Chapter 2

Displays and Man-Machine Interaction

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2019

MEMS

The closest distance between Mars and Earth is 78 million km

The distance is the largest: approximately: 378 million km

The time of travel between Earth and Mars is between 4.3 minutes and 21 minutes, depending on the actual distance between the two planets.

During Curiosity EDL, this delay will be 13 minutes, 48 seconds, about mid-way between the minimum delay of around 4 minutes and the maximum of around 24 minutes.

Role of Display Systems

- 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.
- They provide information related to:
  - Primary flight information,
  - Navigation information,
  - Engine data,
  - Airframe data,
  - Warning information,
  - Infrared imaging sensors,
  - Radar,
  - Tactical mission data,
  - Weapon aiming,
  - Threat warnings.

Airframe Critical Data

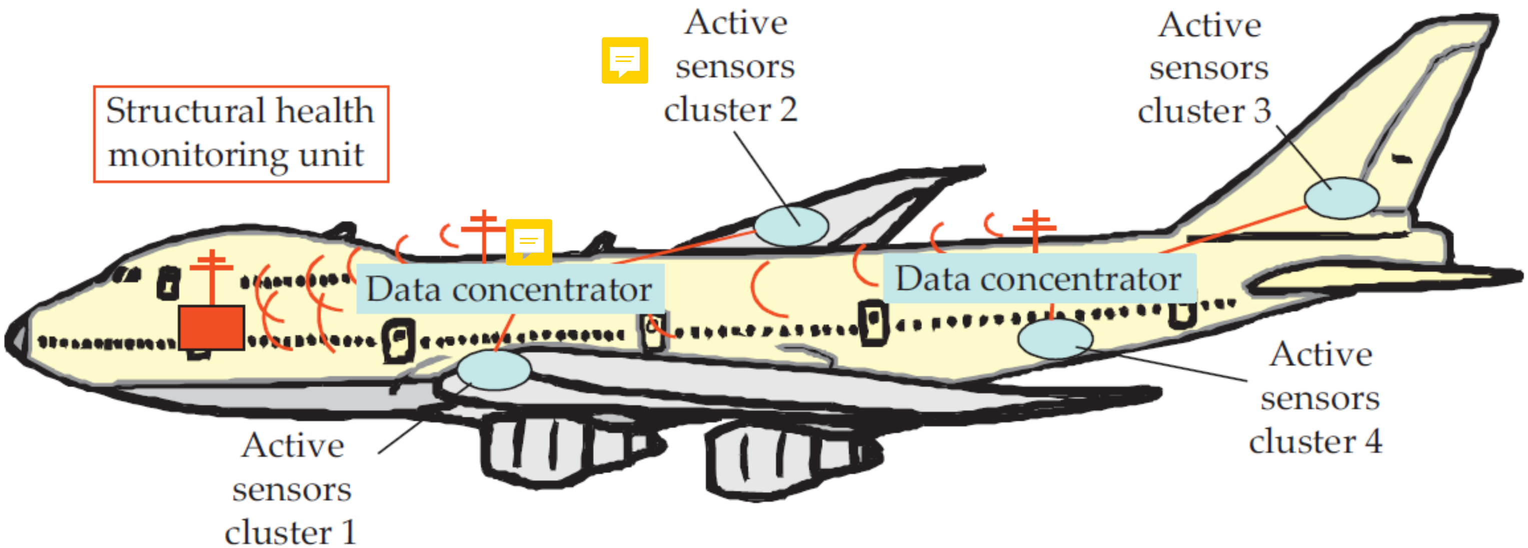


FIGURE 1.1 Schematic representation of a generic airliner SHM system consisting of active sensors, data concentrators, wireless communication, and SHM central unit.

Role of Display Systems

- A number of developments have taken place to improve the pilot–display interaction and this is a continuing activity as new technology and components become available.
- 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.

Synthetic Pictorial Imagery

A modern synthetic vision system produced by Honeywell

Man-Machine Interaction

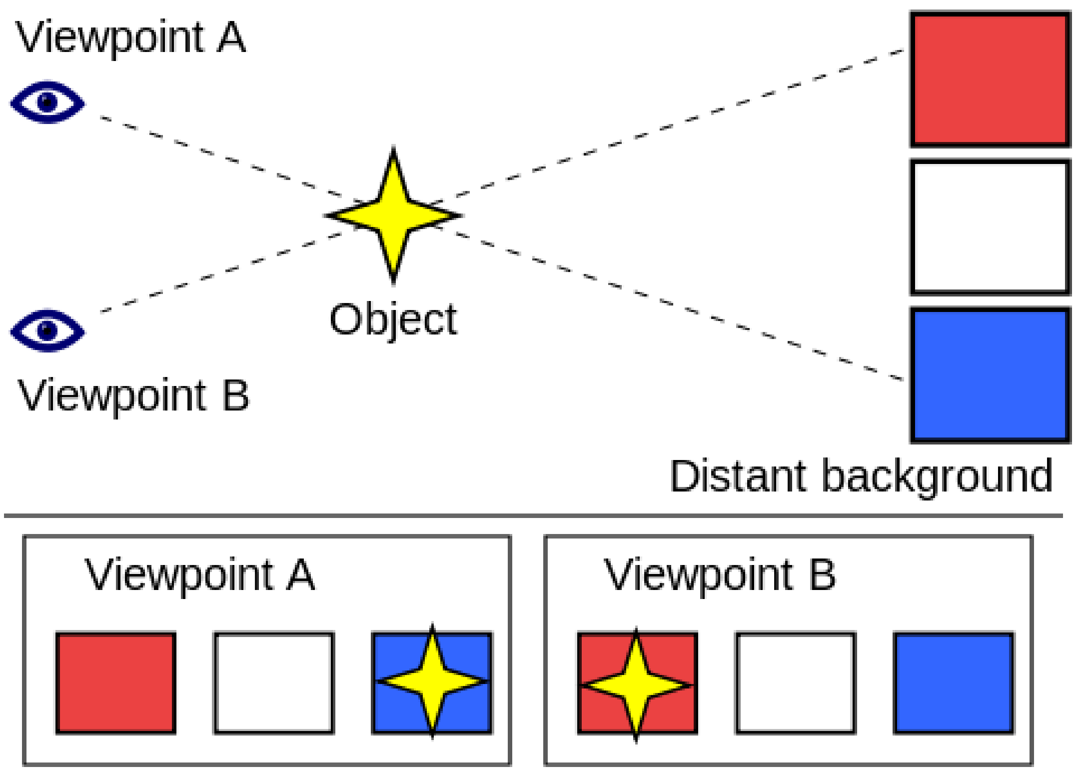
- Equally important and complementary to the cockpit display systems in the 'man machine interaction' are the means provided for the pilot to control the operation of the avionic systems and to enter data.
- Multi-function keyboards and multi-function touch panel displays.
- Speech recognition technology has enabled 'direct voice input' control in the new generation of military aircraft.
- Audio warning systems are now well established in both military and civil aircraft.
- Audio/tactile inputs
- Eye trackers

1. Head Up Displays (HUD)

1. Head Up Displays (HUD)

- ~~A head up display basically projects a collimated display in the pilot's head up forward line of sight~~ so that he can view both the display information and the outside world scene at the same time.
- The first production HUDs, in fact, went into service in 1962 in the Buccaneer strike aircraft in the UK.
- There are no **parallax** errors and aiming symbols for either a flight path director, or for weapon aiming in the case of a combat aircraft, remain overlaid on a distant 'target' irrespective of the pilot's head movement.
- There is a transition time of one second or more to re-focus the eyes from viewing distant objects to viewing near objects a meter or less away.

~~Parallax~~



~~"…a displacement or difference in the apparent position of an object viewed along two different lines of sight." [Source: Wikipedia]~~

1. Head Up Displays (HUD)

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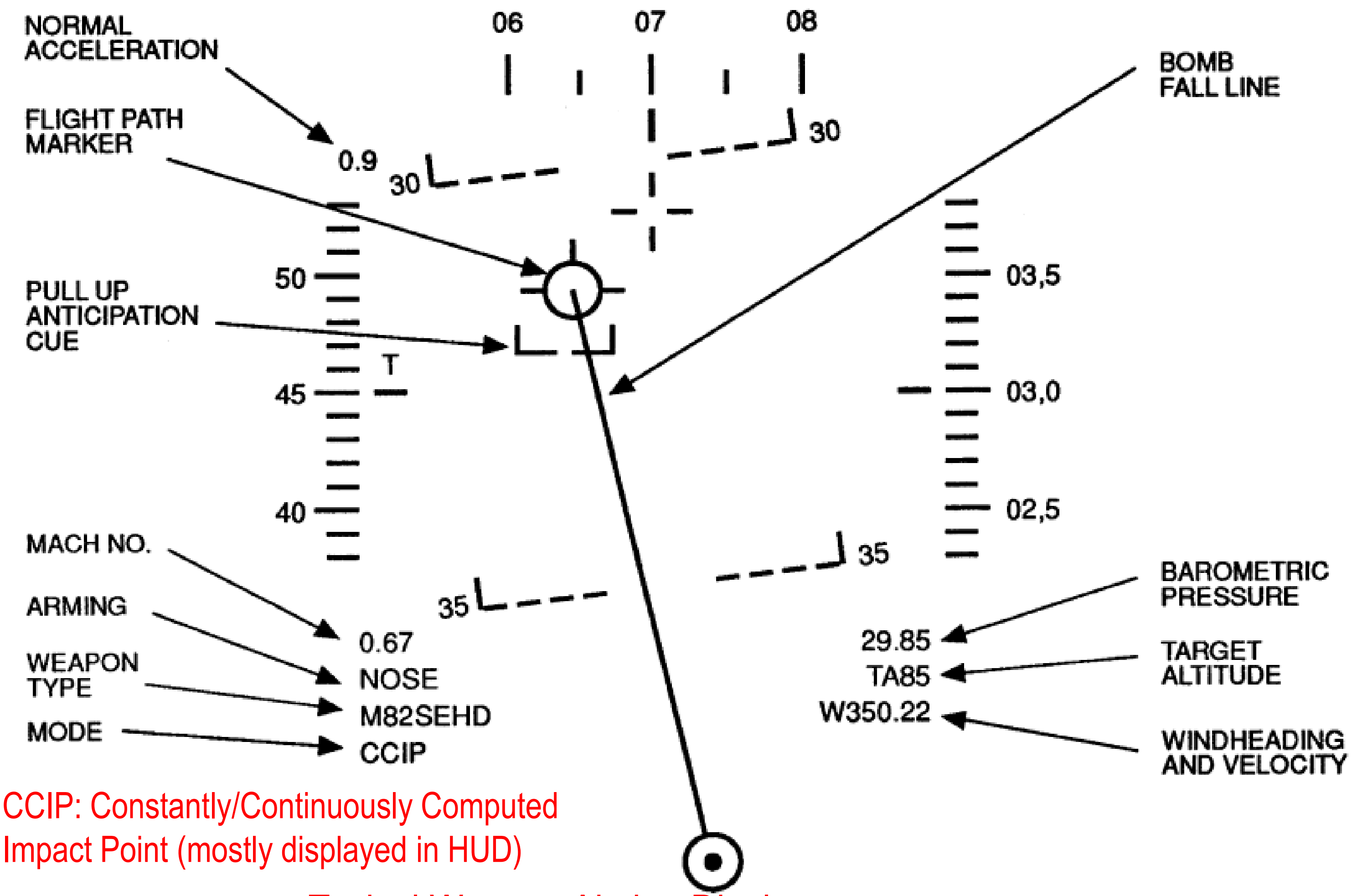


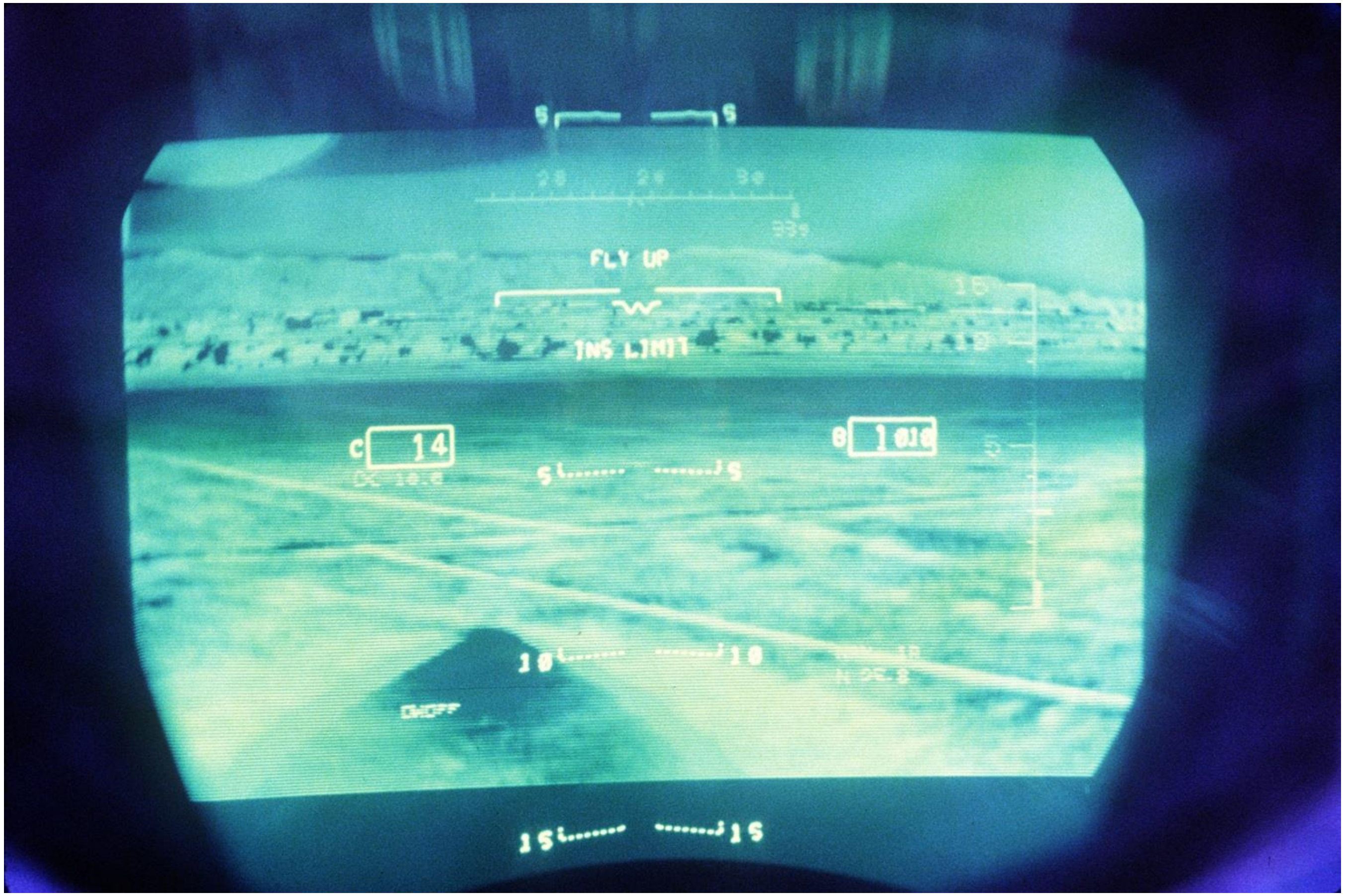
CCIP: Constantly/Continuously Computed Impact Point (mostly displayed in HUD)

Typical Weapon Aiming Display

1. Head Up Displays (HUD)

- The very high accuracy which can be achieved by a HUD and computerized weapon aiming system together with the ability to remain head up in combat have made the HUD an essential system on all modern combat aircraft.
- By using a Forward Looking Infrared (FLIR) sensor, an electro-optical image of the scene in front of the aircraft can be overlaid on the real world scene with a **raster mode** HUD.
- The TV raster picture generated from the FLIR sensor video is projected on to the HUD and scaled one to one with the outside world enabling the pilot to fly at low level by night in fair weather.
- This provides a realistic night attack capability to relatively simple day ground attack fighters.

1. Head Up Displays (HUD)



Electro-optical Image generated on HUD by overlaying the FLIR image over the real world scene.

1. Head Up Displays (HUD)

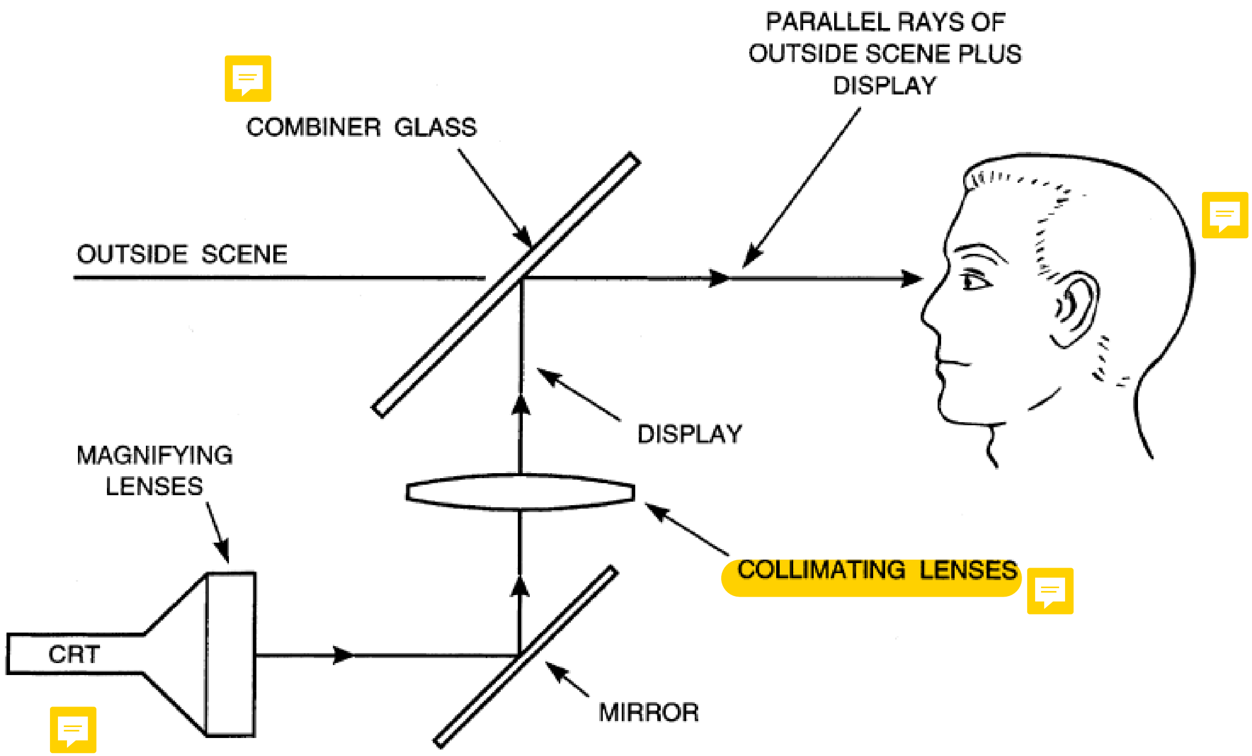
Electro-optical Image generated on HUD by overlaying the FLIR image over the real world scene.

1. Head Up Displays (HUD)

- The **head-up presentation of primary flight information** including depiction of the aircraft's flight path vector, results in improved situational awareness and increased safety in circumstances such as wind shear or terrain/traffic avoidance maneuvers.
- **Automatic landing guidance** enables 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.
- Provides **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 radar sensor in the aircraft.

1. Head Up Displays (HUD)

Basic Principle



Schematic of HUD working principle.

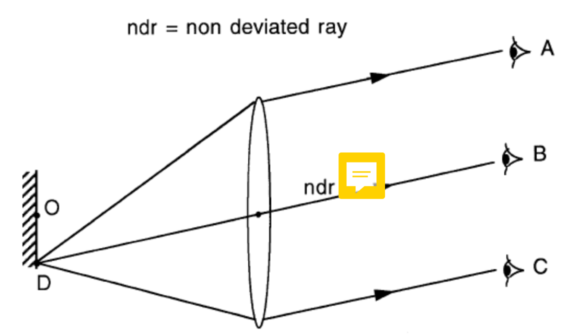
1. Head Up Displays (HUD)

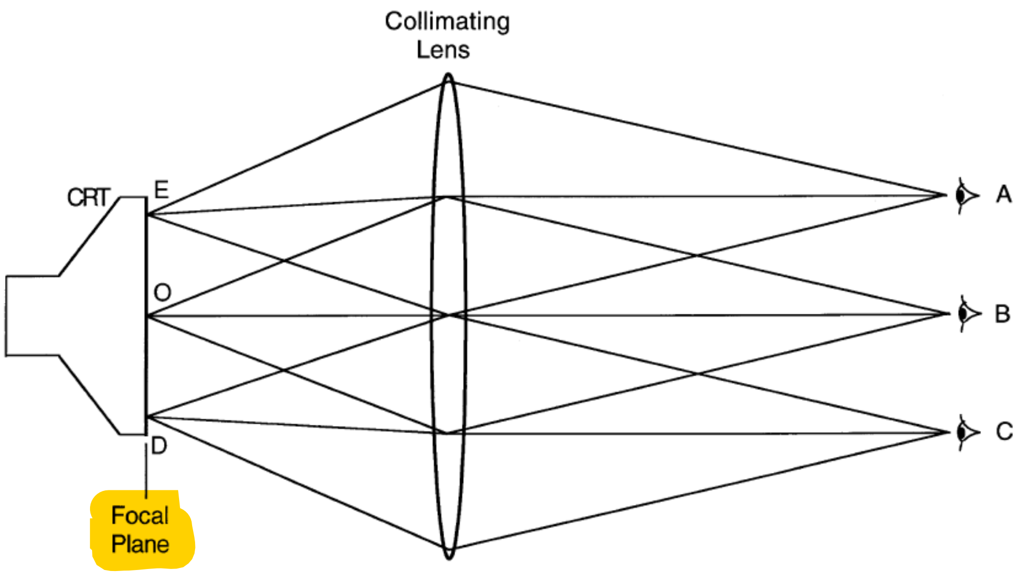
Basic Principle

- The pilot views the outside world through the HUD **combiner** glass (and windscreen). The combiner glass is effectively a 'see through' mirror with a high optical transmission efficiency so that there is little loss of visibility looking through the combiner and windscreen.
- It is called a combiner as it optically combines the **collimated** display symbology (generated from the aircraft sensors and systems such as the INS and air data system) with the outside world scene viewed through it.
- A collimator is defined as an optical system of finite focal length with an image source at the focal plane.

1. Head Up Displays (HUD)

Basic Principle





The appearance of the collimated display is thus independent of the position (or translation) of the eye and is only dependent on the angle of gaze.

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.

1. Head Up Displays (HUD)

Basic Principle

- Symbology generated from the aircraft sensors and systems is displayed on the surface of a cathode ray tube (CRT).
- The display images are then relayed through a relay lens system which magnifies the display and corrects for some of the optical errors which are otherwise present in the system.
- The relayed display images are then reflected through an angle of near 90º by the fold mirror and thence to the collimating lens which collimates the display images which are then reflected from the combiner glass into the pilot's forward field of view. The virtual images of the display symbology appear to the pilot to be at infinity and overlay the distant world scene, as they are collimated.

1. Head Up Displays (HUD)

Basic Principle

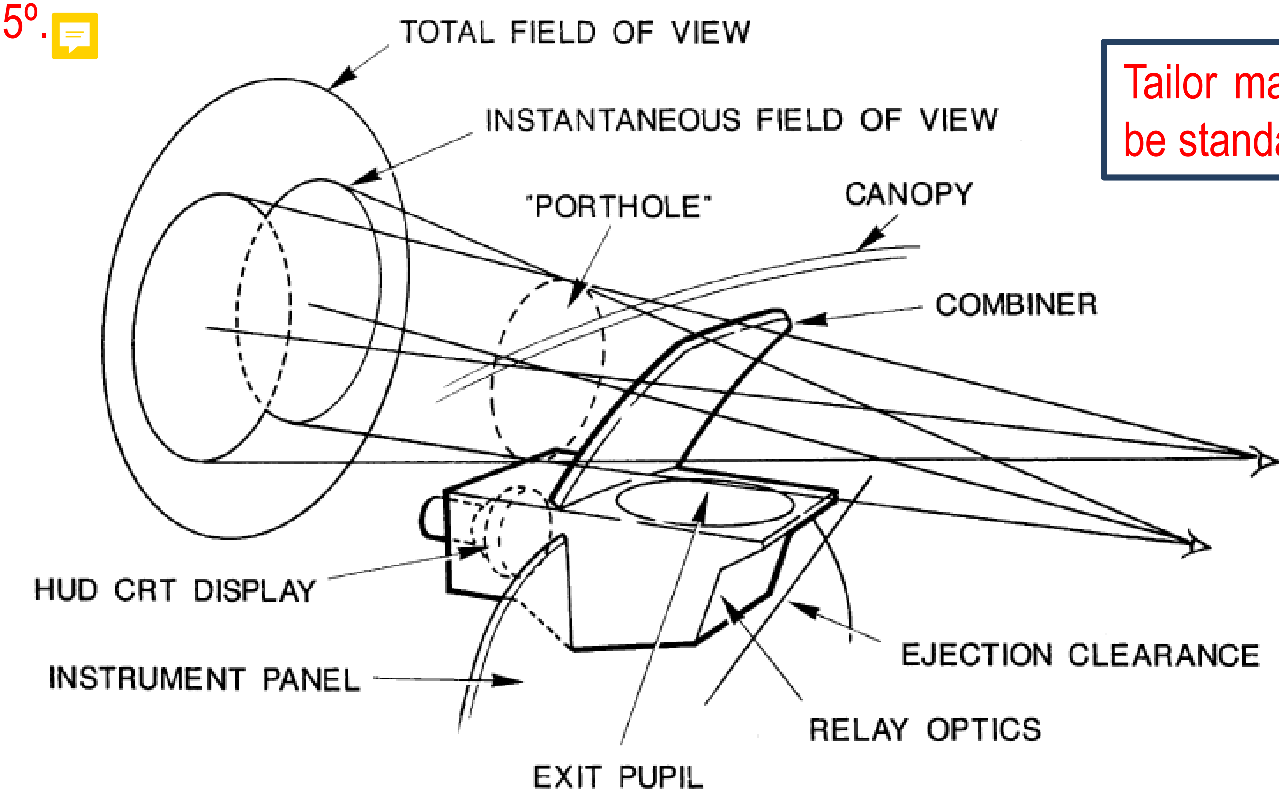
- A very important parameter with any HUD is the **field of view (FOV)**, which should be as large as possible within the severe space constraints imposed by the cockpit geometry.
- A large horizontal FOV is particularly important to enable the pilot to 'look into turns' when the HUD forms part of a night vision system and the only visibility the pilot has of the outside world is the FLIR image displayed on the HUD.
- **Instantaneous Field Of View (IFOV)**: angular coverage of the imagery which can be seen by the observer at any specific instant
- **Total Field Of View (TFOV)**: total angular coverage of the CRT imagery which can be seen by moving the observer's eye position around.

1. Head Up Displays (HUD)

Basic Principle

Typical IFOVs range from about 13º to 18º with a corresponding TFOV of about 20º to 25º.

Tailor made, or can be standard?

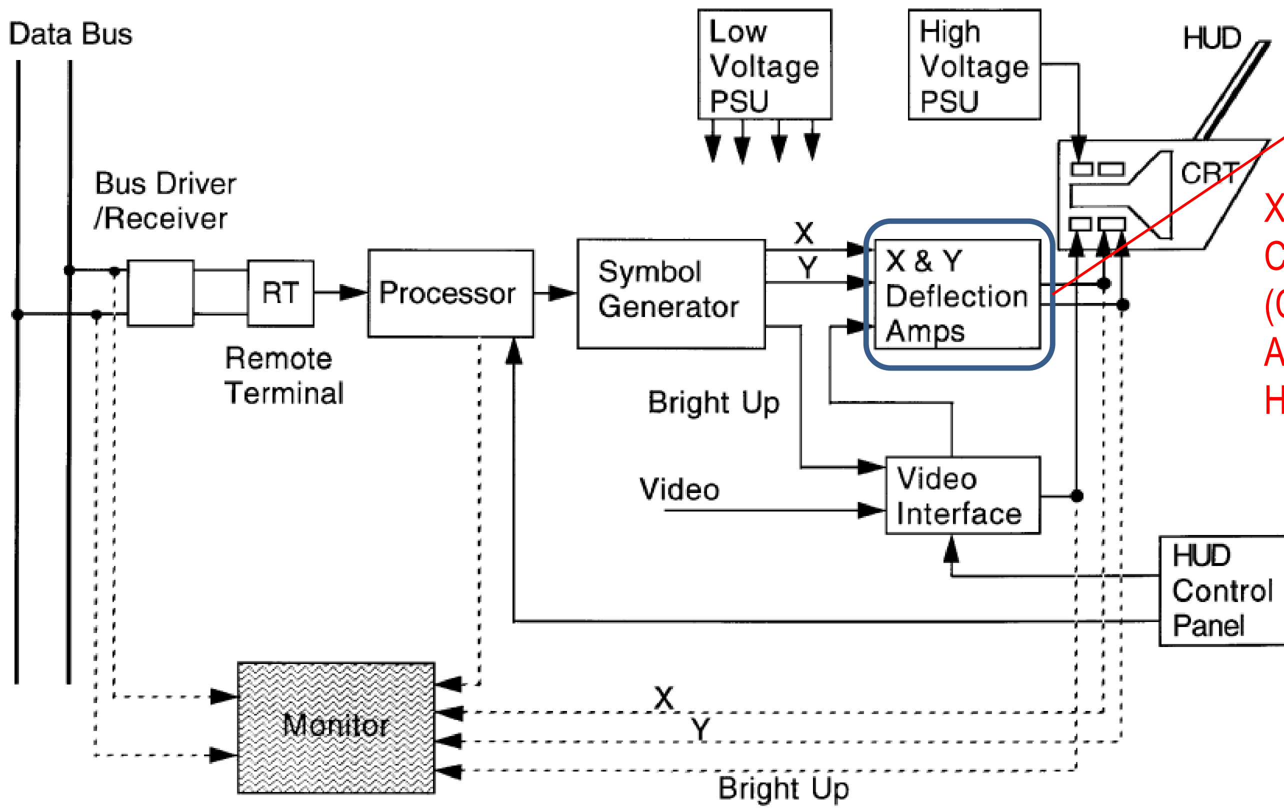


HUD Installation

1. Head Up Displays (HUD)

HUD Electronics

PSU- Power Supply Unit



XY Monitor

XY Monitor are the Cathode Ray Tube (CRT), the Deflection Amplifiers, and the High Voltage Supply.

HUD Electronics

1. Head Up Displays (HUD)

HUD Electronics

- The data bus interface decodes the serial digital data from the aircraft data bus to obtain the appropriate data from the aircraft sub-systems and inputs this data to the display processor.
- The input data includes the primary flight data from the air data system and the INS, such as height, airspeed, vertical speed, pitch and bank angles, heading, etc.
- 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.
- The symbol generator carries out the display waveform generation task (digitally) to enable the appropriate display symbology

1. Head Up Displays (HUD)

Civil Aircraft HUDs

- Increased safety by providing a better situational awareness for the pilot to control the aircraft by the head up presentation of the primary flight information symbology so that it is conformal with the outside world scene.
- The HUD can also provide a flight path director display which allows for the effect of wind shear from a knowledge of the aircraft's velocity vector, airspeed, height and aerodynamic behavior.
- Ground Proximity Warning Systems (**GPWS**) are a very valuable aid in avoiding terrain.
- Traffic Collision Avoidance Systems (TCAS) provide traffic conflict and escape guidance.

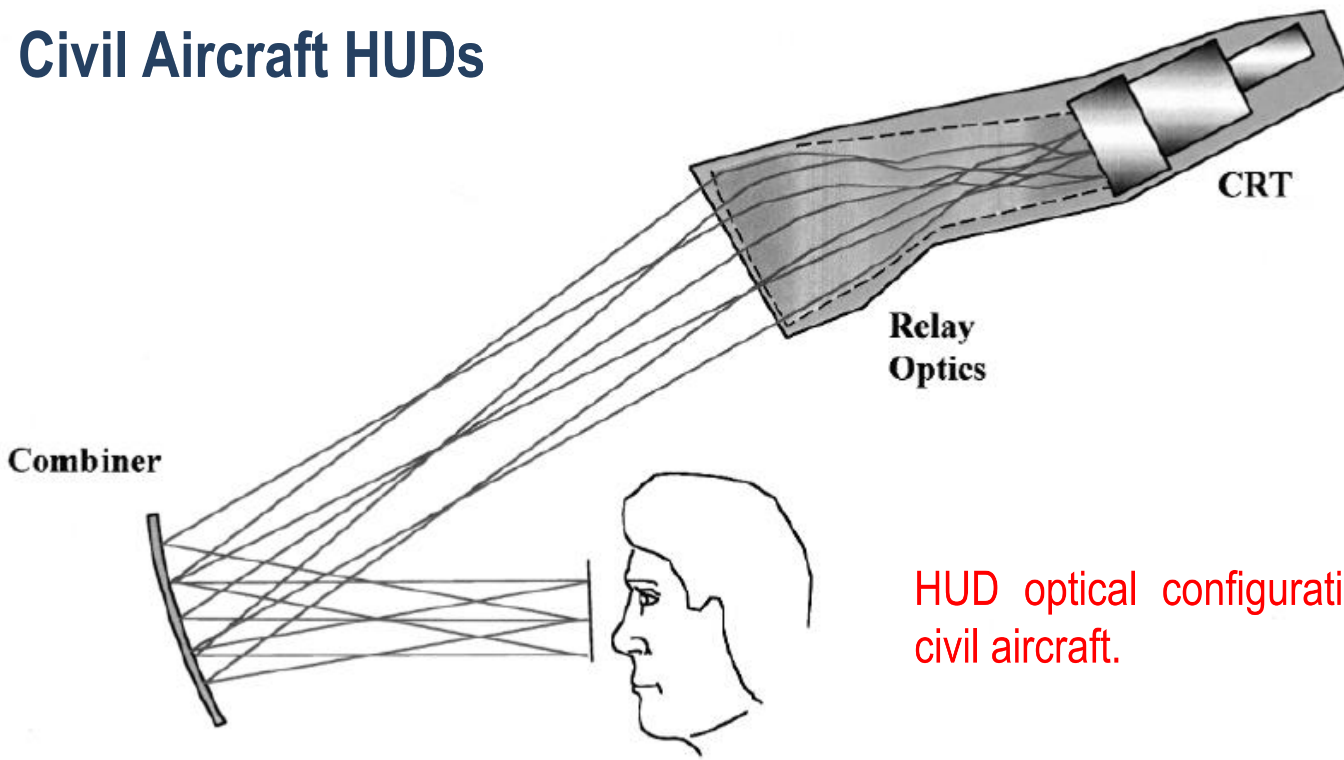
1. Head Up Displays (HUD)

Civil Aircraft HUDs

- Increased revenue earning ability by extending operations in lower **weather minima**.
- Use of the HUD as part of an enhanced vision system to enable operations in lower weather minima at airfields not equipped with automatic landing aids (ILS/MLS).
- The use of the HUD for displaying ground taxiway guidance is being actively investigated, and is considered a likely extension to the HUDs roles.
- Active development of both radar and infrared enhanced vision sensor systems is continuing and their introduction into civil operational service is anticipated in the next decade.
- *Overlaid primary flight information symbology.*

1. Head Up Displays (HUD)

Civil Aircraft HUDs



HUD optical configuration in civil aircraft.

A combination of the HUD and a fail-passive autopilot provides a cost-effective solution for extending the poor visibility operation of many **Air Transport Category Aircraft**.

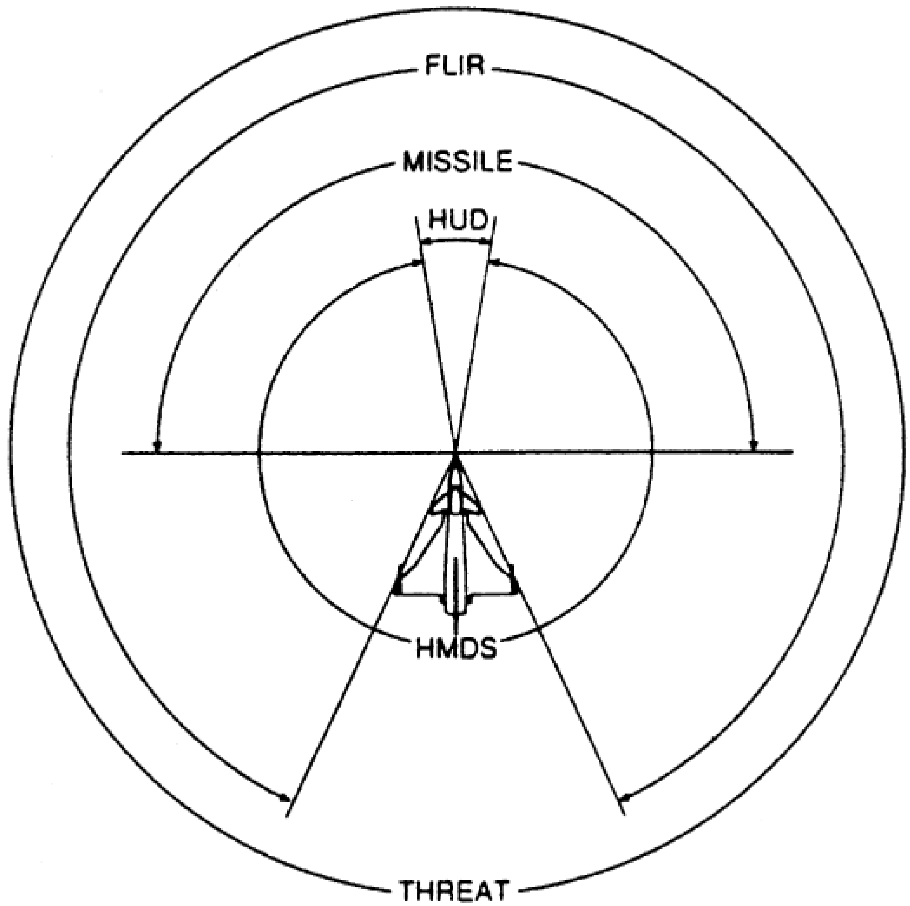
2. Helmet Mounted Displays (HMD)

The pilot requires visual information head up when he is looking in any direction and this requirement can only be met by a helmet mounted display (HMD).

2. Helmet Mounted Displays (HMD)

- The HUD only presents the information in the pilot's forward field of view, which even with a wide FOV holographic HUD is limited to about **30◦ in azimuth** and **20◦ to 25◦ in elevation**. Significant increases in this FOV are not practicable because of the cockpit geometry constraints.
- The pilot requires visual information head up when he is looking in any direction and this requirement can only be met by a helmet mounted display (HMD).
- In its simplest form the HMD can comprise a simple helmet mounted sighting system which displays a collimated aiming cross or circle and some simple alphanumeric information, with a typical FOV of around 5◦.

2. Helmet Mounted Displays (HMD)



Comparison of HUD and HMD field of view.

2. Helmet Mounted Displays (HMD)

- In its most sophisticated form the HMD can provide, in effect, a *HUD on the helmet*.
- This can display all the information to the pilot which is normally shown on a HUD but with the pilot able to look in any direction (attitude information is referenced to his **line of sight (LOS)**).
- The HMD can also have a wider FOV ranging from 35º to 40º for a fighter aircraft application to over 50º for a helicopter application.
- It should be appreciated that the FOV moves with the head, unlike the HUD, and a larger FOV reduces scanning head movement in an HM display.

2. Helmet Mounted Displays (HMD)

- The HMD also enables a very effective night/poor visibility viewing system to be achieved by displaying the TV picture from a gimballed infrared sensor unit which is slaved to follow the pilot's line of sight.
- ~~The pilot's LOS with respect to the airframe is measured by a head position sensing system.~~

2. Helmet Mounted Displays (HMD)

Basic Functions and Helmet Design Factors

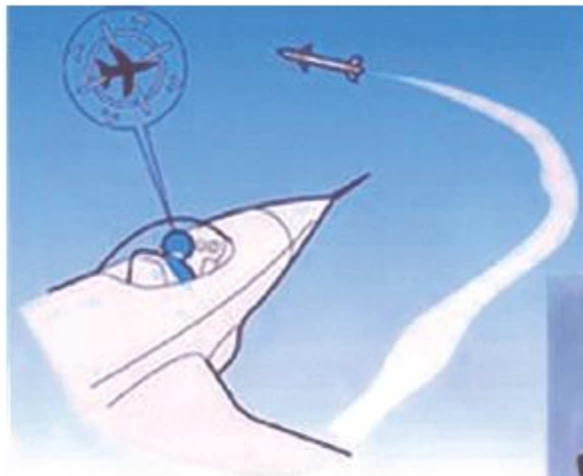
- To protect the pilot's head and eyes from injury when ejecting at high airspeeds.
- To interface with the oxygen mask attached to the helmet. Combat aircraft use a special pressurized breathing system for high **g** maneuvering.
- To provide the pilot with an aural and speech interface with the communications radio equipment.
- In addition to the clear protective visor, the helmet must also incorporate a dark visor to attenuate the glare from bright sunlight.
- The helmet must also be compatible with NBC (nuclear–biological–chemical) protective clothing and enable an NBC mask to be worn.

2. Helmet Mounted Displays (HMD)

Basic Functions and Helmet Design Factors

- Integrating an HMD system into the helmet must thus consider the communications and breathing equipment requirement, the protection, comfort and cooling aspects as well as the visual performance of the display.
- The helmet CG should be in line with the pivoting point of the head on the spine so that there are minimal out of balance moments exerted on the neck muscles.
- ~~The moment of inertia of the integrated helmet system about the yaw and pitch axes of the head should be as low as possible.~~
- There should be at least 25 mm (1 in) clearance, or ‘eye relief’, between the nearest optical surface and the eye.

2. Helmet Mounted Displays (HMD)



<u>Boresight</u>:
The direction in which the aircraft fore and aft axis is pointing.

Helmet mounted sights and off-boresight missile launch.

2. Helmet Mounted Displays (HMD)

Head Mounted Sights

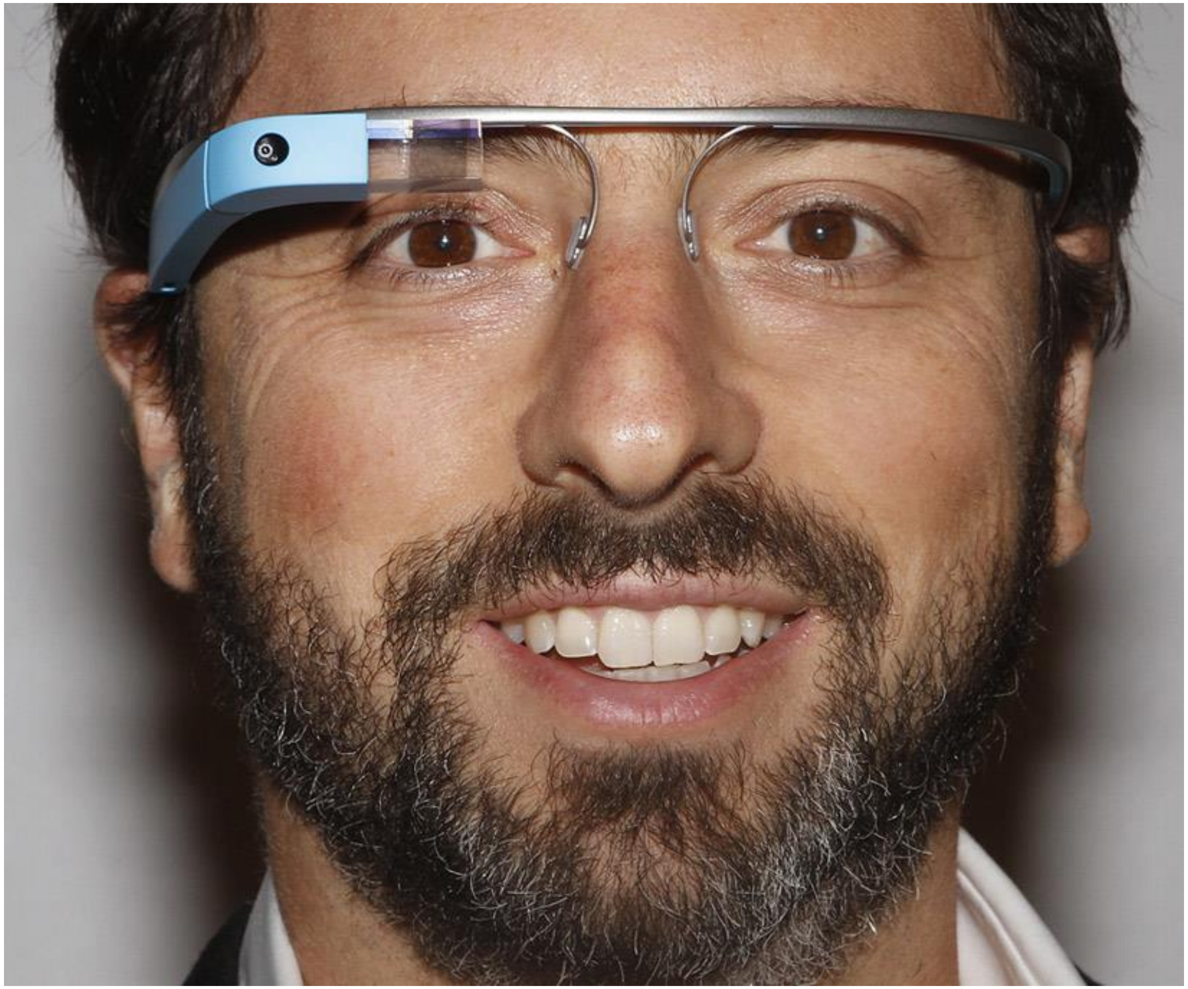
- A helmet mounted sight (HMS) in conjunction with a head tracker system provides a very effective means for the pilot to designate a target.
- The pilot moves his head to look and sight on the target using the collimated aiming cross on the helmet sight.

2. Helmet Mounted Displays (HMD)

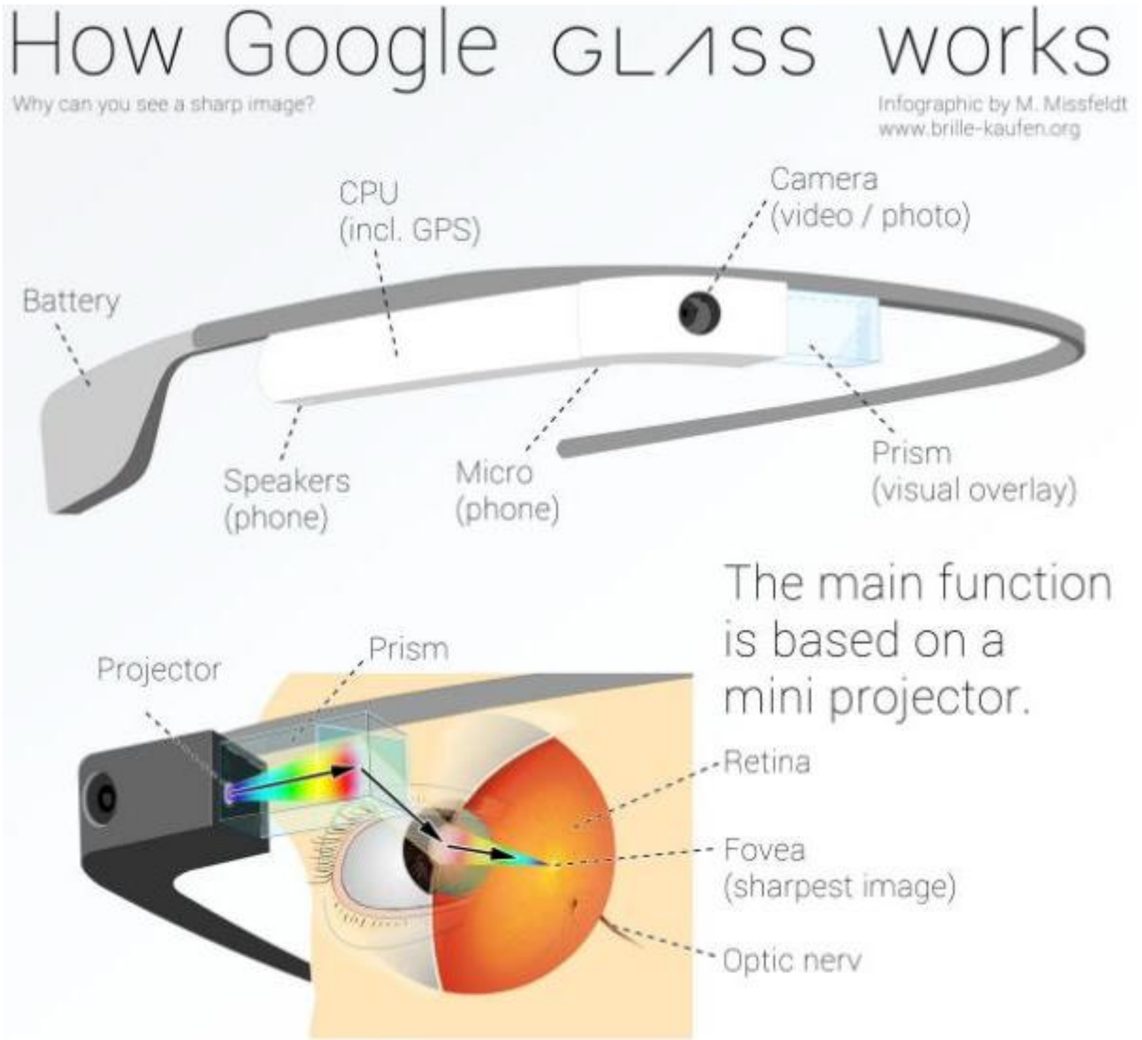
Head Mounted Sights

- This enables attacks to be carried out at large off-boresight angles, given agile missiles with high g maneuvering capabilities.
- The pilot no longer needs to turn the aircraft until the target is within the FOV of the HUD before launching the missile.

Sergei Brim



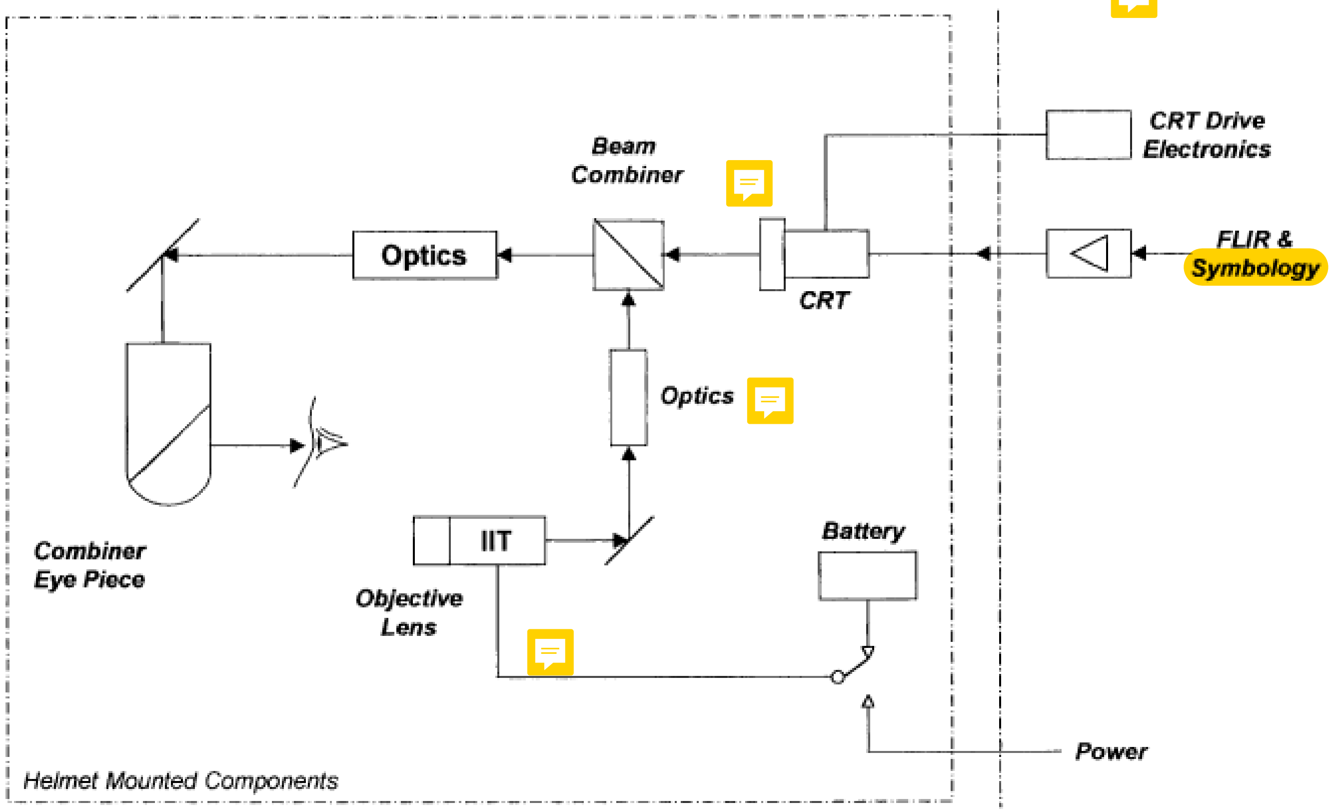
Google Glass


How Google GLASS works
Why can you see a sharp image?
Infographic by M. Missfeldt
www.brille-kaufen.org
CPU
(incl. GPS)
Camera
(video / photo)
Battery
Speakers
(phone)
Micro
(phone)
Prism
(visual overlay)
The main function is based on a mini projector.
Projector
Prism
Retina
Fovea
(sharpest image)
Optic nerv

2. Helmet Mounted Displays (HMD)

- Although monocular HMDs have been built which are capable of displaying all the information normally displayed on a HUD, there can be problems with what is known as '**monocular rivalry**'.
- *It has been shown that a binocular (or biocular) system whereby the same display is presented to both eyes is the only really satisfactory solution.*
- Hence, current HMD designs are generally binocular systems.
- Miniature 0.5 inch diameter CRTs are currently used as the display sources. The development of **miniature, high resolution liquid crystal displays (LCDs)**, however, has changed this situation. HMDs exploiting these devices are now being produced.

2. Helmet Mounted Displays (HMD)



IIT = Image Intensification Tube

IIT (Image Intensifying Tube)

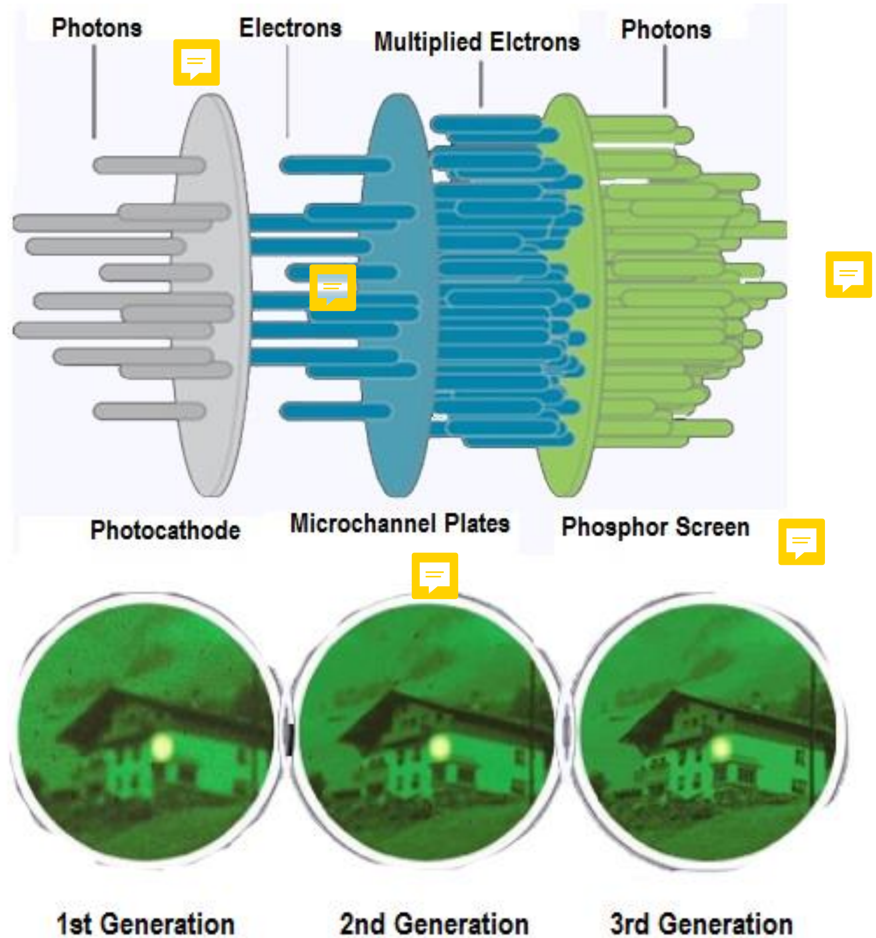
Optical Mixing of IIT and CRT Imagery

2. Helmet Mounted Displays (HMD)

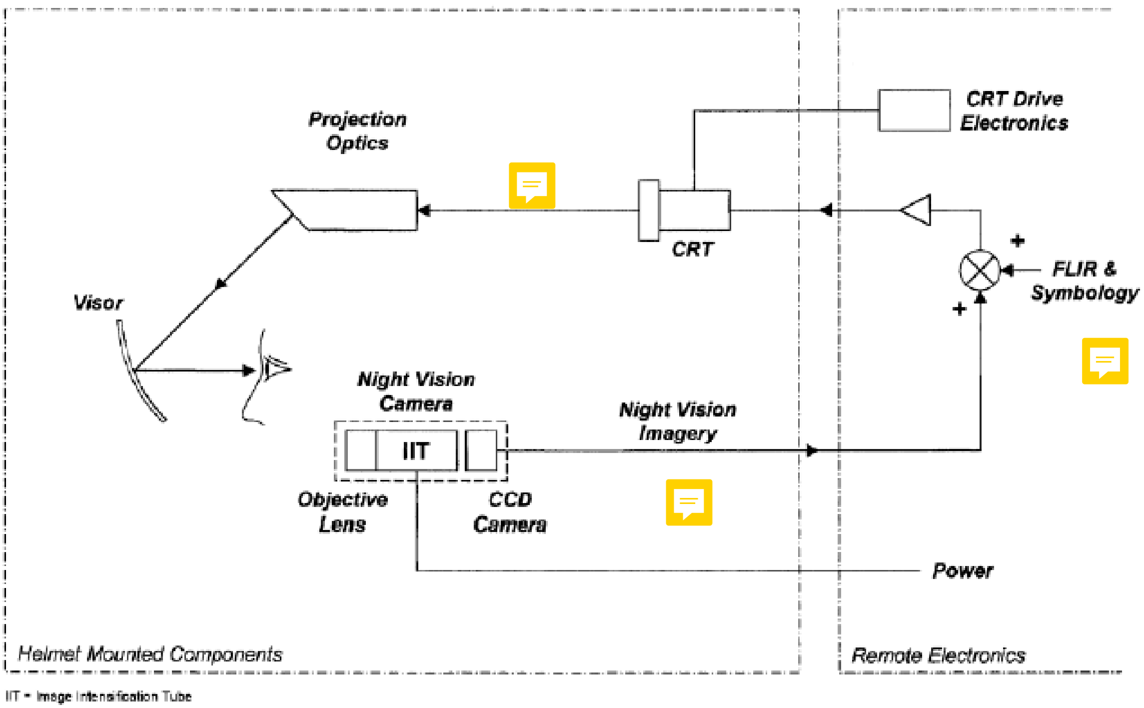
- The image from the Image Intensifier Tube (IIT) is a phosphor screen which emits green light in the centre of the visual band where the eye is most sensitive.
- Night Viewing Goggles (NVGs) incorporating image intensifiers have been in operational use in military helicopters since the late 1970s, and in fast jet aircraft from around the mid 1980s.
- Special cockpit lighting is necessary as conventional cockpit lighting will saturate the image intensifiers. Special green lighting and complementary filtering are required.
- The image intensifier devices can be battery powered from a small battery carried by the pilot.

IIT

The principle of action of Night Vision Devices is based on the transformation of the Photons reflected from the object to electrons, the subsequent multiplication of electrons and return transformation to the photons perceived by the human eye. To provide such transformation and strengthening of light a device named Image Intensifier Tube (IIT) is used.



2. Helmet Mounted Displays (HMD)



CCD (Charge-Coupled Device)

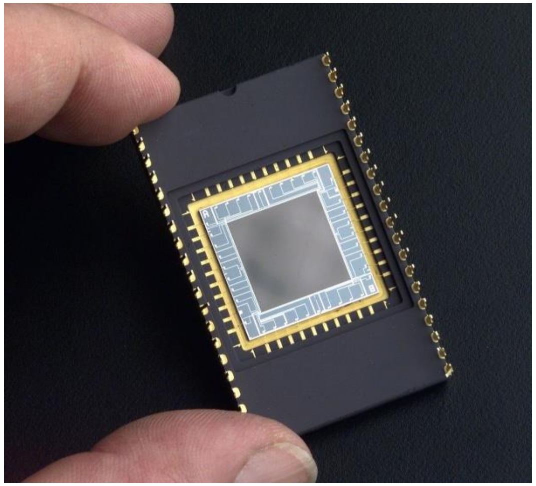
CMOS (Complementary Metal-Oxide Semiconductor)

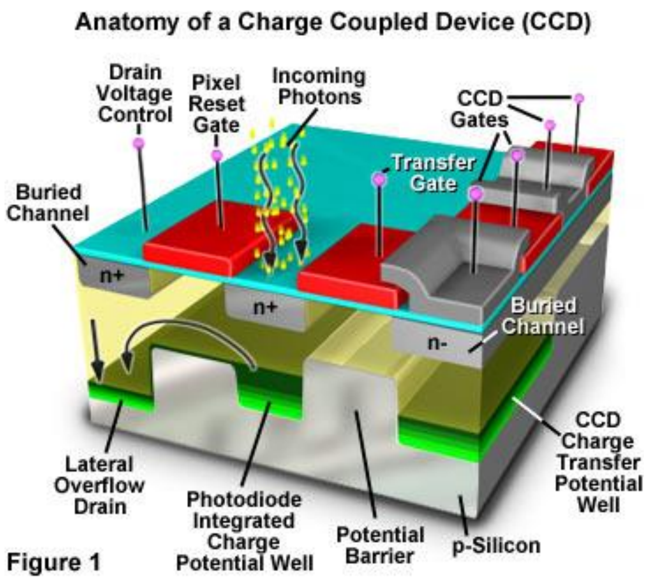
Both CCD and CMOS image sensors convert light into electrons. CCD sensors create high-quality, low-noise images. CMOS sensors are generally more susceptible to noise. CMOS sensors traditionally consume little power.

Electronic combination of IIT and CRT.

CCD

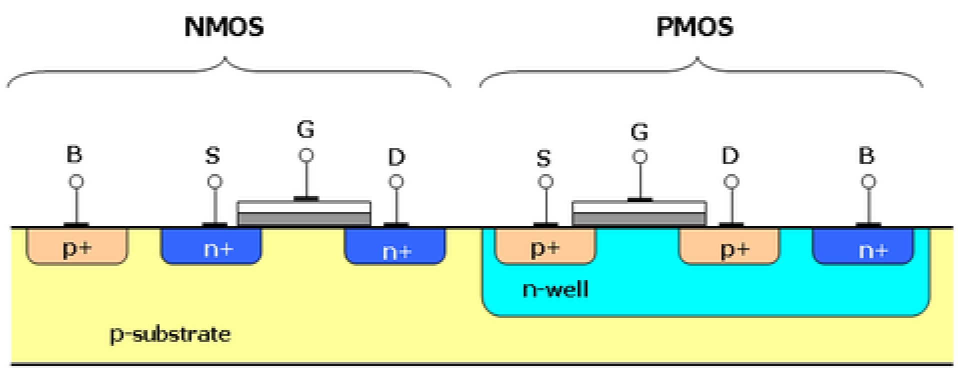
The **charge-coupled device** (**CCD**) is a **device** for the movement of electrical **charge**, usually from within the **device** to an area where the **charge** can be manipulated, for example conversion into a digital value. This is achieved by "shifting" the signals between stages within the **device** one at a time.



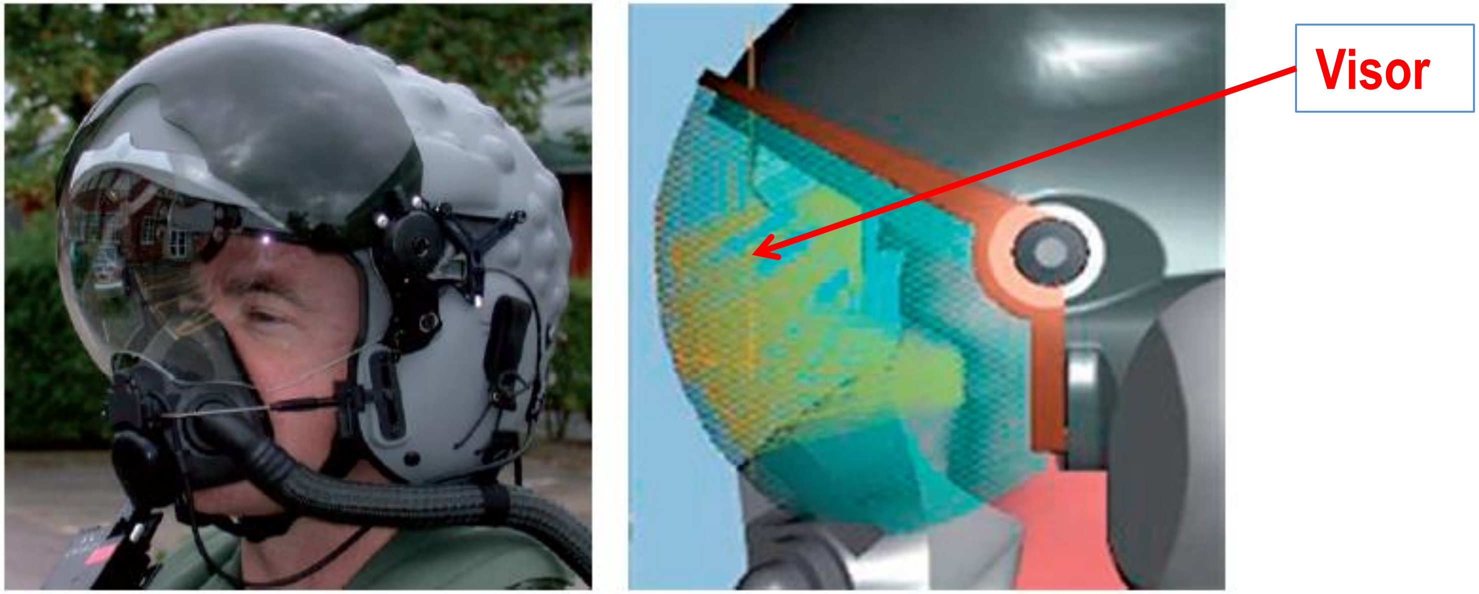


CMOS

CMOS (complementary metal-oxide-semiconductor) is the term usually used to describe the small amount of memory on a computer motherboard that stores the BIOS settings. Some of these BIOS settings include the system time and date as well as hardware settings.



2. Helmet Mounted Displays (HMD)



Binocular visor projected HMD [Eurofighter Typhoon].

It has a 40º binocular FOV and has integral night vision cameras which are electronically combined with the CRTs. An optical head tracker system is used to determine the pilot's LOS. This has a fast response and provides high accuracy.

Expensive! And need more care from damage.

2. Helmet Mounted Displays (HMD)

Head Tracking Systems

- It fulfills the need to measure the orientation of the pilot's head to determine the angular coordinates of the pilot's line of sight with respect to the airframe axes.
- **Optical tracking systems** work in a number of ways, for example,
  - ~~Pattern recognition using a CCD camera.~~
  - ~~Detection of LEDs mounted on the helmet.~~
  - ~~Sophisticated measurement of laser generated fringing patterns.~~
- **Magnetic tracking systems** measure the field strength at the helmet from a magnetic field radiator located at a suitable position in the cockpit.

2. Helmet Mounted Displays (HMD)

Head Tracking Systems

- Angular coverage of the magnetic type of head tracker is typically around$\pm 135°$ in azimuth and $\pm 85°$ in elevation.
- All the systems- optical, magnetic and acoustic – have their individual limitations although the magnetic systems are currently the most widely used.
- Higher accuracy at larger off-boresight angles is attainable, however, with the latest optical systems.
- The sight line measurement accuracy can hence be greatly improved by the use of an **eye tracker system** which measures the direction of gaze of the eye with respect to the helmet.
- An eye tracker can also be used very effectively as a means of data entry- a possible development in future cockpits.

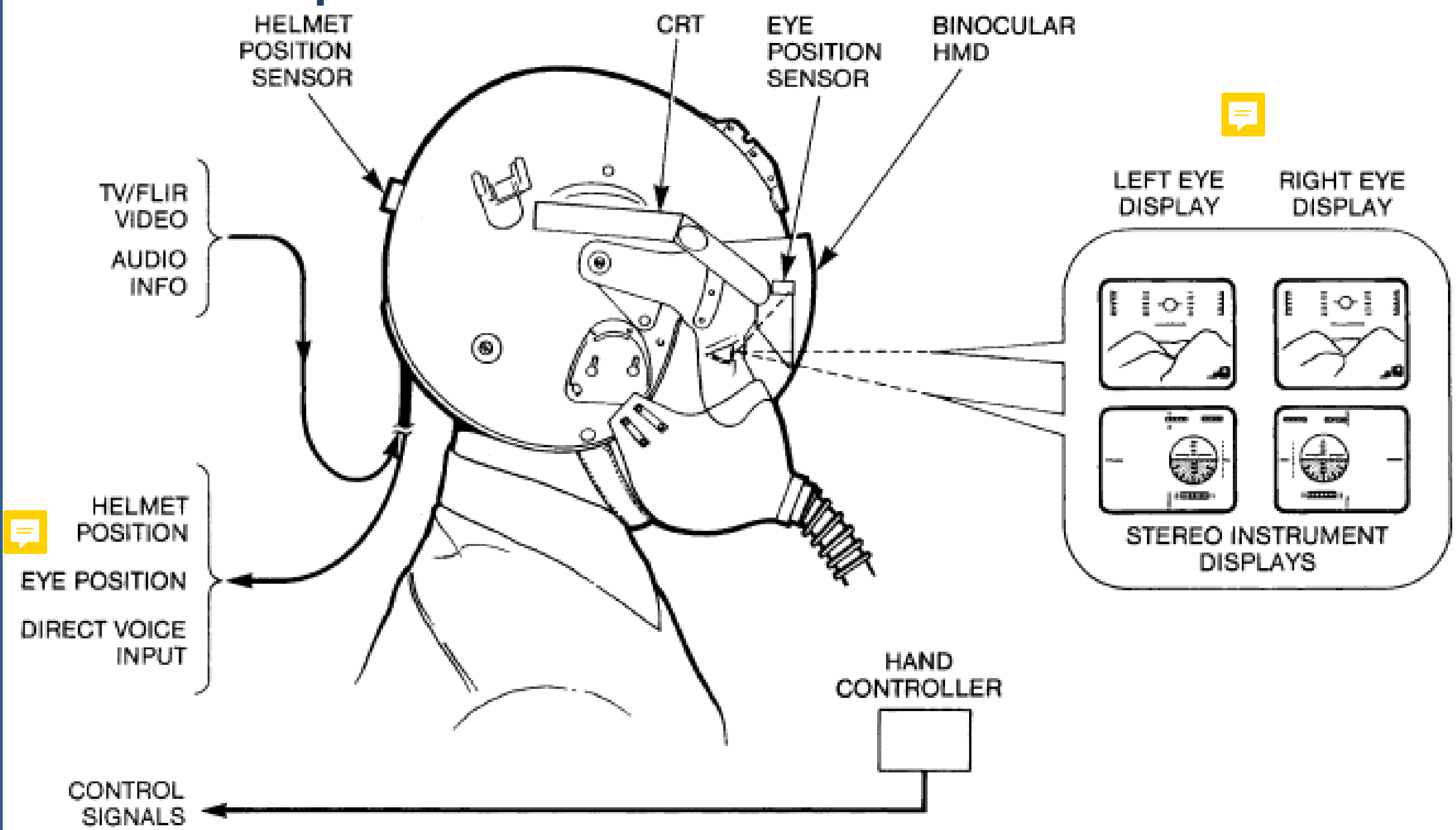
2. Helmet Mounted Displays (HMD)

Virtual Cockpit

- The concept of a 'virtual cockpit' where information is presented visually to the pilot by means of computer generated 3D imagery is being very actively researched in a number of establishments both in the USA and the UK.
- The increasing use of **Remote Piloted Vehicles (RPVs)** and their control from a 'parent' aircraft, or ground station, is another future application for HMDs and virtual cockpit technology.
- A correctly designed **Binocular HMD (BHMD)** is a key component in such systems because it is able to present both a display of information at infinity and also stereo images to each eye so that the pilot sees a 3D image.

2. Helmet Mounted Displays (HMD)

Virtual Cockpit



Binocular HMD and Virtual Cockpit.

2. Helmet Mounted Displays (HMD)

Virtual Cockpit

- When head up, the pilot views the outside world directly, or indirectly by means of a TV display on the HMD from a head steered gimballed electro-optical sensor unit (e.g. infrared imaging sensor, low light TV camera or CCD camera).
- When looking down at the instrument panel, the virtual cockpit computer system recognizes the pilot's head down sight line from the head tracker output and supplies this information to the display generation system.
- The display generation system then generates a stereo pair of images of the appropriate instrument display on the panel which corresponds to the pilot's sight line, e.g., a 3D image of that instrument display appearing in the position it normally occupies – i.e. a virtual instrument panel display.

2. Helmet Mounted Displays (HMD)

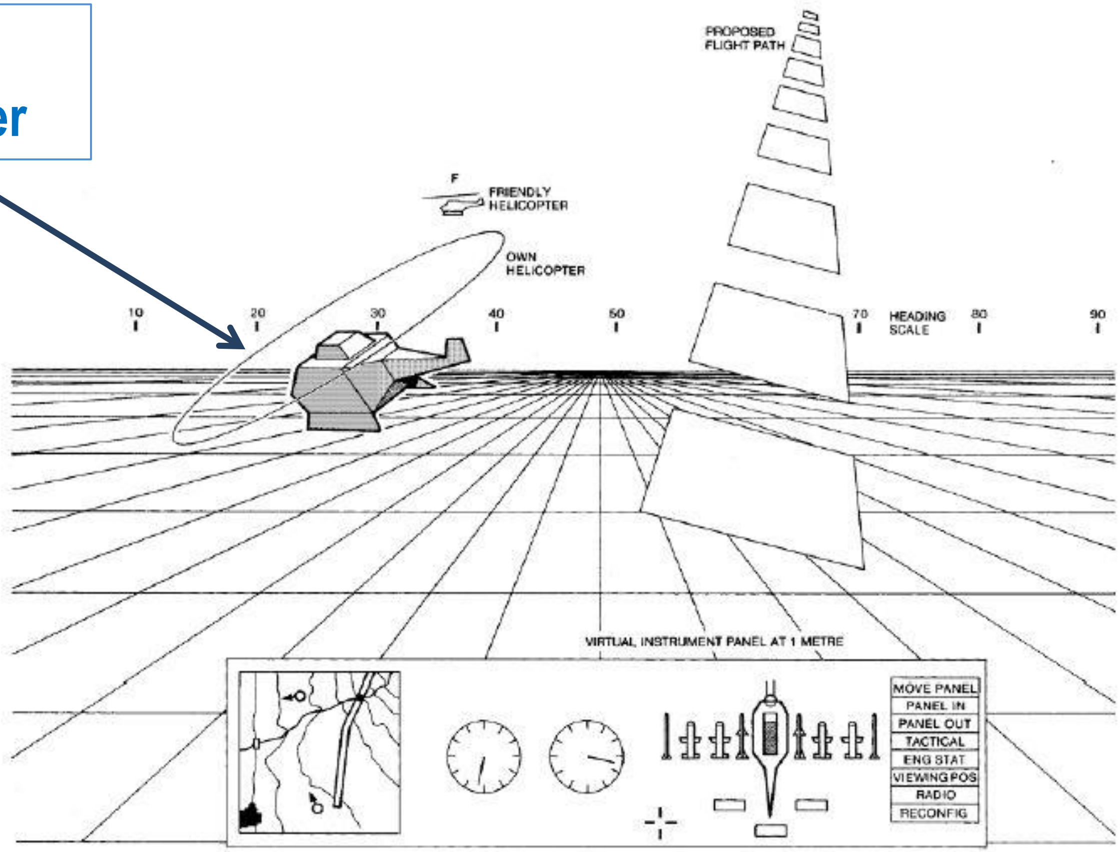
Virtual Cockpit

- Novel ways of presenting information to the pilot by means of the BHMD include displaying a 3D **'pathway in the sky'** as a flight director display, which can be overlaid on the normal outside scene (directly or indirectly viewed) or on a computer generated outside world scene created from a terrain data base.
- A **'God's eye view'** can also be presented; for example, what the pilot would see if he was outside the aircraft and looking down from a height of say 2000 ft above and slightly behind his aircraft.
- There has been disquiet regarding the physiological and psychological effects of prolonged viewing of commercial 'virtual reality' systems and the ability of the user to switch back to the real world without delay.

2. Helmet Mounted Displays (HMD)

Virtual Cockpit

Piloted Helicopter



God's eye view display concept

2. Helmet Mounted Displays (HMD)

Virtual Cockpit

- Anticipation also lie on what are referred to as **Virtual Retinal Displays (VRDs)** for future virtual cockpits.
- In such systems, images are not presented on a display surface but instead are projected directly on to the retina of the pilot's eye by a raster scanned laser light beam.
- ~~The current technology of implementing a virtual retinal display involves lasers, optical fibers and miniature vibrating mirrors for raster scanning the retina of the eye, together with coupling optics.~~

3. Computer Aided Optical Design

- ~~Modern optical design software enables very sophisticated optical designs to be optimized and the performance determined.~~
- ~~An automatic optimization program can be carried out iteratively whereby the curvature of all the individual elements, their spacing, tilt,~~ refractive index can be varied to seek an optimal solution.
- These programs take several hours to run even on the most modern main frame computers.
- None of the modern HUDs and HMDs, in fact, would have been feasible without the use of Computer Aided Optical Design methods.

4. Head Down Displays (HDD)

Primary Flight Display

4. Head Down Displays (HDD)

- By the early 1980s, it became viable to effect a revolution in civil flight-decks and military cockpits by replacing the majority of the traditional dial type instruments with multi-function color CRT displays
- Traditional dial instruments which are still used are the electromechanical standby instruments such as the altimeter, airspeed indicator, artificial horizon and heading indicator.
- These electro-mechanical standby instruments, however, are now being replaced by all solid state equivalents with a color LCD display presentation, in the new generation of aircraft entering service, or in avionic update programs.
- The color CRT is still a major display technology in terms of the number of aircraft equipped with color multi-function CRT displays.
- The situation, however, has changed rapidly over the last decade with the development of high resolution, **Active Matrix Color LCDs (AMLCDs)**.

4. Head Down Displays (HDD)

- Typically, a HDD comprises the display together with the drive electronics and power regulation.
- As with the HUD, there is frequently a simple processor and housekeeping software to control the brightness, self test and mode changes.
- Some units now contain a full processor and symbol generator and data bus interface, but it is more usual for the HDDs to be driven by a central display processor(s).

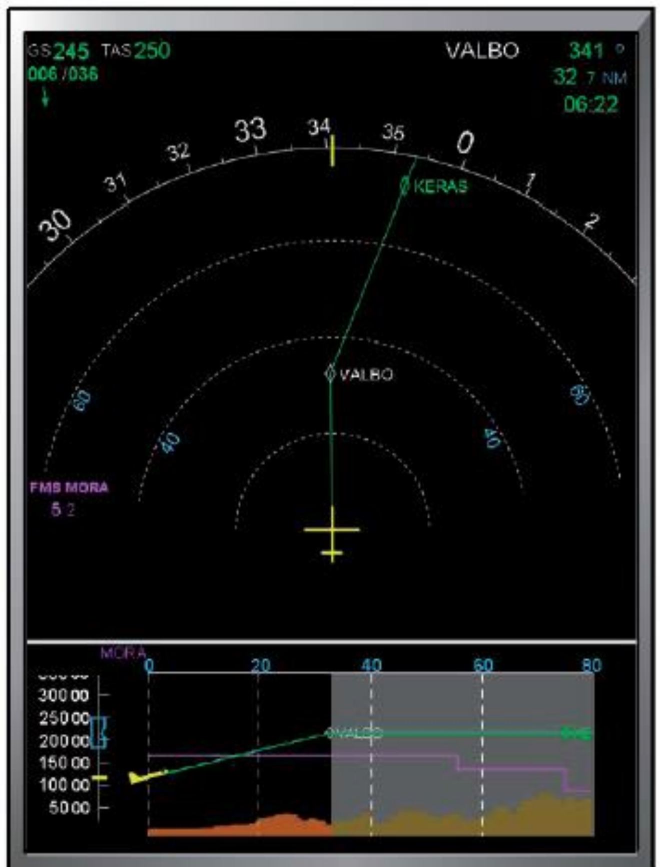
4. Head Down Displays (HDD)

Civil Cockpit HDDs

- The displays are duplicated for the Captain and Second Pilot and being multifunction it is possible to reconfigure the displayed information in the event of the failure of a particular display surface.
- The electronic Primary Flight Display (PFD) replaces six electro-mechanical instruments: **altimeter**, **vertical speed indicator**, **artificial horizon/attitude director indicator**, **heading/compass indicator** and **Mach meter**.

4. Head Down Displays (HDD)

Civil Cockpit HDDs



Navigation (or horizontal situation) display.

4. Head Down Displays (HDD)

Civil Cockpit HDDs

Engine/Warning Display

4. Head Down Displays (HDD)

Military Cockpit HDDs

- Video head down displays now include FLIR, ~~LLTV~~ and maps.
- All the HUD functions may be repeated overlaid on the video pictures. Fuel and engine data, navigation waypoints and a host of 'housekeeping' functions (e.g. hydraulics, pressurisation) may be displayed.
- A stores management display is also required showing the weapons carried and their status.
- Typical advanced military cockpits are configured with four head down displays.
- There are two large colour displays; a **Horizontal Situation Display (HSD)** providing a 6 × 8 inch map display in 'portrait' format with symbol overlay of routeing and threat data and a **Vertical Situation Display (VSD)** providing an 8×6 inch Irvideo display showing targeting video at various magnifications.

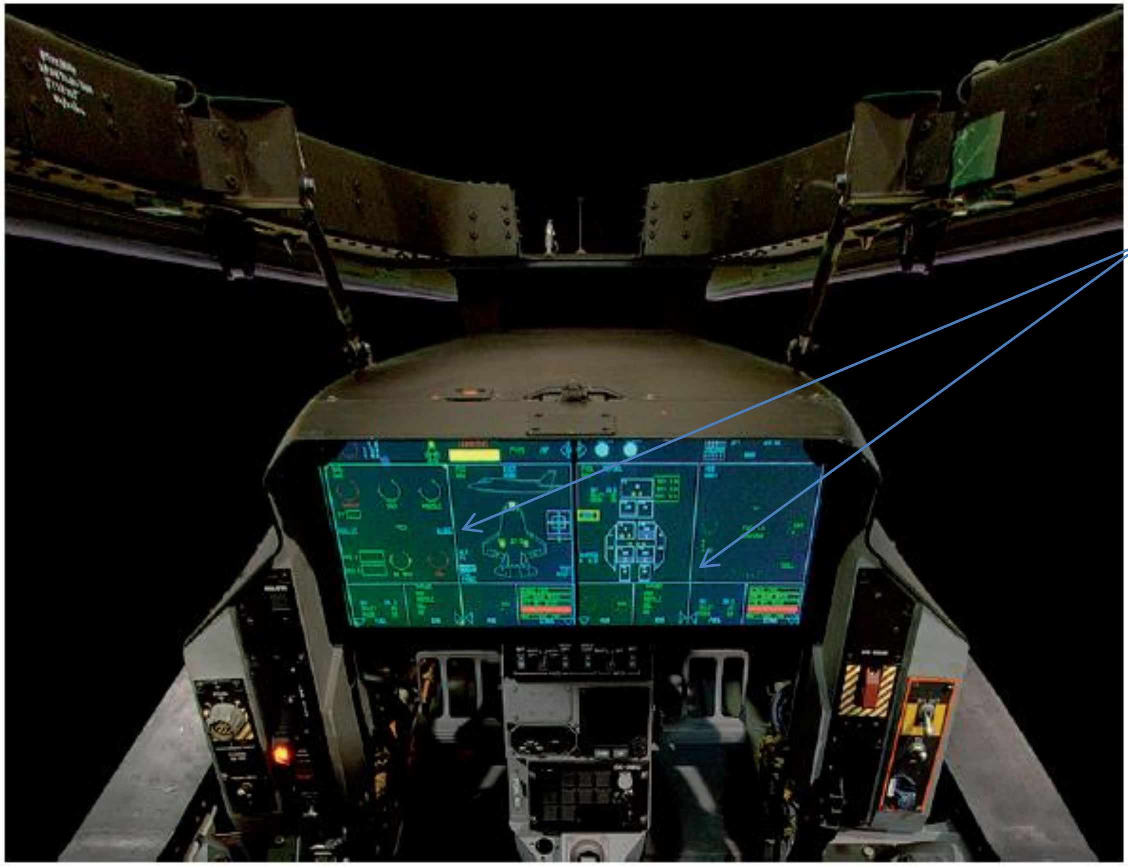
4. Head Down Displays (HDD)

Military Cockpit HDDs

- The other two displays are smaller 5×5 inch monochrome displays comprising a **Systems Status Display (SSD)** displaying systems status data and **a Systems Control Display (SCD)** displaying systems control data.
- Both these displays have tactile data entry overlay.
- The advanced cockpits for the new generation of fighter/strike aircraft have just two large color displays as the primary head down displays.

4. Head Down Displays (HDD)

Military Cockpit HDDs



Two large flat panel color display surfaces.

Lockheed Martin 'Lightening 2' Joint Strike Fighter cockpit.

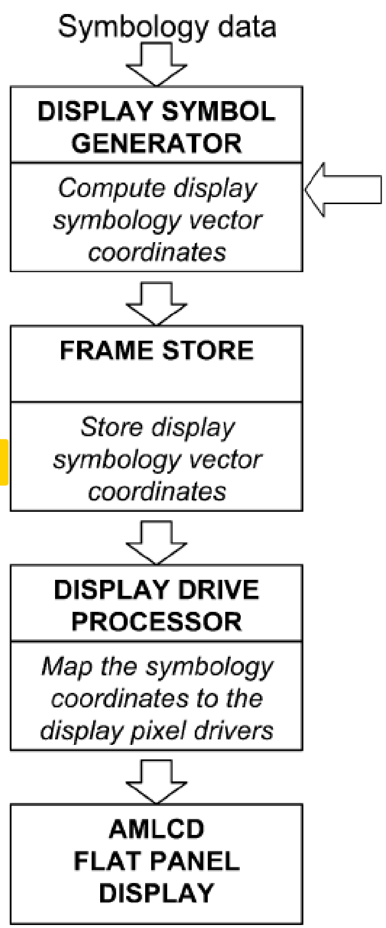
4. Head Down Displays (HDD)

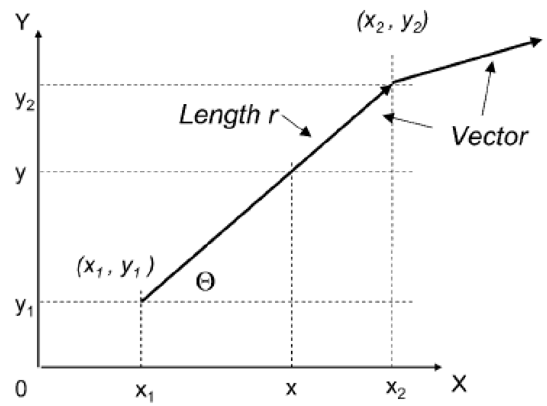
Display Symbology Generation

- Symbology such as lines, circles, curves, dials, scales, alpha-numeric characters, tabular information, map display features is drawn as a set of straight line segment approximation, or vectors (like a ‘join the dots’ children’s pictures).

4. Head Down Displays (HDD)

Display Symbology Generation





Given vector origin coordinates, (x_1, y_1), vector length, r, and angle to X axis, (Θ); coordinate of end of vector, (x_2, y_2), are given by :

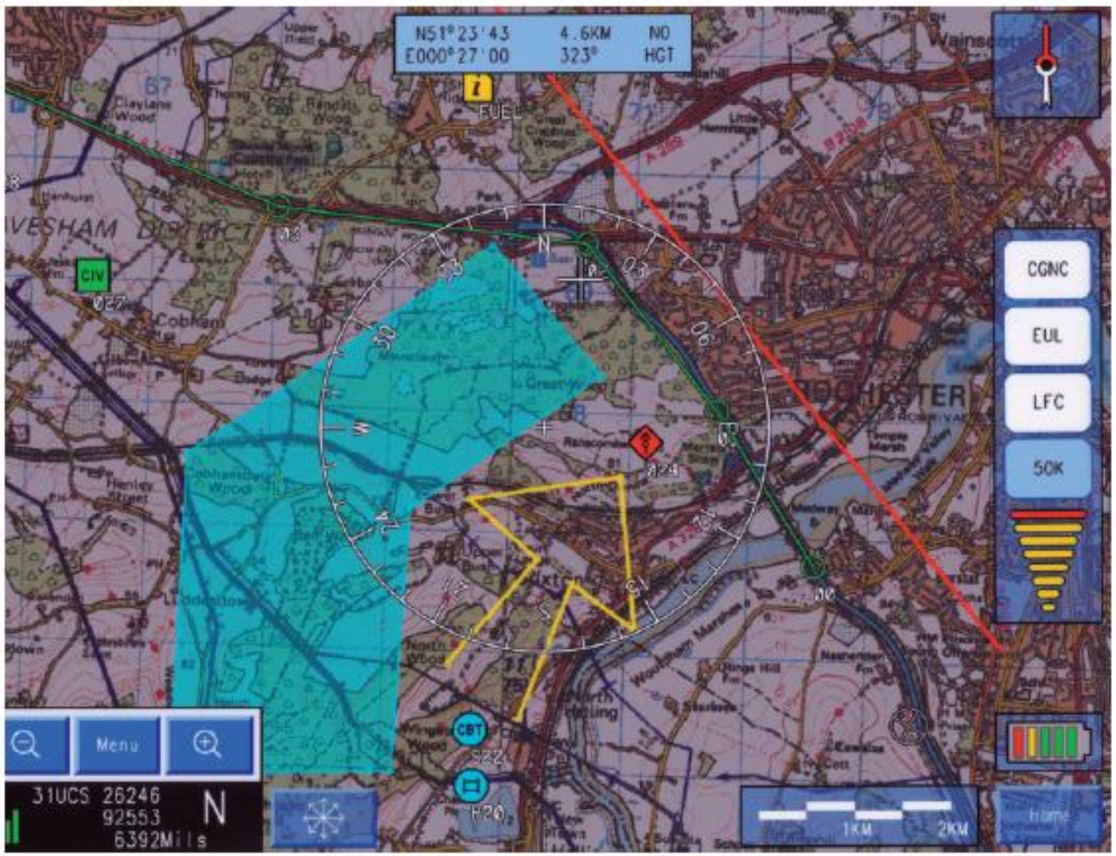
$$x_2 = x_1 + r\cos\Theta$$

$$y_2 = y_1 + r\sin\Theta$$

Symbology generation and display.

4. Head Down Displays (HDD)

Display Symbology Generation

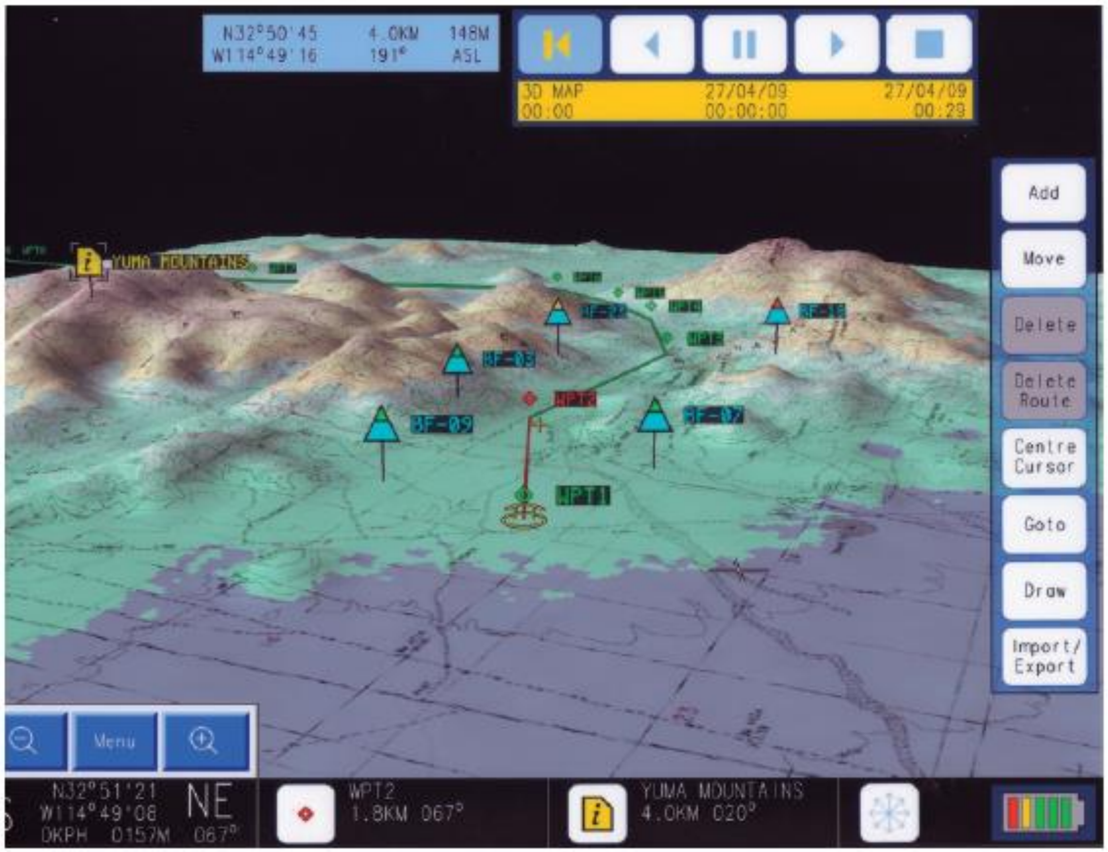


Digitized map with information overlay.

Digitally generated moving color maps.

4. Head Down Displays (HDD)

Display Symbology Generation

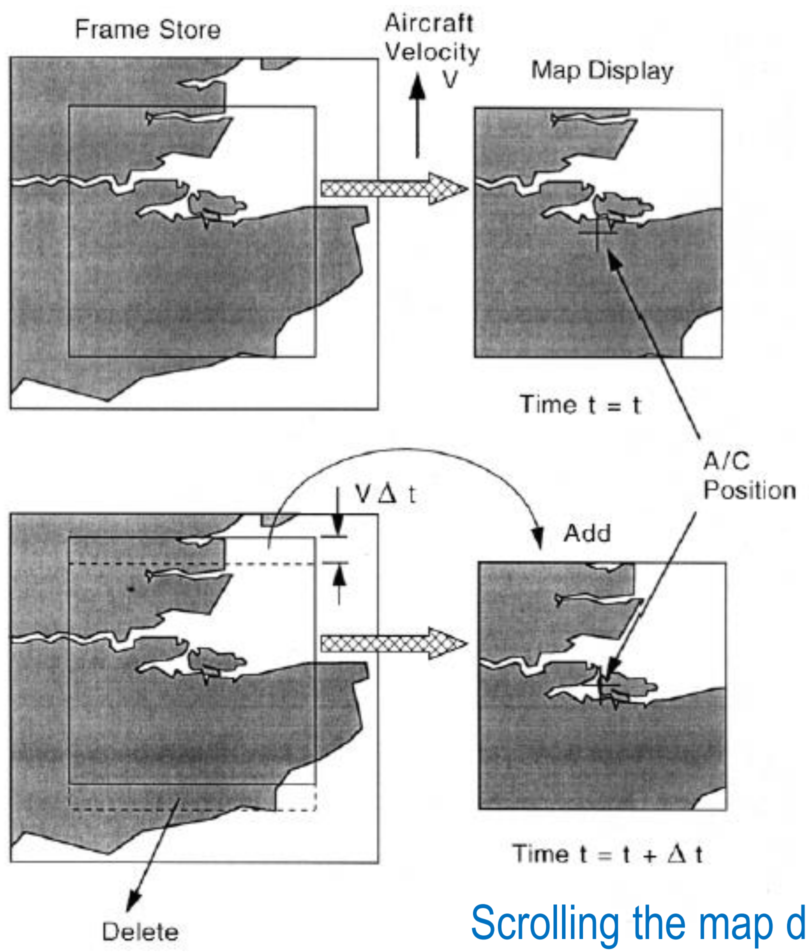


Digitally generated moving color maps.

3D terrain map display.

4. Head Down Displays (HDD)

Display Symbology Generation

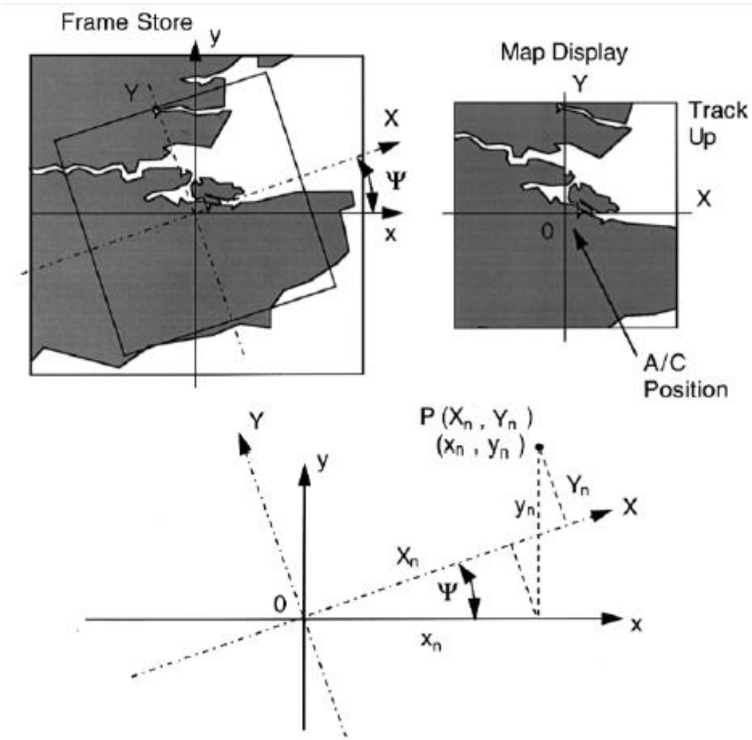


Scrolling the map display window.

Digitally generated moving color maps.

4. Head Down Displays (HDD)

Display Symbology Generation



Coordinates of point P with respect to Map Display axes, 0X & 0Y, are (X_n,Y_n), and with respect to Frame Store axes, 0x & 0y, are (x_n,y_n).

Data for point P (x_n,y_n) on Map Display is held in Frame Store coordinates

$$x_n = X_n \cos \Psi - Y_n \sin \Psi$$
$$y_n = Y_n \cos \Psi + X_n \sin \Psi$$

Digitally generated moving color maps.

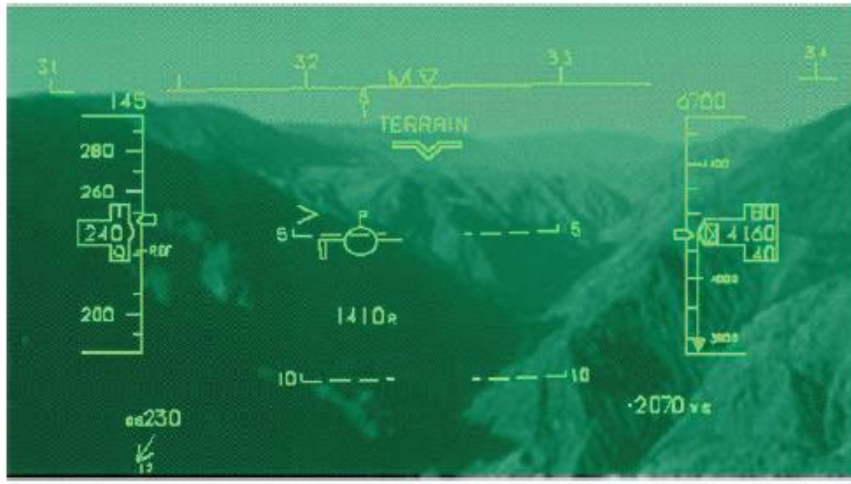
Rotating the map display window.

5. Data Fusion

- Data fusion is the name given to the process of combining the data from a number of different sources to provide information which is not present in the individual sources.
- For example, a synthetic 3D picture can be derived of the terrain in front of the aircraft from an accurate **terrain data base** and accurate information on the **aircraft's position and attitude**.
- The aircraft's position and attitude information are provided by a GPS and an INS.
- The synthetic picture of the terrain can be overlaid one to one with the outside scene derived from a FLIR sensor and displayed on a HUD or a head down display.
- This system enables the pilot to continue visual flight in conditions of marginal visibility where normally it would be necessary to pull up and fly at a higher altitude.

5. Data Fusion

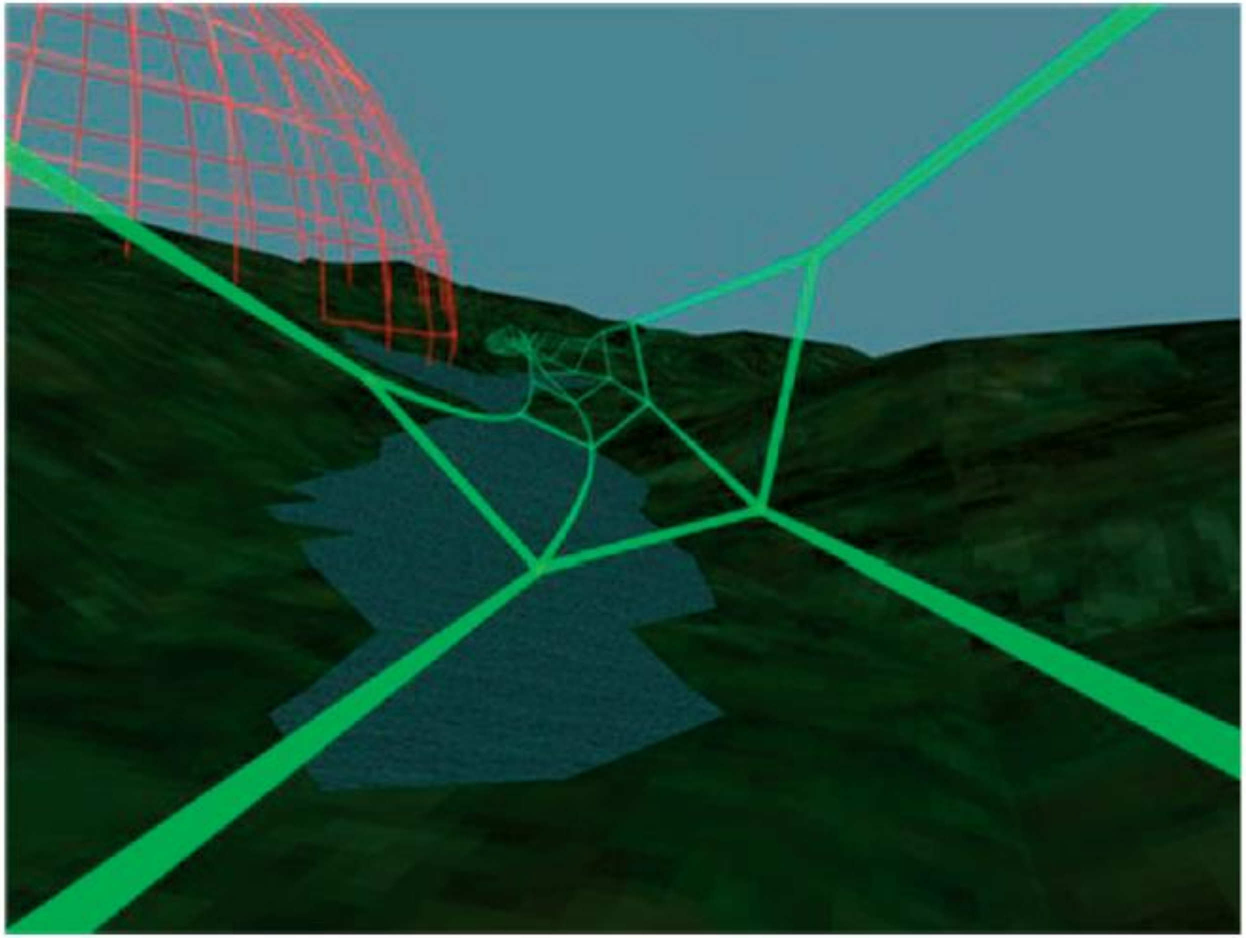
HUD display while carrying out an erroneous decent in mountainous scenario.



Enhanced vision display.

Synthetic vision display.

5. Data Fusion



‘Pathway in the sky’ pictorial display.

5. Data Fusion

- These displays provide a pictorial presentation of the aircraft's spatial situation and flight path using synthetically generated ground imagery, and exploit data fusion.
- All pilots learn to fly using this primary flight information format and its retention in color head down displays has enabled their acceptance to be achieved in a smooth and straightforward manner with very little learning curve required.
- The display of information, however, in any application involves a process of abstraction, and a 'mental translation' is required to build up a situational awareness and mental picture of what is happening.
- The objective of these new pictorial displays is to provide the pilot with a more intuitive and natural appreciation of the situation in terms of the aircraft's state, its actual flight path, and the desired flight path with respect to the outside world.

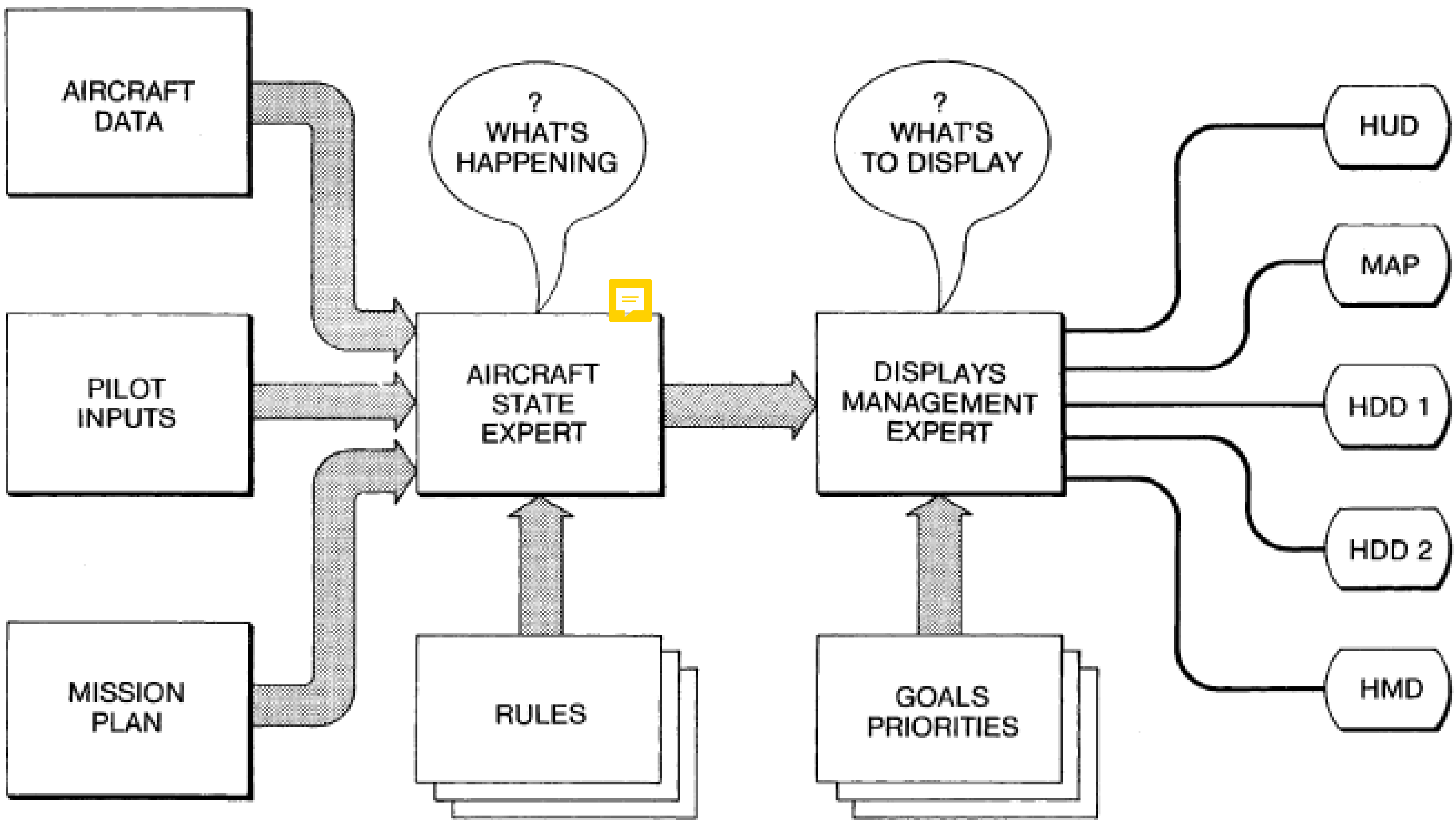
5. Data Fusion

- With systems exploiting the data fusion technologies, a more easily assimilated pictorial type display presentation can be produced compared with the present symbolic presentations of flight and navigational information.
- To generate these pictorial displays is not a problem with the technology now available.
- There is, however, a big difference between demonstrating an experimental system and the development of a production system approved by the airworthiness authorities.
- The costs involved in achieving certification by the civil airworthiness authorities is a significant sum (as with any airborne system); the software is safety critical and the flight trials to prove the system do not come cheaply.

6. Intelligent Display Management

- The exploitation of **intelligent knowledge based systems (IKBS)** technology, frequently referred to as 'expert systems', to assist the pilot in carrying out the mission is the subject of a number of very active research programs.
- A subset of all the proposed expert systems on an aircraft is an intelligent displays management system to manage the information which is visually presented to the pilot in high work load situations.
- **It is the unexpected or uncontrollable that leads to an excessive work load**, examples being:
  - The 'bounce' – interception by a counter attacking aircraft with very little warning.
  - Evasion of ground threat – **SAM** (surface–air missile).
  - Bird strike when flying at low altitude.
  - Engine failure.
  - Weather abort or weather diversion emergency.

6. Intelligent Display Management



Intelligent display management.

7. Display Technology

Replacing the HUD CRT

- The vast majority of HUDs currently in service worldwide use a CRT as the display source, and CRT based HUDs will remain in service for many years to come.
- The CRT is basically a very simple and technically elegant device which has truly been one of the greatest enabling inventions of the twentieth century.
- The continuing development, however, of projected display systems has now enabled a competitive, higher reliability replacement of the HUD display source to be produced. New HUD systems exploiting these developments are now entering service and the CRT based HUD will be eventually superseded.

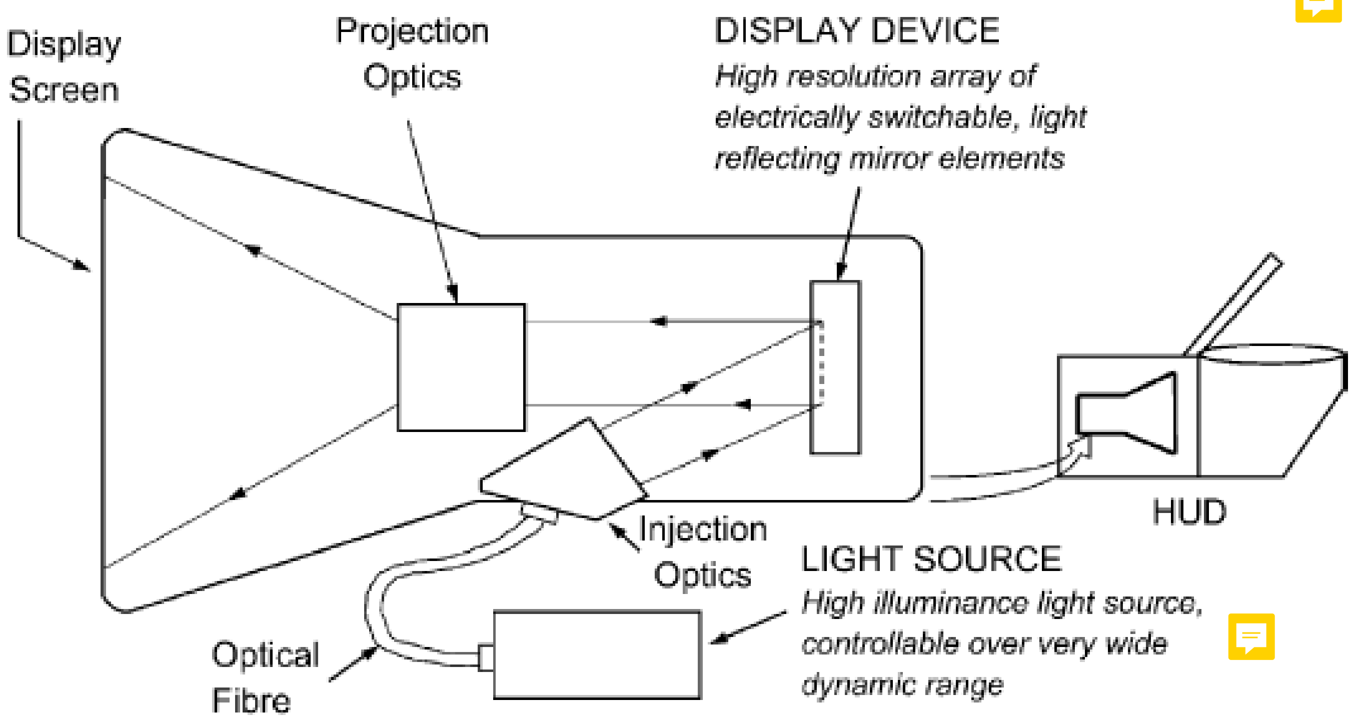
7. Display Technology

Replacing the HUD CRT

- The CRT, however, has major advantages which have been hard to match such as sharp, crisp cursive display symbology and the very wide viewing angle inherent with an emissive display, and extremely high display integrity; the probability of the CRT itself displaying misleading information is less than 1 part in a billion per hour.
- The current solution to replacing the CRT is to use a projected type display with a very high luminance light source to illuminate a light modulator, such as a flat panel high resolution display device.
- Although losses in the light modulation process constrain the display efficiency, the HUD requirements can be met and the reliability greatly increased.

7. Display Technology

Replacing the HUD CRT



Projection Display Unit for a HUD

7. Display Technology

Replacing the HUD CRT

- However, high luminance LEDs which meet the HUD luminance requirements have also become available fairly recently.
- The reflection efficiency of reflective type LCDs, however, is only about 15% and requires a high luminance light source to meet the required display brightness levels. (Transmissive type LCDs are unsuitable as their transmission efficiency is too low.)

7. Display Technology

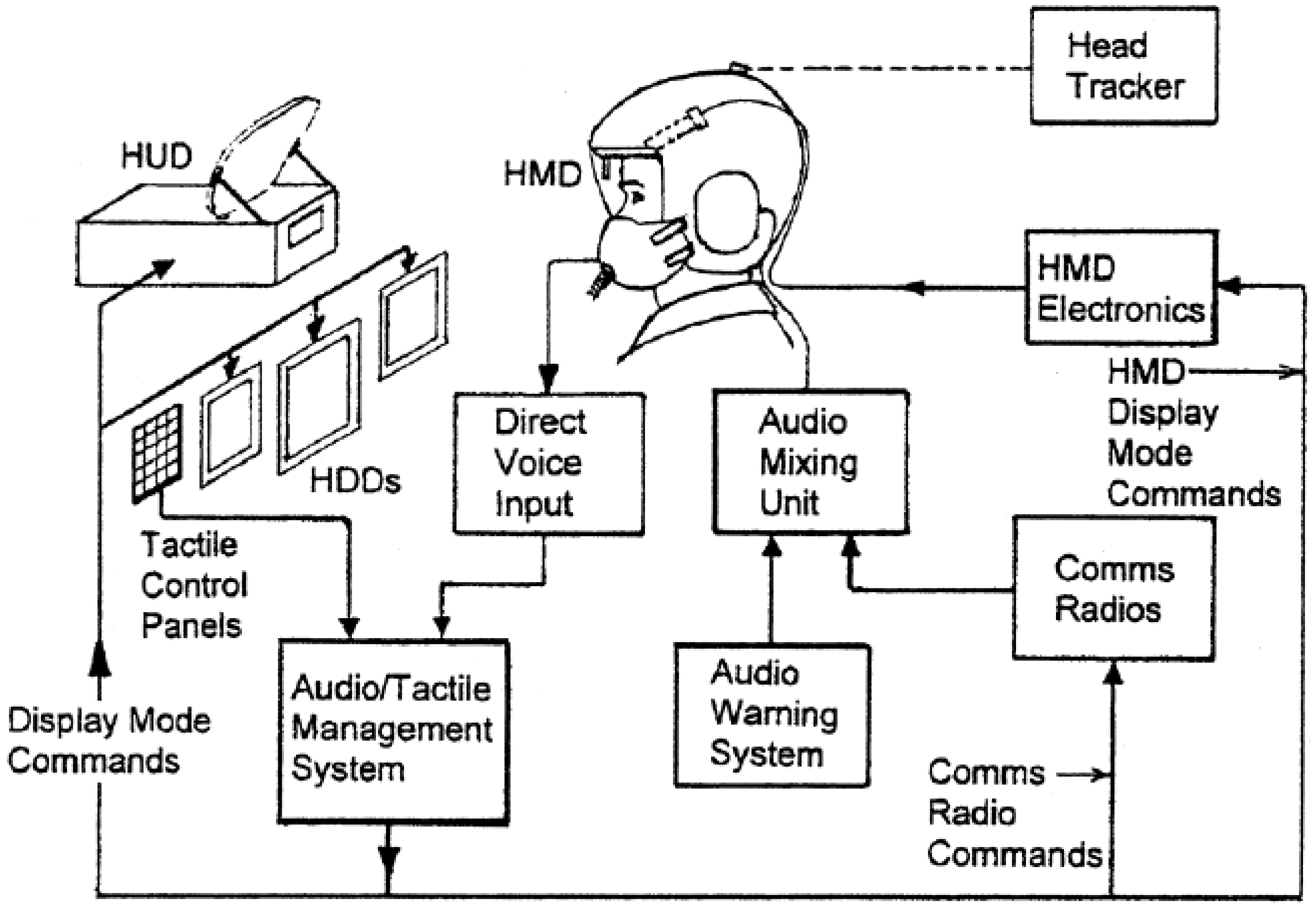
HMD/HUD Optical System Technology

- Recent developments in holographic waveguide technology, however, will have a profound impact on future HMD and HUD design. Exploitation of this technology offers a major improvement in terms of mass, cost, volume, simplicity and optical performance.
- The advantages the new technology offers can best be seen by reviewing the optical requirements for any HMD/HUD system and the limitations imposed by using current optical technology.
  - **Internal Reflection**: to be minimized and solar imaging well controlled.
  - Compactness
  - **Contrast**: to be visible under all ambient light conditions.
  - Field of View
  - Weight
  - Reliability

8. Control and Data Entry

- **Tactile Control Panel**
- **Direct Voice Input (DVI):** control is a system which enables the pilot to enter data and control the operation of the aircraft's avionic systems by means of speech.
- **Speech Output System**: Audio warning systems using speech synthesizers to provide voiced warning messages to the pilot/crew of system malfunctions and dangers/threats. They are also complementary to a DVI system to provide the essential feedback that a spoken command/data input has been correctly recognized.
- **Display Integration with Audio/Tactile Inputs**: enables a very significant reduction in the pilot's workload to be achieved in the new generation of single seat fighter/strike aircraft.
- **Eye Trackers:** These are being fairly widely used and evaluated in ground simulators for such future applications as improved target designation accuracy by enabling a more accurate measurement of the pilot's gaze angle to be made in conjunction with a head tracker system.

8. Control and Data Entry



Audio-Tactile Management System.