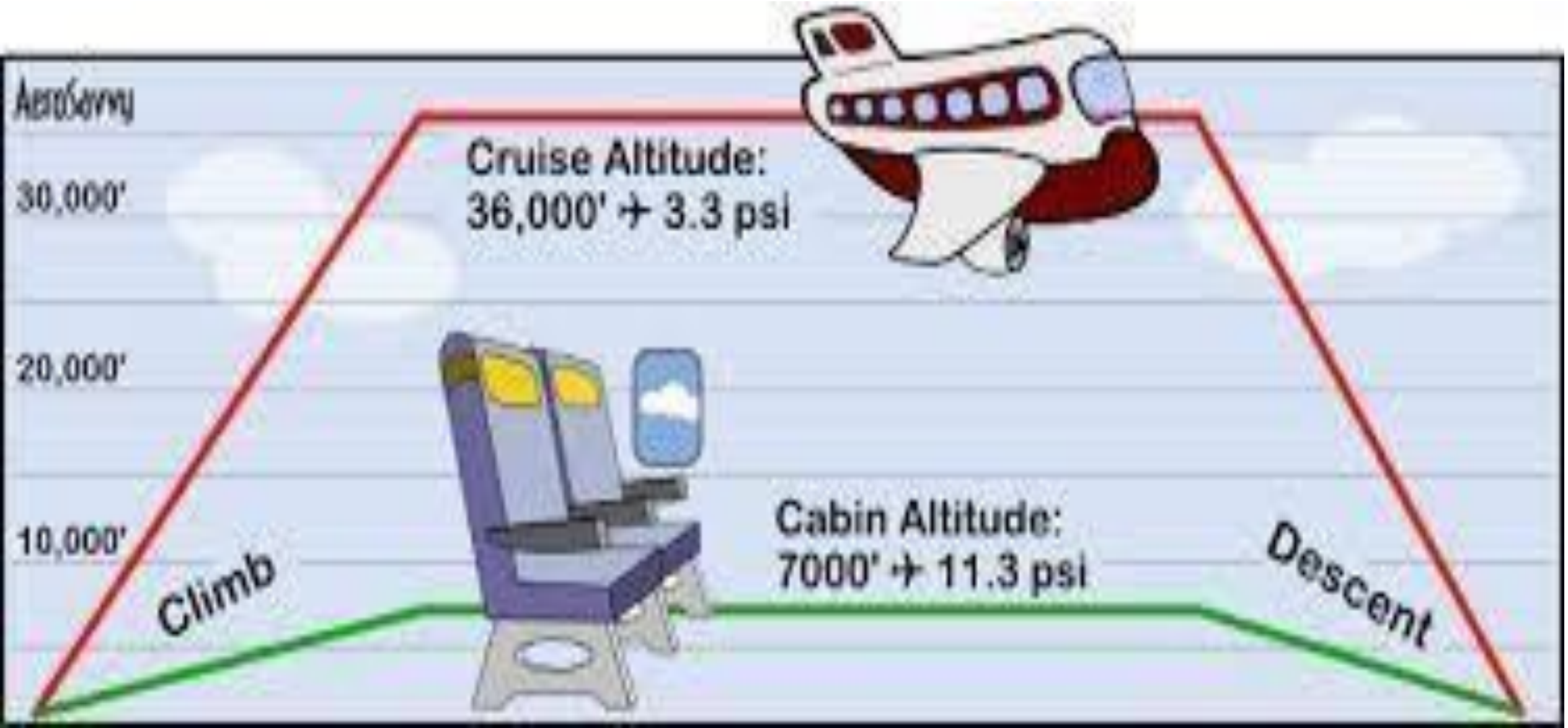
--- **Fuel management: This embraces fuel flow and fuel quantity measurement and control of fuel transfer from the appropriate fuel tanke to minimize changes in the aircraft trim**


Right Engine Feed
Left Engine Feed
(C) T. Anft
HOME OF
Right Wing Tank
Right Feed
(Cell 4)
Aft Fuselage
(Cells 5,6,7,8)
Vent Tank
Right External Tank
4
8
6
5
7
1
2
3
Left Wing Tank
Forward
Fuselage
(Cells 1 & 2)
Left External
Tank
Left Feed
Wing Box
(Cell 3)

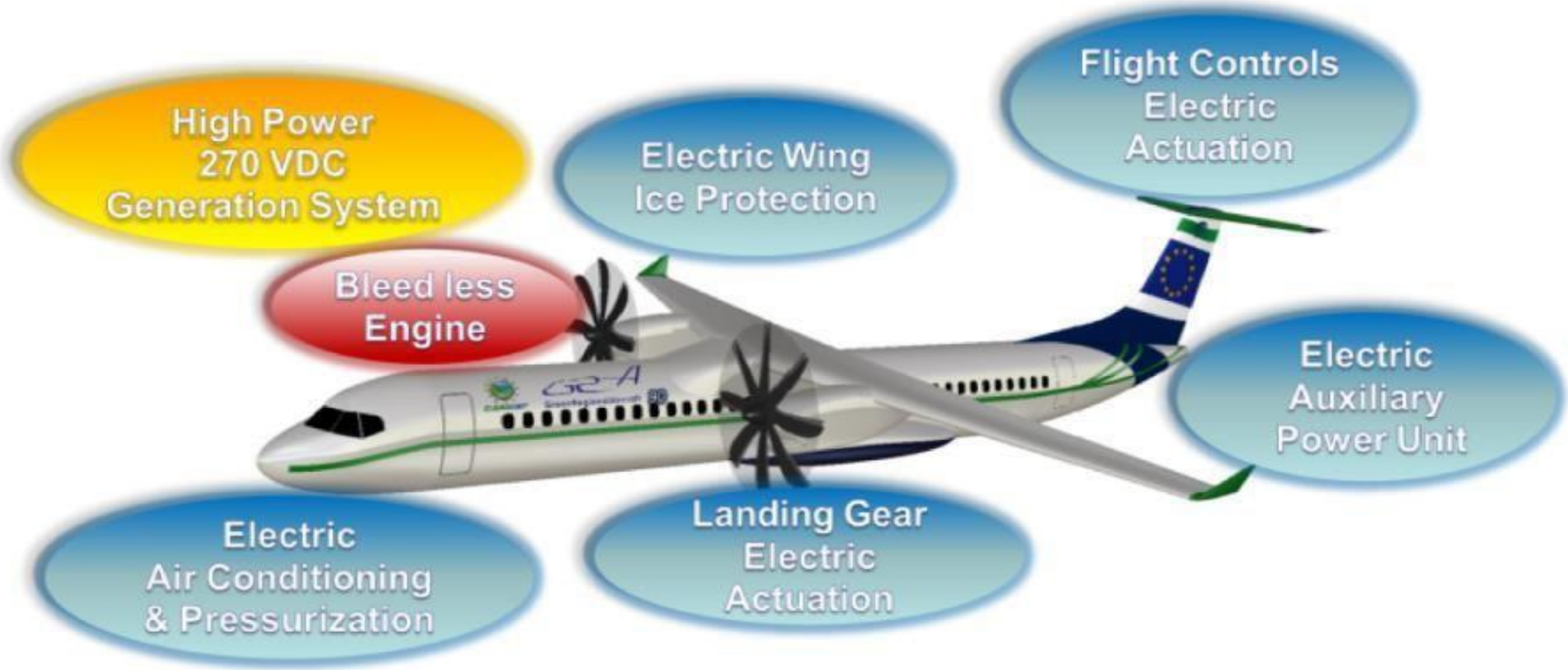
Electrical Power Supply System Management



Cabin / Cockpit Pressurization Systems



Environmental Control Systems



Warning Systems

Maintenance and Monitoring Systems

--- Maintenance and Monitoring Systems: These comprise monitoring and recording systems **which integrated into an onboard maintenance computer system**. This provides the information **to enable ;**

- **speedy diagnosis and rectification of equipment** and

- system failures by pin-pinting faulty units and providing all the information, such as **part numbers etc., for replacement units to module level in some cases**.

FAULT TOLERANT SYSTEMS

FAULT TOLERANT SYSTEMS:

This is used to continue satisfactory operation in the presence of one or more hardware or software faults.

Fault Detection in Hardware:

i) Duplication and comparison

ii) Self checking

Fault Detection in Software: Fault Tolerant Software,

- Multi-version Programming:

In this two or more versions of a program are developed with performs a specific function. A common input is given and results are compared to detect any fault.

- Recovery Blocks:

It consist of primary and other alternate versions and each version is subjected to a test.

If the versions produces an acceptable result means that block is ok otherwise it is under fault.

iii) **Run – time Assertion:**

a) Watch dog timer (detects crash, overload, Infinite Loap)

b) Analytical Redundancy Technique

Hardware Assessment and Validation

i) Fault Tree Analysis

ii) Failure mode and Effect Analysis Catastrophic Failure

Critical Effect

Slight Effect No Effect

Software Assessment and Validation

i) **Top down Design**
ii) **Interfacing and Partitioning**
iii) **Coding**
iv) **Testing**
v) **Integration**
vi) **Integration with Hardware**

Computer Based Reliability Modeling and Prediction

ARIES – Automated Reliability Interactive Estimation System

CARSRA – Computer – Aided Redundant System Reliability Analysis

CARE III – Computer Aided Reliability Estimation

Utility Systems Reliability And Maintainability: Maintenance

An item to be retained in or restored to specific condition when maintenance is performed by a person having specified skill levels, using prescribed procedures and resources.

Maintenance Requirements

Maintenance Requirements

- **Skilled persons are required for maintenance.** The maintenance tasks may be performed in flight line or in maintenance department.

For easy maintenance one have to **prepare the maintenance manuals, procedures and equipment**.

- **Use standard units for design.**

- **Electro static Discharge sensitive devices** should have protection facilities built into the LRU's.

- **Line Replaceable Unit LRU** is a modular component of an airplane, that is designed to be replaced quickly at an operating location. It is usually a sealed unit such as radio or other auxiliary equipment.

- **Many LRU's for commercial aircraft core designed according to ARINC specifications**.

In the military, Electronic LRU's are typically designed to interface according to data bus standards such as MIL STD 1553.

BITE: (Built In Test Equipment)

It is a powerful maintenance tool that takes advantage of the intrinsic capabilities of digital avionics, which is given in figure 5.8.

This BITE should be capable of providing extensive data for engineering analysis. This should be able to recognize and correctly identify at least 95% of possible faults. Failure of BITE should also be clearly indicated.

BITE: (Built In Test Equipment)

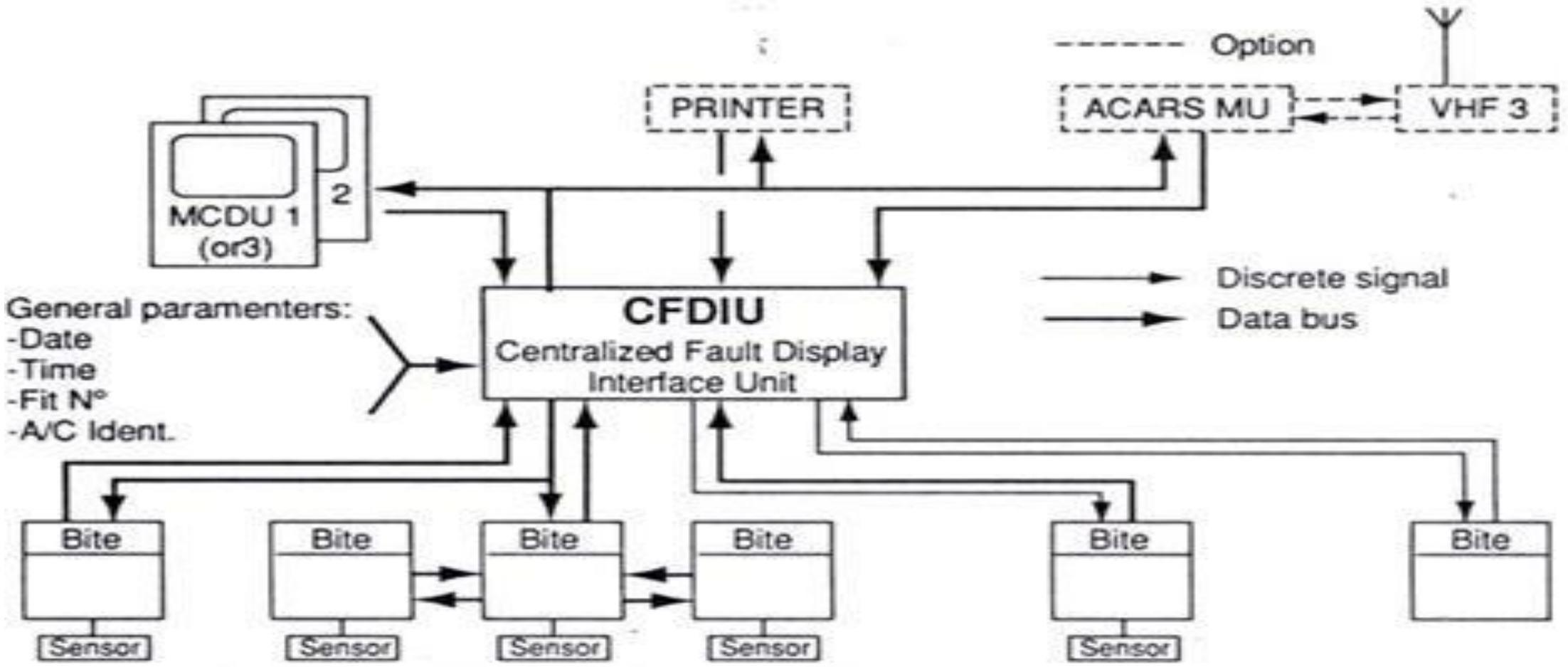


Figure 5.8 Fault Display system

Reliability

- **The probability that an item can perform its intended functions for a specified interval under stated conditions.**
- **The duration or probability of failure-free performance under stated conditions**
- **The probability that an item can perform its intended functions for a specified interval under stated conditions**

Reliability Analysis

It is a well known method which is used for predicting equipment failure rates.

$$\Sigma$$

Where

λ_{Equip} = **total equipment failure rate**

λ_{Gi} = **generic failure rate for the generic part type**

Π_{Qi} = **quality factor for i^{th} generic part type**

N_i = **quantity of ith generic part type**

n = **number of different generic part types**

QUESTIONS

Part – A

1.Write about the need of communication system in airline.
2.List out the types of navigation.
3.Write notes on Dead reckoning type of navigation.
4.What is INS?
5.What is GPS?
6.Explain about P and C/A codes.
7.Compare INS and GPS.
8.What is Flight control system?
9.Give the advantage of FBW over conventional FCS.
10.What is meant by strap down Navigation?
11.What is FMS?
12.Write about jammers in electronic warfare.
13.Give short notes on RADAR.
14.Discuss about Electronic warfare.
15.Bestow the advantages of GPS over conventional navigation.

Part – B

1. Describe a FBW flight control system and its characteristics and redundancy concept in detail.
2. Explain the operation of inertial navigation system and explain its two types of construction.
3. What is the need for a communication system in aircraft?
Explain one of the most modern reliable communication systems used in aircraft with a block diagram.

4. What is GPS and explain the working of it with codes of communication used for locating the object.
5. Explain in detail about Radar Electronic war fare and its salient features and its usage.
6. Explain Certification and explain the various steps involved in certification of avionics system.
7. What is Dead reckoning navigation system and explain any one type in detail.
8. Explain Conventional Flight control system and advantage of FBW to overcome the

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Thank You!