AVDASI 1
AENG 10001

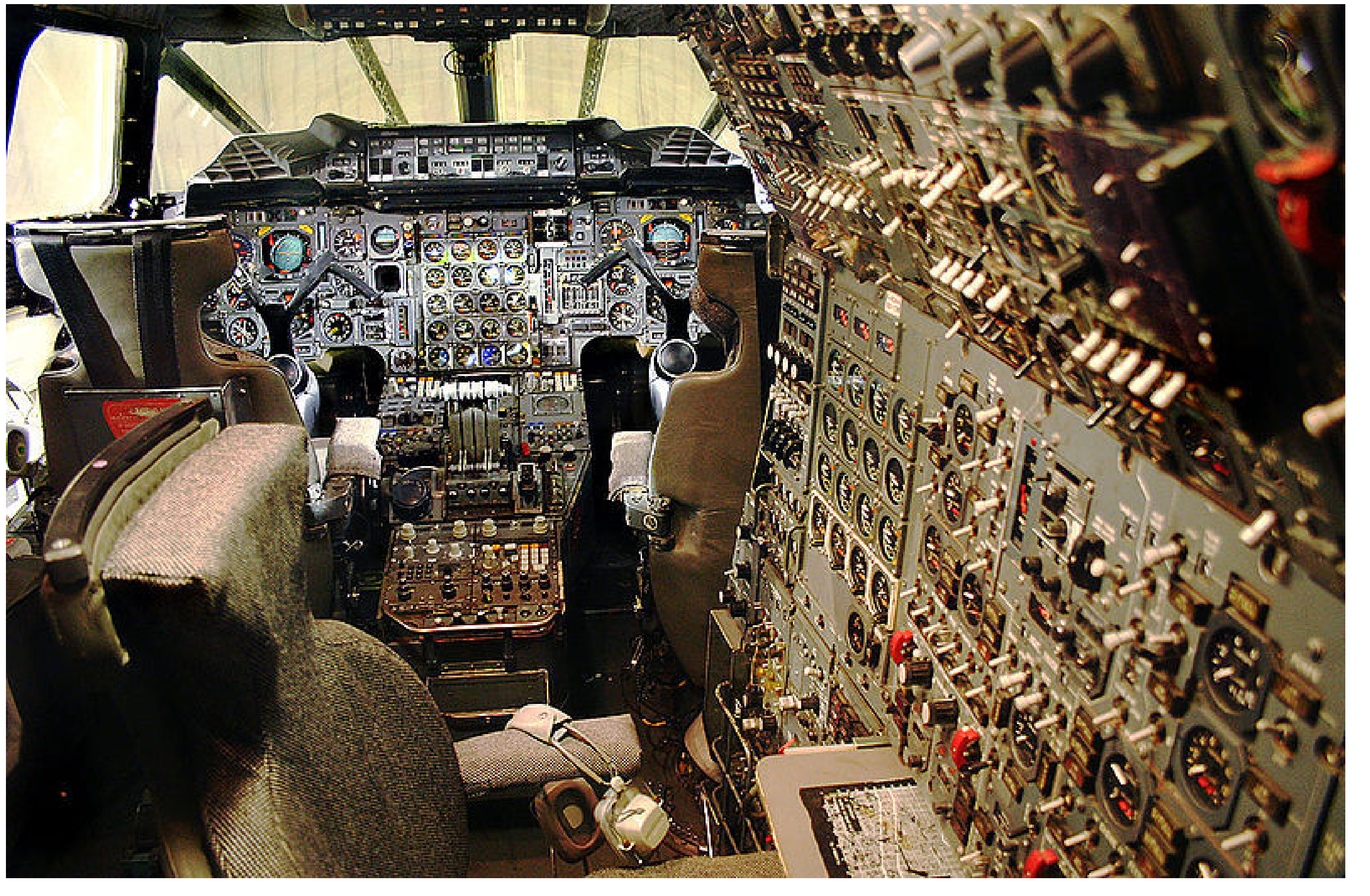
Head-up Displays, FLIR and Night Vision

University of BRISTOL

Content

- Head-up displays
- Thermal imaging - Infrared
- Image intensifiers - Night vision

Concorde – mechanical dials and instruments



A380 large area LCD

Head-up displays

Head-up displays

- Head-up displays are evolved from the original aircraft gun sights.
- The pilot sees information, normally symbolic, but sometimes numeric, superimposed on top of their view of the outside world.
- Widely used in military applications, they also appear in recent civil applications

HUD and HMD

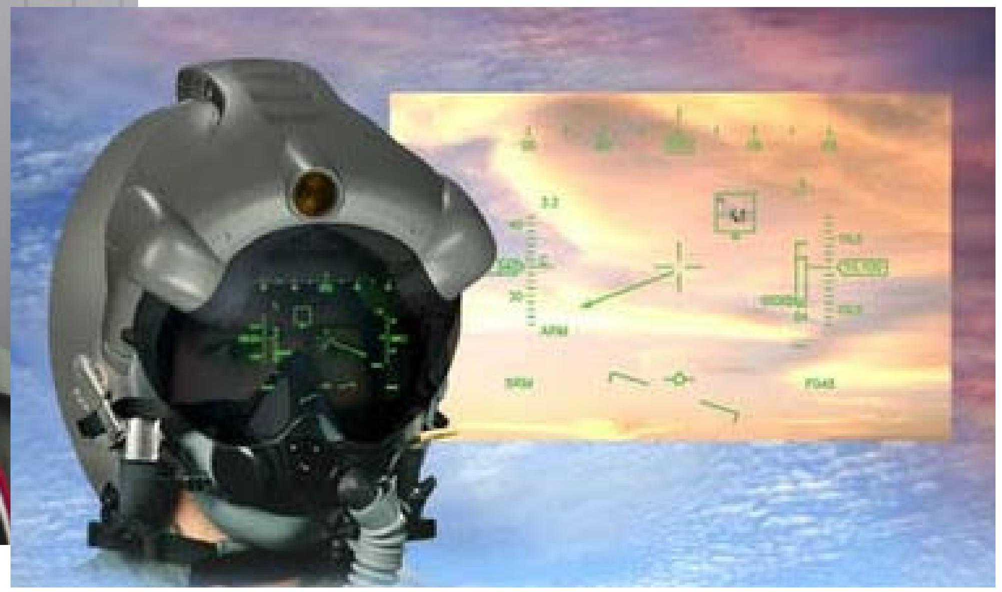
- HUD – Head Up Display
  - Pilot looks through display which is mounted to the airframe
  - Design issues include maximising the field of view (FoV) and brightness of symbology

- HMD – Helmet Mounted Display
  - Pilot looks through display that is helmet-mounted.
  - Requires accurate knowledge of the relative position of the helmet to the aircraft.
  - Mostly military applications.

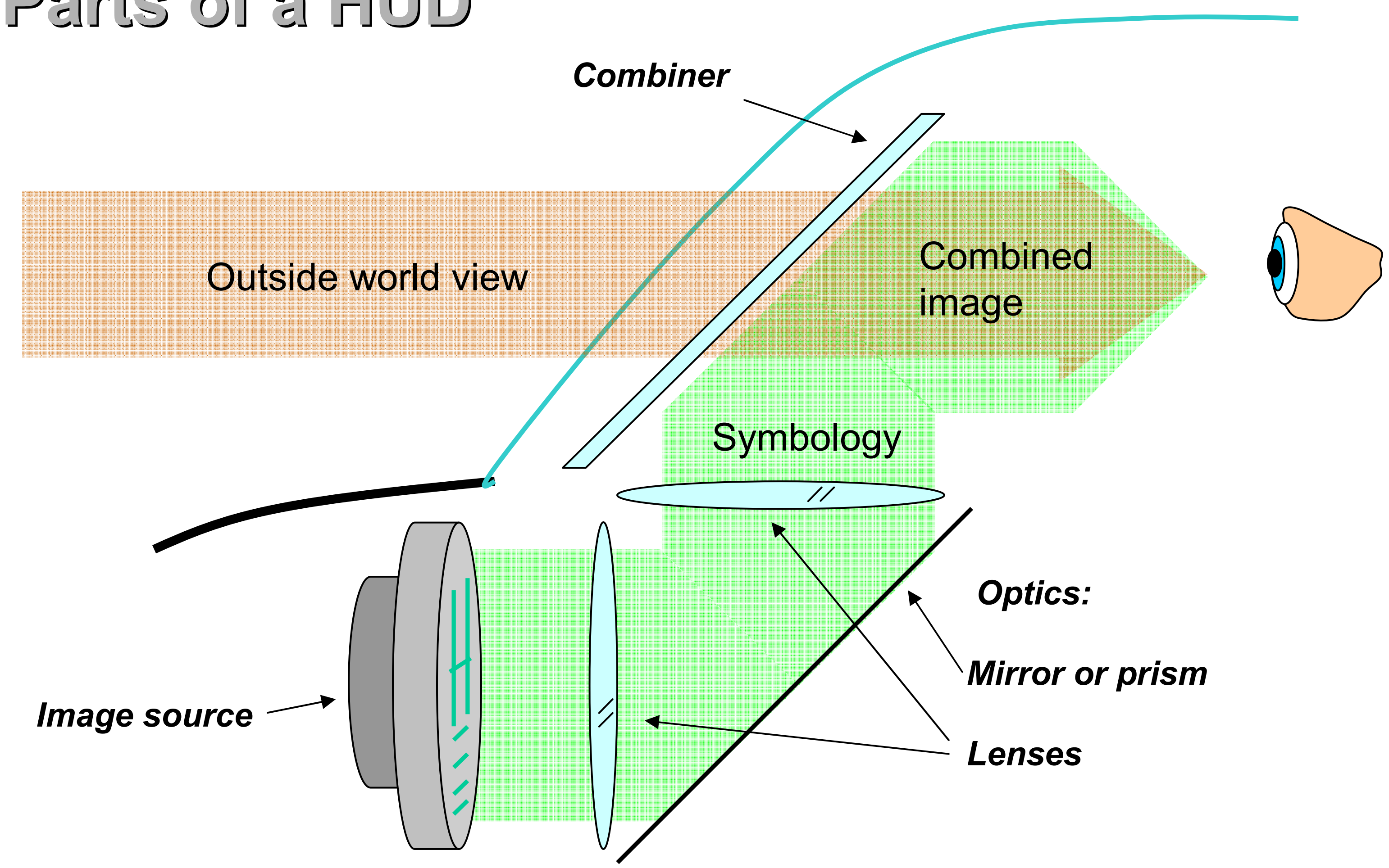
HUD

HMD

F-35 JSF HMD

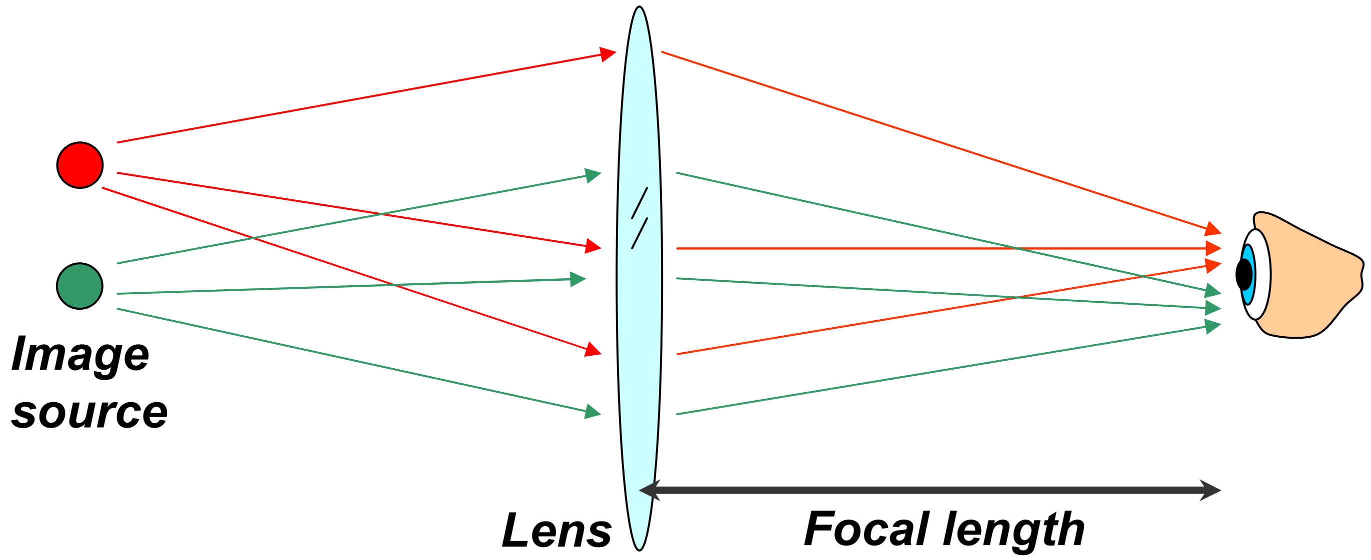


Parts of a HUD



Collimated image

- The pilot must see both images in focus *at the same time*
- To achieve this the symbology image is *collimated* (or focussed at infinity)



Simple lens system: image only in focus at the focal point

Collimated image

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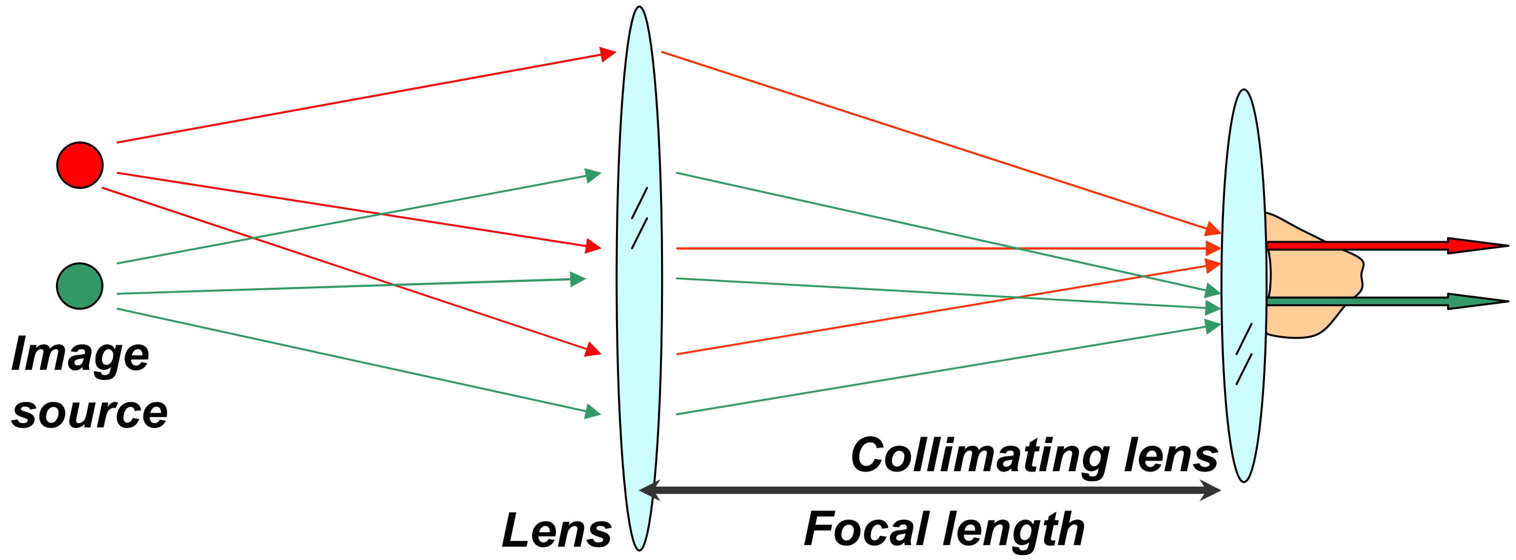


Simple lens system: image only in focus at the focal point
Colimated lens system: image in focus at any distance

Head-up display units

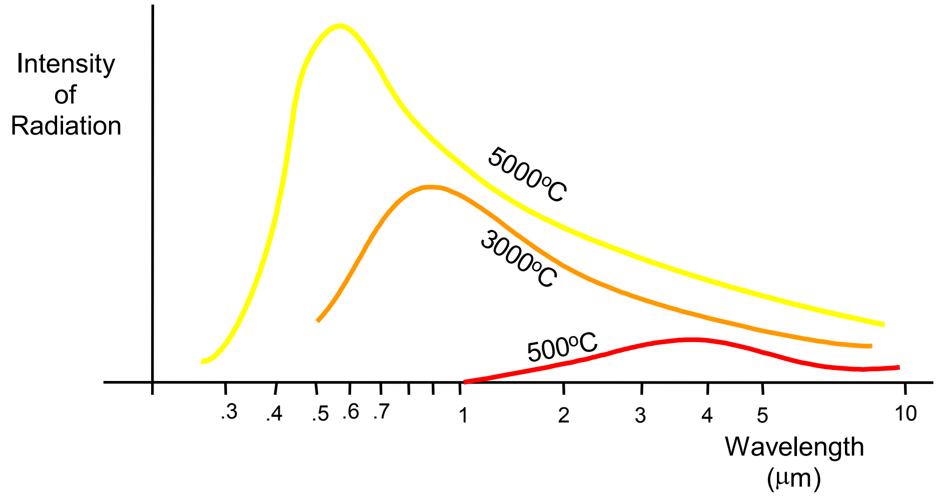



Thermal imaging

Thermal Imaging

- Thermal imaging creates a two dimensional representation of the temperature of a scene.
- We perceive visible light in terms of luminance (intensity) and chrominance (colour/frequency).
- Thermal imaging systems measure the intensity of Infrared emissions from a scene and convert the information into a visible light image.
- IR systems have many parallels with visible light systems but use differing semiconductors as detectors.

Spectrum and intensity of emission

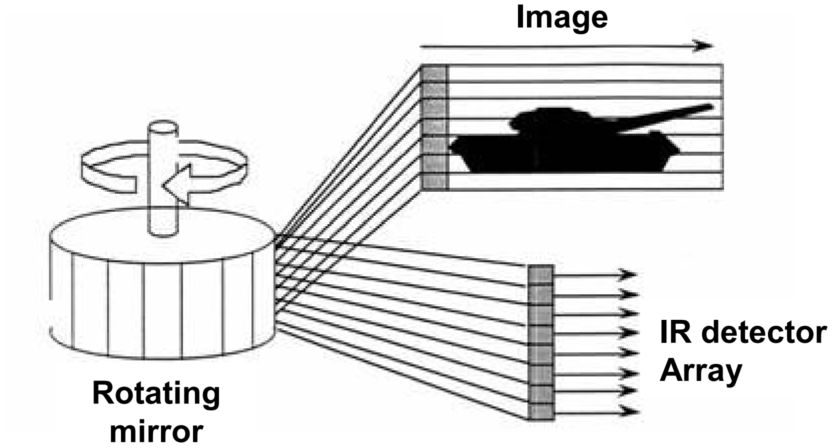


$$B_\lambda(T) = \frac{2hc^2}{\lambda^5} \frac{1}{e^{hc/\lambda kT} - 1}$$

Where;
B = specific intensity
h = Planck constant
λ = Wavelength
T = Temperature
k = Boltzman's constant
C = speed of light

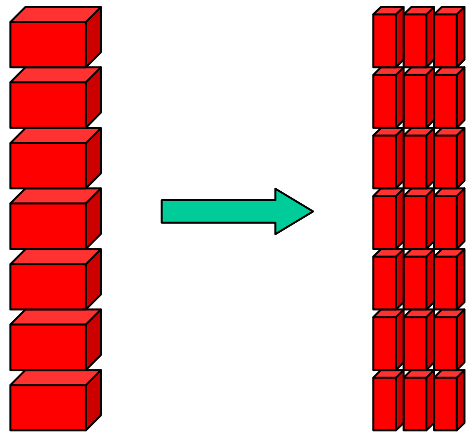
The temperature of a object alters the spectrum of the EM radiation as well as the intensity (think of a heated metal bar). This spectrum is described by planck's law. Higher temperatures produce an increase in radiation at all frequencies however the frequency at which the peak power is radiated increases with temperature

Scanned Arrays

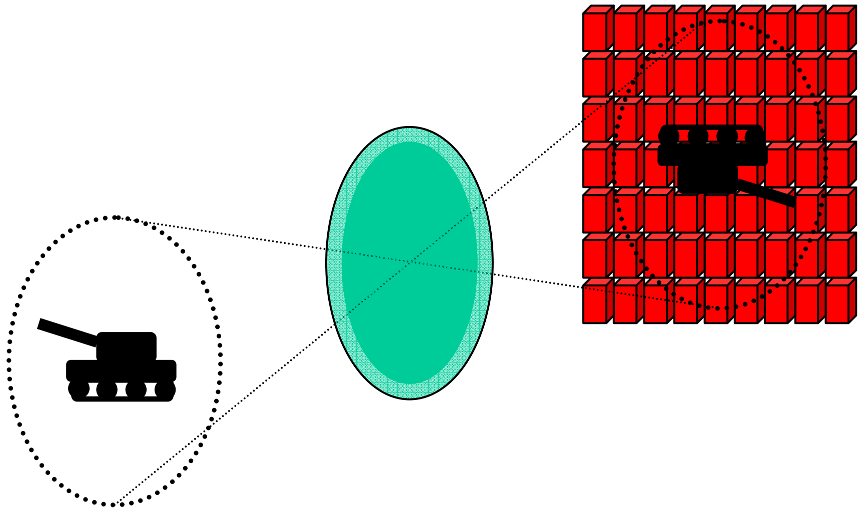


A typical scanned array uses an arrangement of mirrors to focus a small vertical slice of the image onto the detector array. The image is scanned at a known rate and this enables the processing electronics to reconstruct the 2D image

If a single row of detectors is used the system can be sensitive to the tolerance between individual array elements. For this reason more complicated scanning arrays are often used. The electronics aggregates the output of several array elements to reduce the effect of individual detector variation.



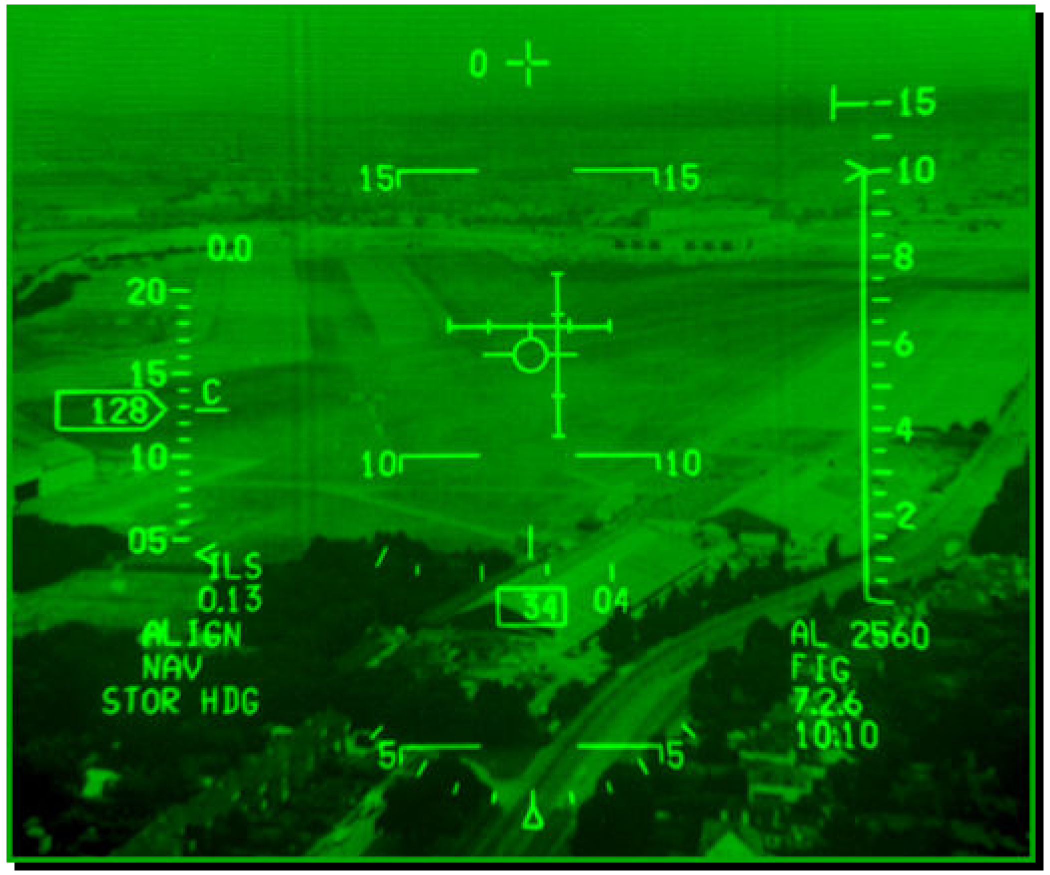
Staring Arrays



The mechanical simplicity of staring arrays makes them appealing however there are serious drawback to their application for IR detectors. The variation of sensitivity of individual elements presents offset problems, and it is impractical to solve this with more elements. One technique to compensate is to calibrate each element with zero incident power.

The cooling requirement of the detectors also becomes problematic in large arrays. In particular the large number of connections provide a thermal path. CCD (Charge Coupled Device) arrays of HgCaTe have been constructed with 1024x1025 elements.

Avionic Application - FLIR

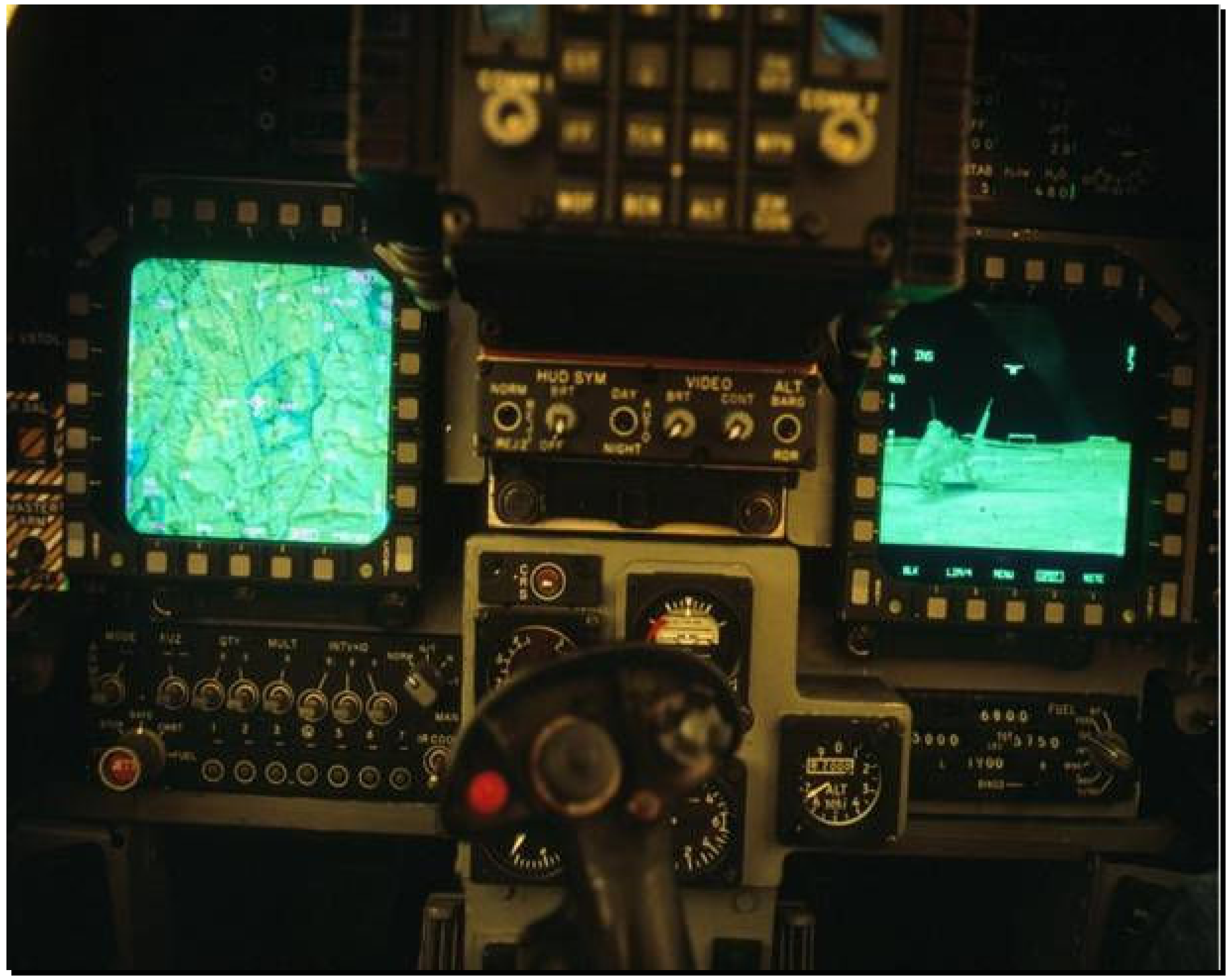


FLIR (Forward Looking InfraRed) is a common application of thermal imaging.

If displayed Head-Down the image will usually be overlaid with targeting information from the radar system. If displayed Head-Up the image will usually be overlaid with primary flight information.

Head-up the image must be harmonised (aligned) with the real world.

FLIR - Controls



The user is typically able to adjust;

- Area of regard
- Gain and offset
- Polarity
- Brilliance and contrast

FLIR - Gain and Offset

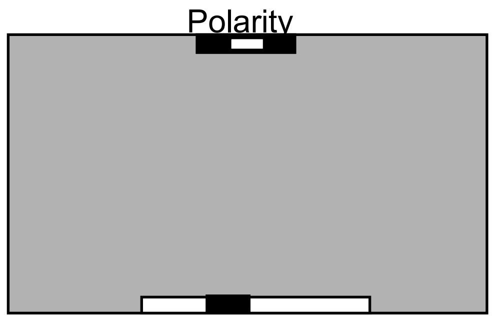
Gain and Offset set the ‘area of interest’ over which the FLIR will indicate temperature differences translated into the video scene image from ‘black’ to ‘white’.

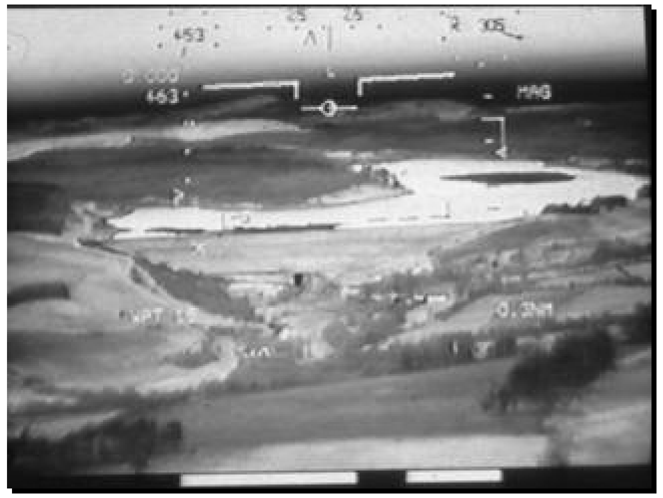
FLIR Polarity

Black hot or white hot?

- Operational use and thermal conditions tend to favour one over the other.
  - Black hot more intuitive to fly
    (sky is cold = white)
  - White hot better for target location.
    (highlighted against background)

- There is no universal rule, operator is usually given the choice,





IRST InfraRed Search and Track

One of the key advantages of IR detection systems is that they are passive. Unlike radar or laser detection systems it is not possible to determine if an IR system is in use. This gives IR systems a stealth advantage over other systems.

The latest developments of IR imaging systems have combined FLIR systems with target identification to produce a system capable of detecting and tracking a target and launching weapons.

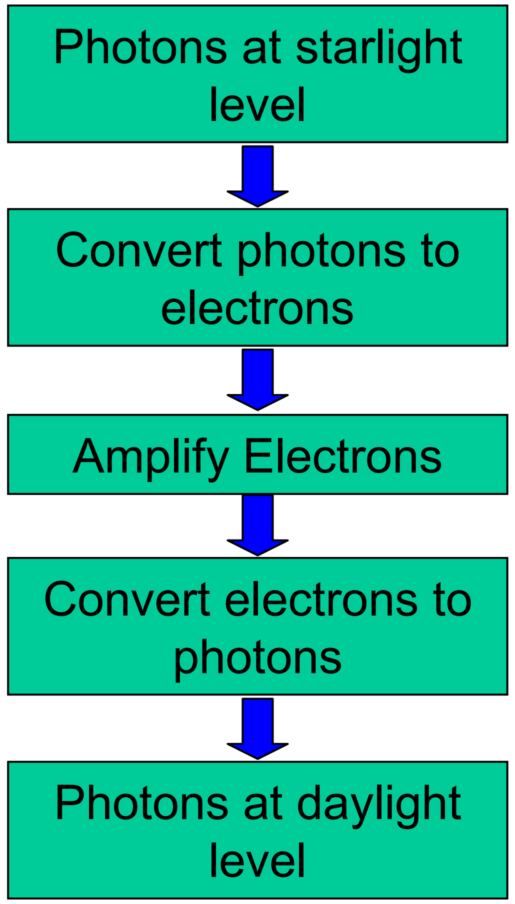
Image intensifiers – night vision

Night Vision Systems

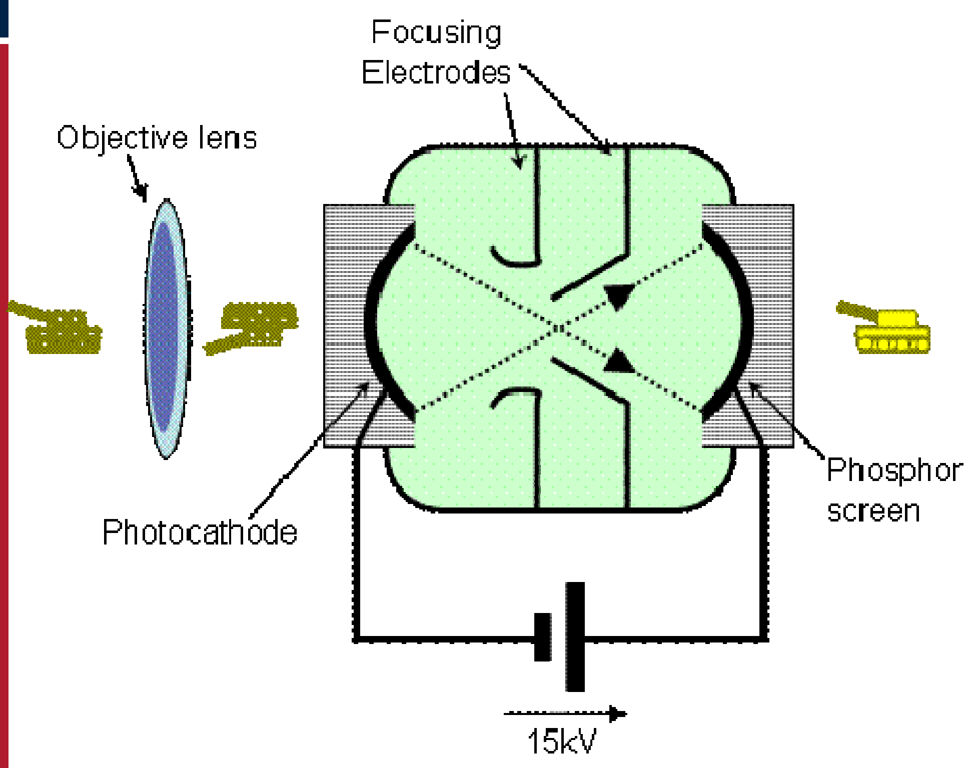
Once the intensity of light has fallen below a certain level the human eye is no longer able to respond.

Image Intensifiers, the most familiar of which are night vision goggles, act to collect any available reflected light and amplify it to a level that the human eye can detect.

The most abundant sources of radiation in low light conditions are starlight and near Infrared. By the choice of appropriate photocathode material these sources can be exploited.

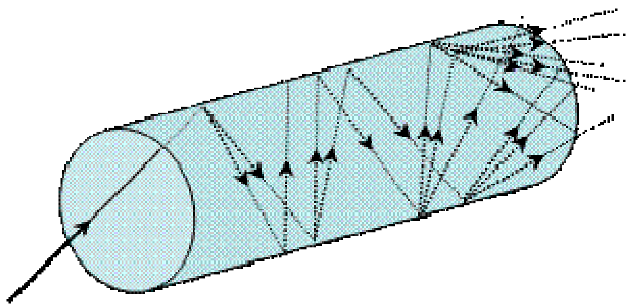


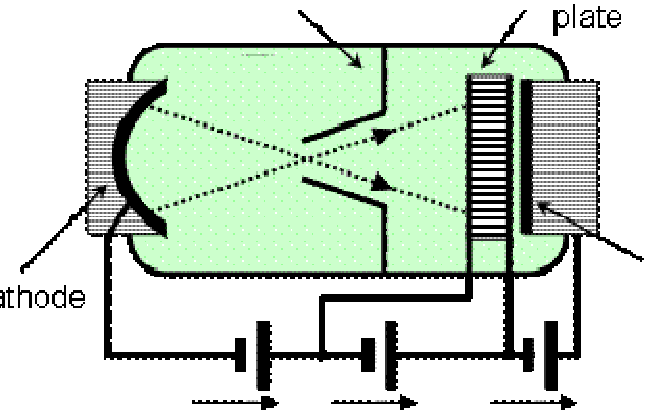
First Generation Cascade Tubes



First generation cascade tubes achieved light amplification levels of around x50. The photocathode material is typically Gallium Arsenide, GaAs. Similar considerations to IR detectors arise – e.g. silicon would appear to have good wide frequency response but thermal noise limits use at room temperatures. Higher amplifications are required for starlight and this led to several stages being linked together. This increases blur due to phosphor persistence

Second Generation – Micro Channel Plates





Micro channel plates are formed from a bundle of about a million glass fibre tubes fused into a plate. Primary electrons entering the tube strike the walls releasing a variable number of secondary electrons. These electrons are accelerated towards the phosphor screen by a potential of 1kV across the plate. The gain of a single stage can be as high as 50,000. Micro channel plate stages suffer greater noise than the first generation cascade stages but offer much greater gain in a more compact space.

NVG Goggles in Aircraft

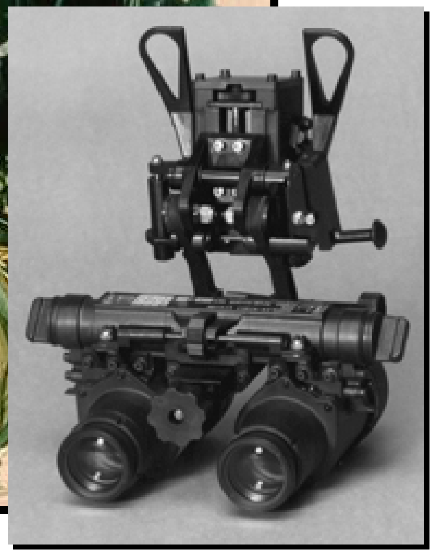
Modern NVG (US 'NVIS') make use of third or fourth generation image intensifiers. These employ micro-channel plates with more sensitive photo-cathode materials.

NVG have been used in aircraft for ~35 years.

- Two Goggle Types;
  - Type I (direct view)
  - Type II (projected)
- Three Classes;
  - Class A (625nm),
  - Class B (650nm)
  - Class C (green leak)

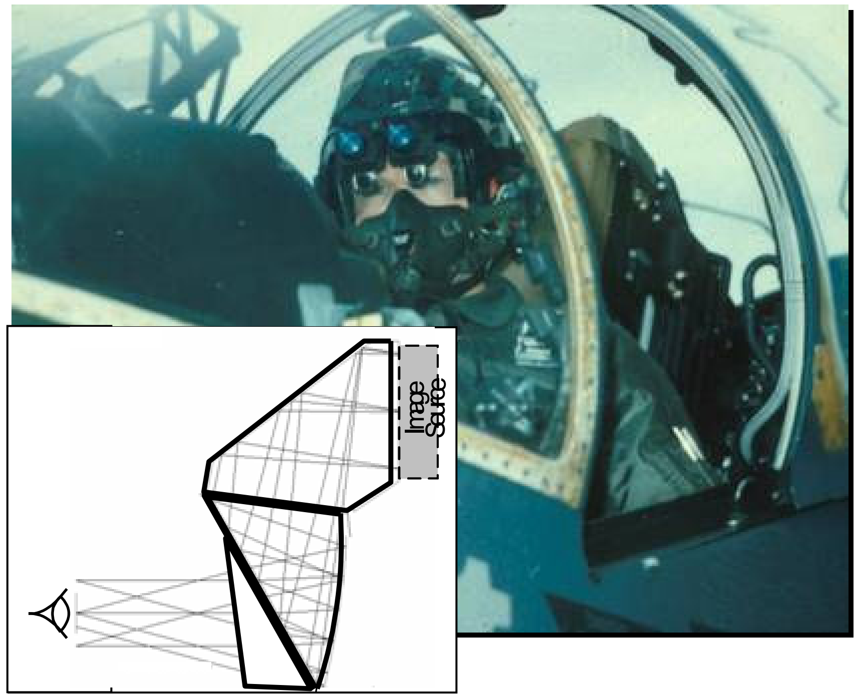
NVG Configurations – Type I; Direct View

- Pilot sees outside world only through NVgs.
  - Field of view is NVG FoV
  - Resolution is NVG resolution
  - Spectrum is NVG IR spectrum
- HUD image is not seen unless a special ‘green’- leak filter is used.
  - Then HUD + outside world is seen in one colour (the NVG phosphor colour, usually P1 green)
  - and at one focal length.
- Cockpit instruments are not seen by the NVGs,
  - If viewed through NVG will be dim, and unfocussed
  - Seen by looking ‘below’ NVG eyepiece.



NVG Configurations – Type II; Projected

- Pilot sees combined image of: -
  - outside world with unaided eye
  - HUD with unaided eye
  - NVG IR spectrum of outside world.
- HUD image may include FLIR video
- HUD FLIR + NVG IR image
  - Sensors at different spectrum wavelengths
  - FLIR polarity (black hot –white hot)
  - Unlikely to be spatially harmonised / registered
  - Both images are bright and green, but different spectra (P1 and P53 green)
- <u>Both images together are confusing, therefore need some mechanism to separate the images.</u>
- (As before, cockpit instruments are not seen by the NVGs)



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