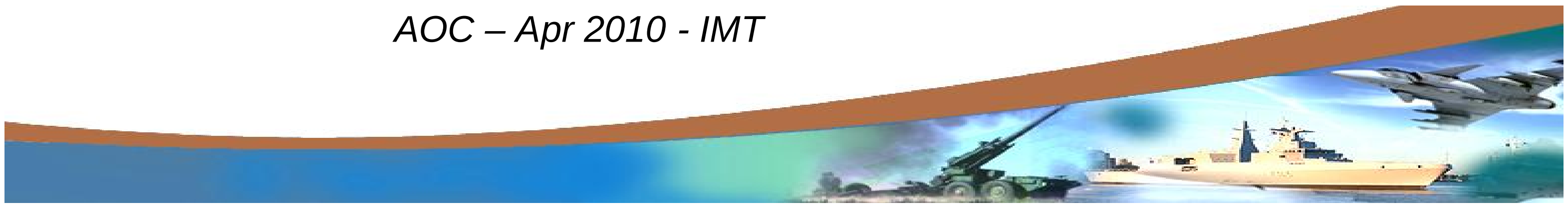
NAVAL ELECTRO-OPTICS & ELECTRONIC WARFARE

by

W H Gunter

IMT

AOC – Apr 2010 - IMT



ARMSCOR DEFENCE INSTITUTES

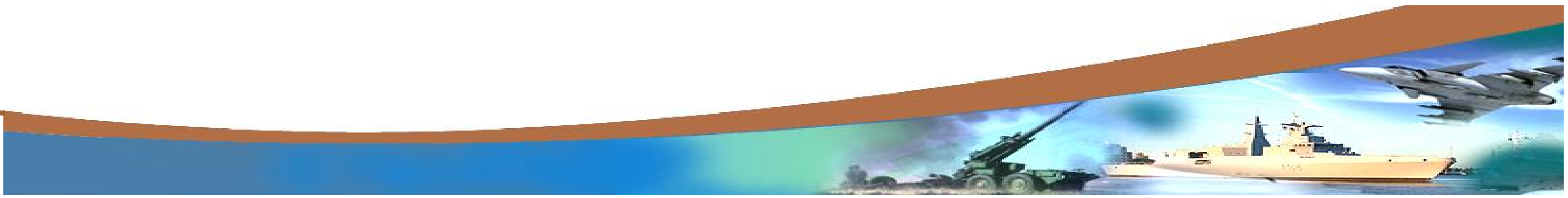
PRESENTATION OVERVIEW

- Introduction
- Trends & Status in Naval EO Technology
- Naval Electro-Optic EW

INTRODUCTION

Electro-Optics is the group of systems that convert photons to electrons operating in the wavelength region from 0.2 to 14 μm (UV to LWIR).

Electronic Warfare refers to any action involving the use of the electro-magnetic spectrum or directed energy to control the spectrum, attack an enemy, or impede enemy assaults via the spectrum. The purpose of electronic warfare is to deny the opponent the advantage of, and ensure friendly unimpeded access to, the EM spectrum.



EO Technology Status & Trends

Passive Day-Time Sensors (/1)

The current mainstream solid-state imaging sensor technology used for day-time video is CCD (charge-coupled device) and CMOS (complementary metal-oxide semiconductor).

The most important system characteristics for image sensor performance are responsivity (or sensitivity), dynamic range, signal-to-noise, uniformity, size, power consumption, reliability and cost.

For responsivity (signal produced/unit incident optical energy i.e. sensitivity), reliability and cost the two technologies are similar.

For dynamic range, uniformity and shuttering CCD is superior, while for windowing, read-out speed, size and anti-blooming CMOS is better.

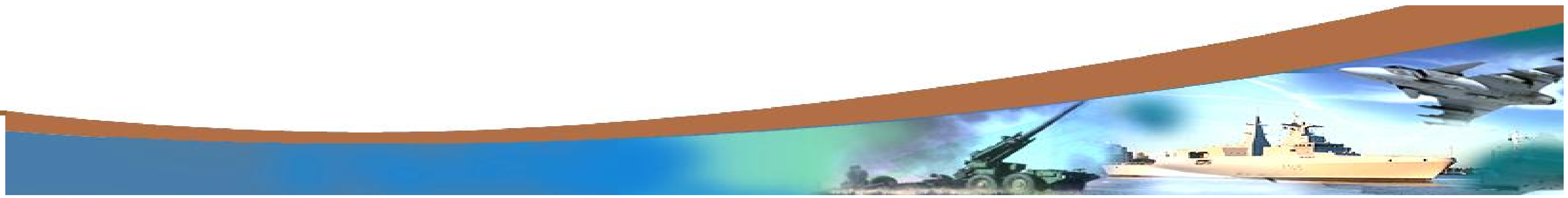
EO Technology Status & Trends

Passive Day-Time Sensors (/2)

CMOS imagers offer superior integration, power dissipation and system size at the expense of image quality (particularly in low light) and flexibility. This is the technology of choice for high-volume, space constrained applications where image quality requirements are lower.

CCDs offer superior image quality and flexibility at the expense of system size. They remain the most suitable technology for high-end imaging applications, such as digital photography, broadcast television, high-performance industrial imaging, and most scientific, medical and military applications.

Over time, CMOS imagers should be able to advance into higher-performance applications. For the moment, CCDs and CMOS remain complementary technologies - one can do things uniquely that the other cannot. However, CCD is currently the more mature technology and is in most respects the equal of CMOS.



EO Technology Status & Trends

Passive Day-Time Sensors (/3)

Trends

The most important trend is the drive towards higher resolution (i.e. multi mega-pixel) and smaller format CCD/CMOS sensor chips. This impacts mostly on the sensitivity, resolution and system cost. With more detector elements the spatial resolution increases, but with smaller detector sizes the sensitivity goes down (signal-to-noise ratio scales with the square root of the sensor area) and the demand for higher quality optics goes up. Currently, sensors that can deliver HDTV resolution (e.g. 1920x1080p) sits at the lower end of the resolution scale which goes up to sensor densities of 20 Mega-pixels and more.

Video Interface Protocols

With the ever increasing detector element densities the demand for ever increasing video data transfer rates have lead to new developments in video interface standards. Currently the important competing video interface protocols are IEEE 1394 or Firewire (and 1394b, the fibre optic version), CameraLink, USB 2 and Giga-bit Ethernet (GigE).

Passive Day-Time Sensors (/4)

Video Interface Protocols

GigE is a serial network standard that offers attractive advantages including high bandwidth, long cable lengths, and a low cost interface that is widely used in standard computer networking hardware. GigE also supports compressed and uncompressed data, full multicast support and scalability and offers a natural upgrade path to the next generation which is 10 GigE.

EO Technology Status & Trends

Passive Night-Time Sensors (/1)

Solid state imaging systems used for night-time surveillance operate on one of two principals; detection of reflected light or detection of emitted thermal/heat energy. Thermal imaging systems performs equally well during day- and night-time and will be addressed under 24-hour surveillance systems.
The systems under discussion here are therefore those low-light levels systems that detect reflected light from the scene.

The mainstream and new low-light level (LLL) technology that is used for night-time surveillance involves image intensifiers, specialized CCDs (e.g. EMCCD, deep depletion back illuminated CCD) and specialized CMOS sensors (e.g. germanium -enhanced), NIR/SWIR InGaAs sensors (hybridized with CMOS readouts) and active illumination NIR systems (mostly CCD).

Passive Night-Time Sensors (/2)

Image Intensifiers

The latest development in image intensifiers is the co-called generation “4th” tubes (not officially recognised as a new generation) that use the same photo-cathode as generation 3 tubes but with an auto-gating capability and removal/thinning of the ion barrier film that protects the tube and extends the tube life.

For direct viewing by humans, intensifier tubes are normally integrated into night vision devices (NVDs) like night vision goggles (NVGs) or rifle scopes.

One interesting new NVD development is the Panoramic Night Vision Goggle (PNVG), which doubles the user’s field-of-view to around 95º by using four 16 mm image intensifier tubes.

EO Technology Status & Trends

Passive Night-Time Sensors (/3)

EMCCD

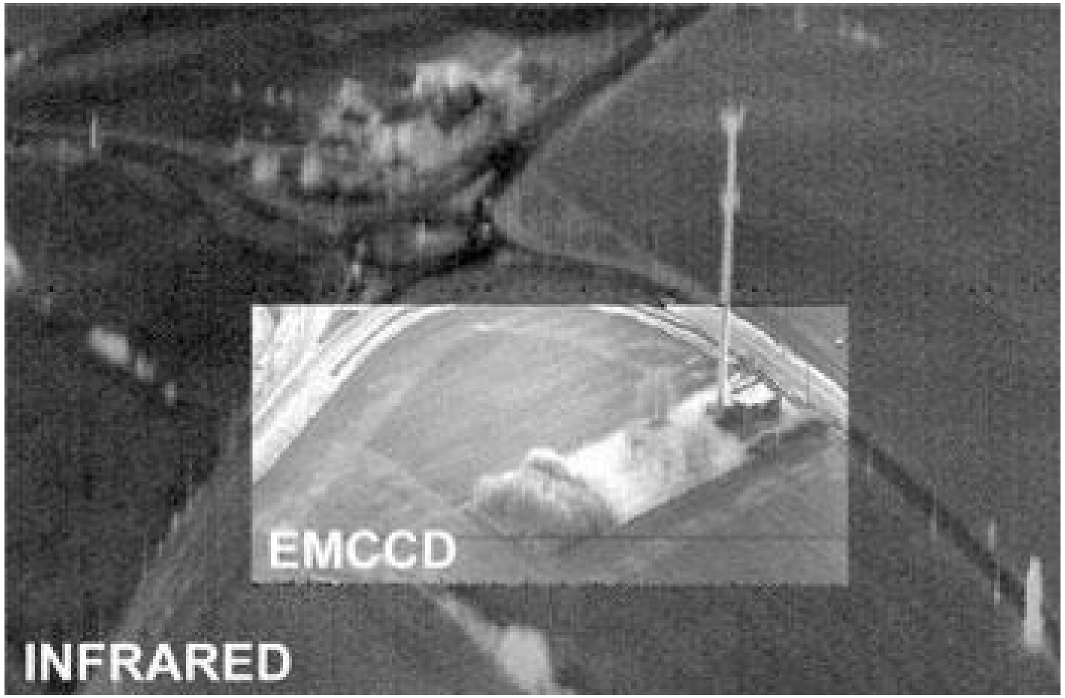
The electron-multiplying CCD (or EMCCD, which is also also known as the L3Vision or Impactron CCD) is a modification of the normal CCD to reduce the readout noise.

EMCCDs show a similar sensitivity to ICCDs. Because of the lower costs and the somewhat better resolution EMCCDs are capable of replacing ICCDs in many applications. ICCDs still have the advantage that they can be gated very fast and thus are useful in applications like range-gated imaging. EMCCD cameras need a cooling system to cool the chip down to temperatures around 170 K.

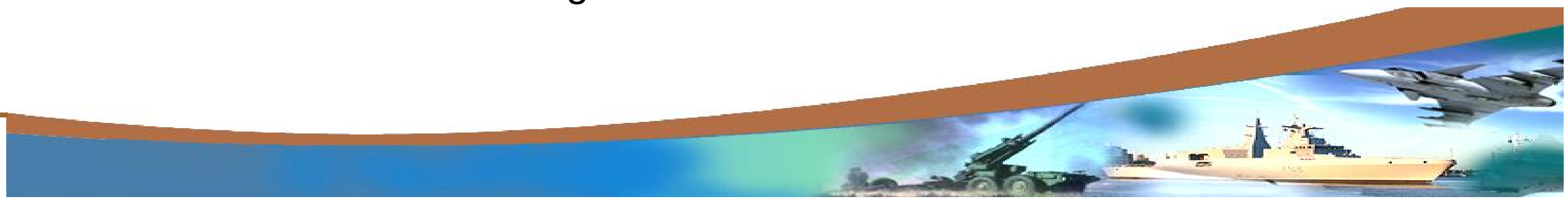
A composite infrared and EMCCD image example is shown below (captured under starlight conditions).

EO Technology Status & Trends

Passive Night-Time Sensors (/4)



Example fused image comparing EMCCD with infrared under starlight conditions



Passive Night-Time Sensors (/5)

Ge - Enhanced CMOS

This technology enhances the long wavelength response of a standard CMOS image sensor through the addition of germanium, enabling it to detect naturally occurring light from the Earth's upper atmosphere emitted in the SWIR band (1.2 – 1.8 μm).

Examples of moonless night-time SWIR images using Ge-enhanced CMOS detectors

Passive Night-Time Sensors (/6)

Cooled Deep Depleted Back Illuminated CCD

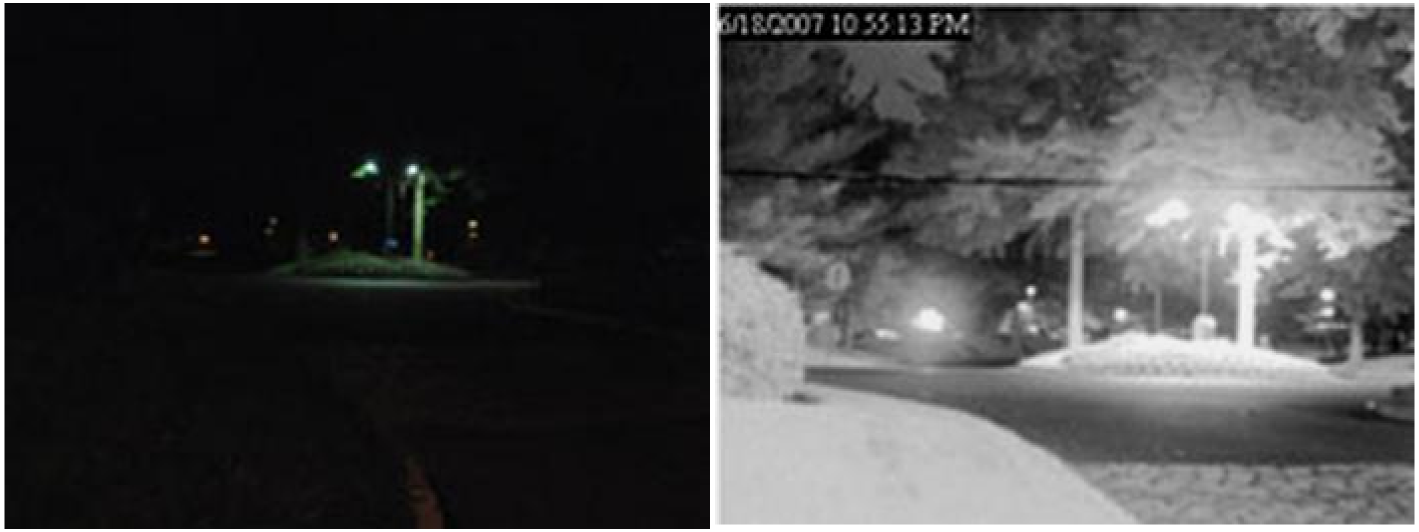
This technology offers high NIR sensitivity and by cooling the CCD (TE to -90ºC) the dark current is reduced to very low levels (~ 0.02 e^-/p/s) allowing operation at VLLL. These sensors are expanding the frontiers of lowlight NIR imaging below 1100 nm.

NIR/SWIR InGaAs

Large-format InGaAs arrays have been developed with near quantum noise-limited performance and high sensitivity that can operate under starlight-only conditions. The spectral response of these sensors include many lasers operating in the NIR and SWIR band.

Passive Night-Time Sensors (/7)

NIR/SWIR InGaAs



A parking lot at night with a normal VIS (left) and special InGaAs SWIR camera (right).

EO Technology Status & Trends

Passive 24-h Sensors (/1)

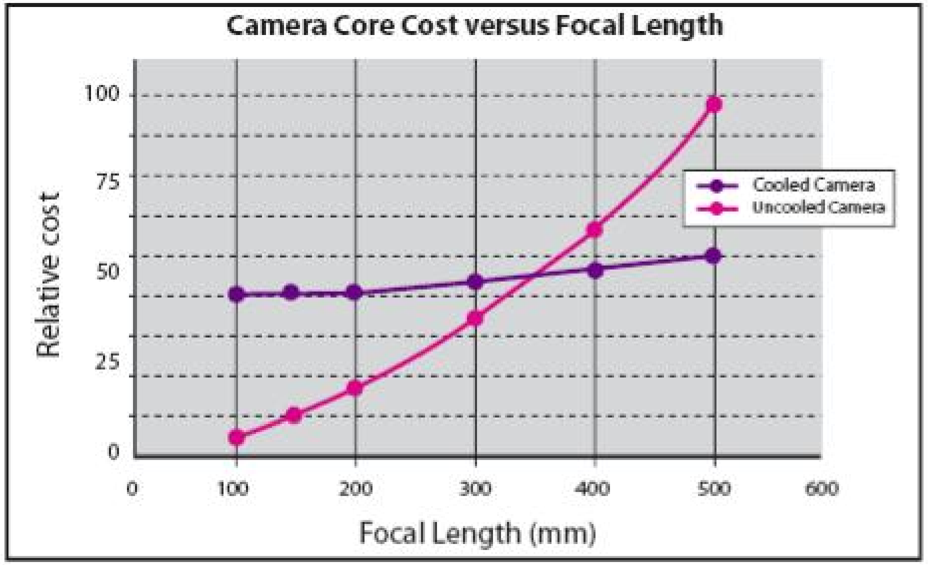
There are two main classes of thermal infrared detectors, namely cooled and un-cooled. Cooled detectors rely on a cryogenic cooling mechanism to achieve very high sensitivity. MCT and InSb are the most popular materials.

Un-cooled infrared detectors have become an alternative and are much more commonly used in many commercial, industrial and nowadays also military IR camera products. They enjoy substantial advantages in maintainability as well as a significant reduction in size, complexity and cost.

The downside is that uncooled IR sensitivity is not yet considered sufficient for all military applications. Where long range is not the overriding requirement, uncooled IR is increasingly being applied. The main disadvantage of using uncooled systems for long range application is the fact that big aperture optics are required to keep the sensitivity up. This result in huge cost as shown in the figure below.

EO Technology Status & Trends

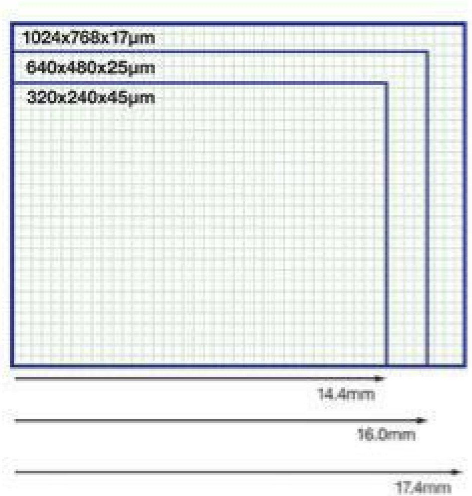
Passive 24-h Sensors (/2)



Relative camera cost of cooled and un-cooled IR systems as function of lens focal length

Passive 24-h Sensors (/3)

Micro-bolometer detectors are mainly used for un-cooled systems and the two most common micro-bolometer detector materials are amorphous silicon (a-Si) and vanadium oxide (VOx). It appears that a-Si is the better technology due to superior detector uniformity, sensitivity and fast response time (30 Hz no problem).



IR image captured with 1024x768 un-cooled a-Si FPA (ULIS) and illustration of nearly constant sensor size even as array density increase (right).

EO Technology Status & Trends

Passive 24-h Sensors (/4)

IRST Systems

Infrared Search and Track systems produces a 360º panoramic image around the observing platform. Different types of systems are available covering the application spectrum from very accurate, extreme sensitive, cooled dual-band, long-range ASM detection systems to un-cooled single-band (staring), close-in detection systems. Good examples of the expensive high-spec and low cost un-cooled IRSTs are respectively the Thales Sirius and Gatekeeper system.

Gatekeeper is based on staring cameras, providing a high frame rate 360º picture. The basic configuration consists of up to four sensor heads, a processing platform and an optional user console. Each sensor head consists of 3 un-cooled IR cameras and 3 colour TV cameras covering a sector of 120°. The IR camera detector is a 320x240 element un-cooled 8-12 µm bolometer with a 48x36º FOV (HxV). The daylight TV camera is a colour 1600x1200 element CCD detector with the same FOV. The high-resolution TV cameras improve classification during daytime.

Passive 24-h Sensors (/5)

Thales Gatekeeper System

EO EW

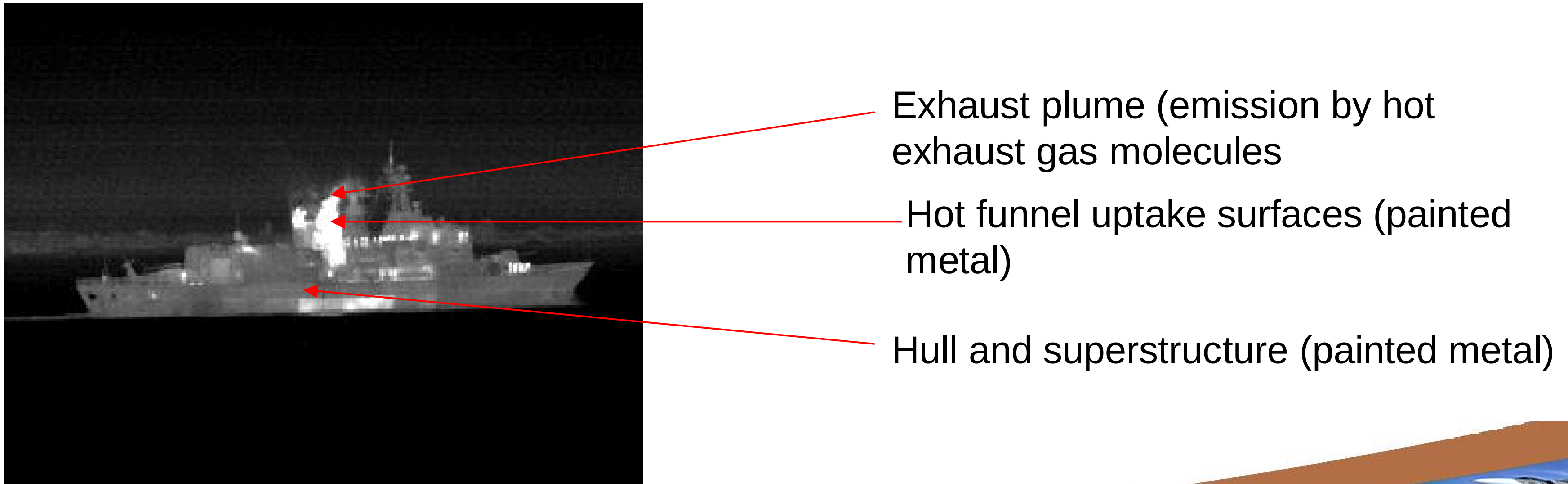
Important Threats

§ Missiles

- Conventional missile threats (IR ASMs)
- Emerging Asymmetrical Missile Threats
  - LBR missiles (difficult to jam)
  - SL SAMs (e.g. lock onto sunlight reflections from bridge windows)

§ Laser Guided Bombs

Typical Ship Infrared Image



EO EW

Important IRCMs

§ **1. Infrared Signature Suppression (IRSS)**

- Funnel Surface cooling/screening (optical blocking). Can reduce MWIR/LWIR signature by more than 90% & 70% resp.

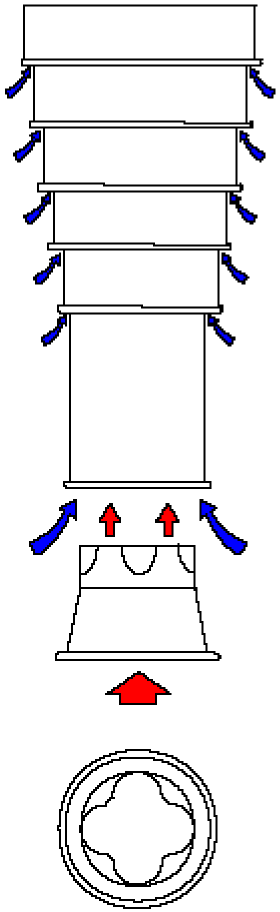
- Exhaust Gas Cooling (water spray injection). Can reduce EGT to below 100 ºC at exhaust exit.

- Hull/superstructure cooling (water spray/wash). Can be very effective during high solar loading conditions.

- Surface material (paint) emissivity control (e.g. LSAPs, LEPs). LSAP can reduce IR signature by ~ 40% during high solar loading conditions for aerial observers.

EO EW

Example system: Funnel surface/exhaust gas cooling & cavity screening
WR Davis Engineering “DRES” BALL system.

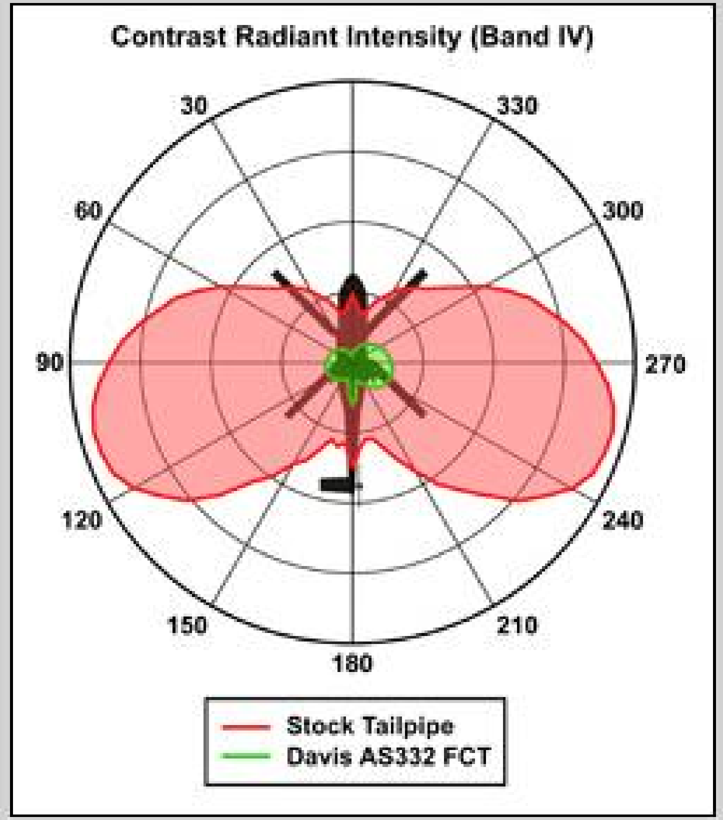


- Ambient air & fan assisted cooling of hot gases
- Optical block that prevents looking down into the exhaust cavity
- Reduction in MWIR signature >90%
- Reduction in LWIR signature >70%
- Funnel surfaces < 25ºC above ambient
- Exhaust gas temperature <250ºC

EO EW

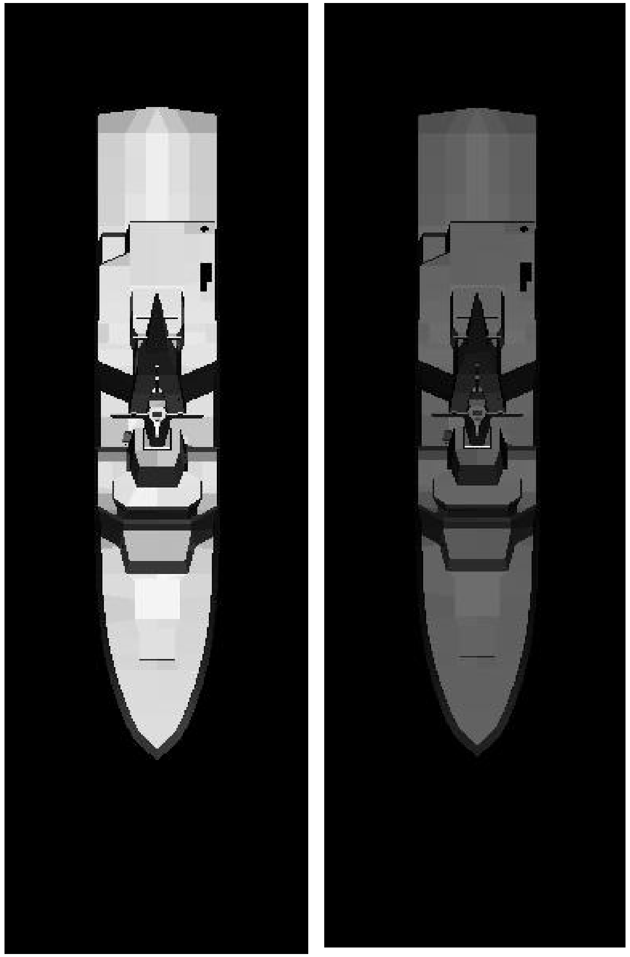
Example system: WR Davis Helicopter Suppressor System (Super Puma)

The AS-332 Film Cooled Tailpipe (FCT) redirects the exhaust gases to the aft of the aircraft via a bent ejector. The serpentine shape of the tailpipe provides a full optical block of the ejector The device is supported by a structural frame which is installed within the aft engine cowling. The AS-332 FCT is FAA certified and is in operation.



EO EW

Low Solar Absorption Paint (LSAP)

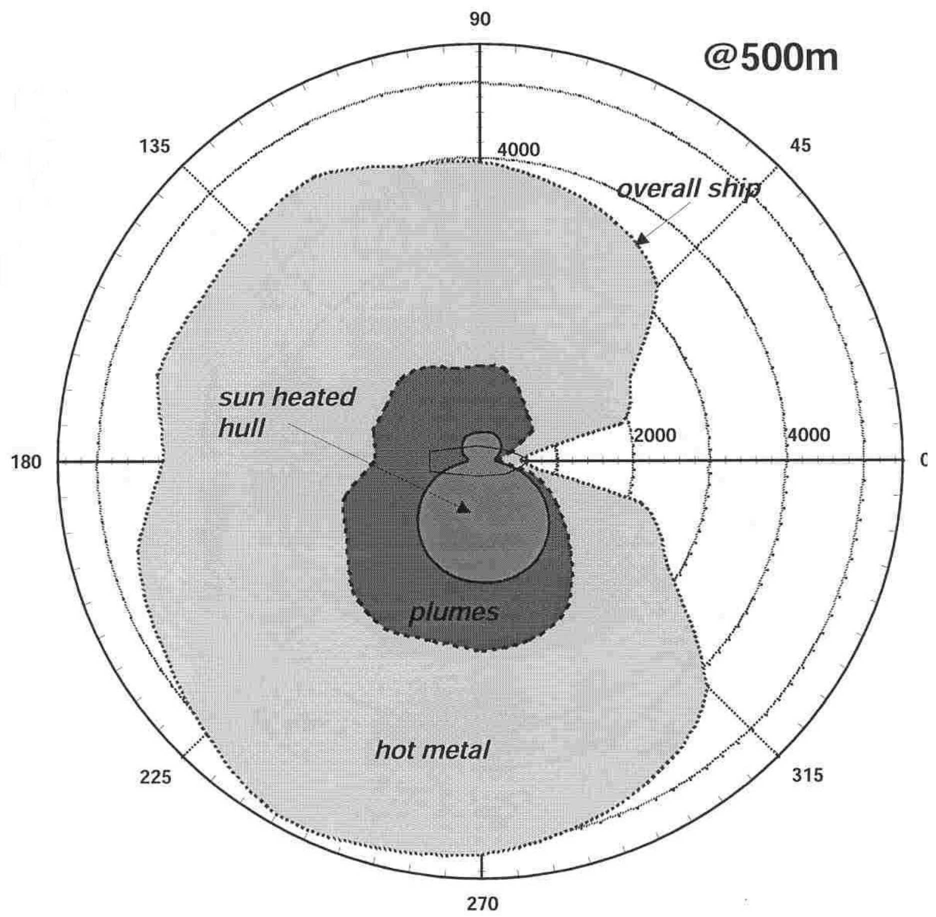


MWIR Signature Simulation – Frigate Size Vessel

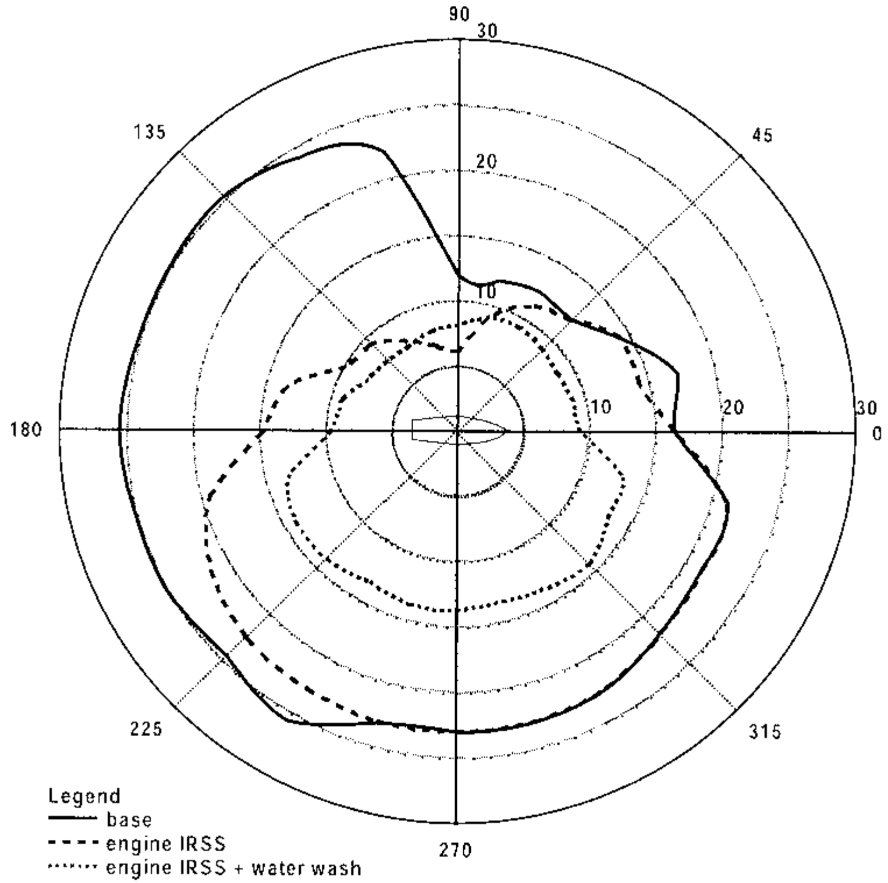
- ~ 40% reduction in MWIR intensity
- Max solar loading conditions
- 45º down-look angle onto ship

EO EW

Ship IR Signature Polar Plot



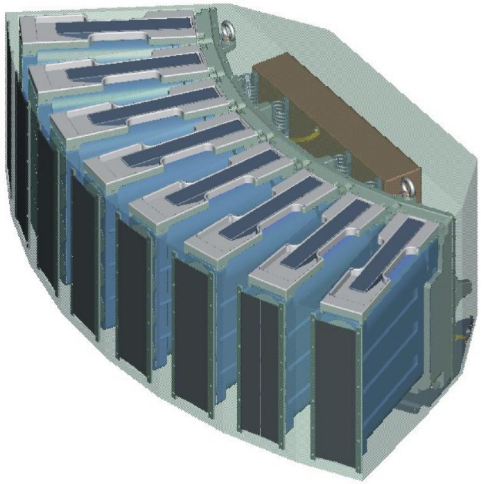
IR Missile LO Polar Plot

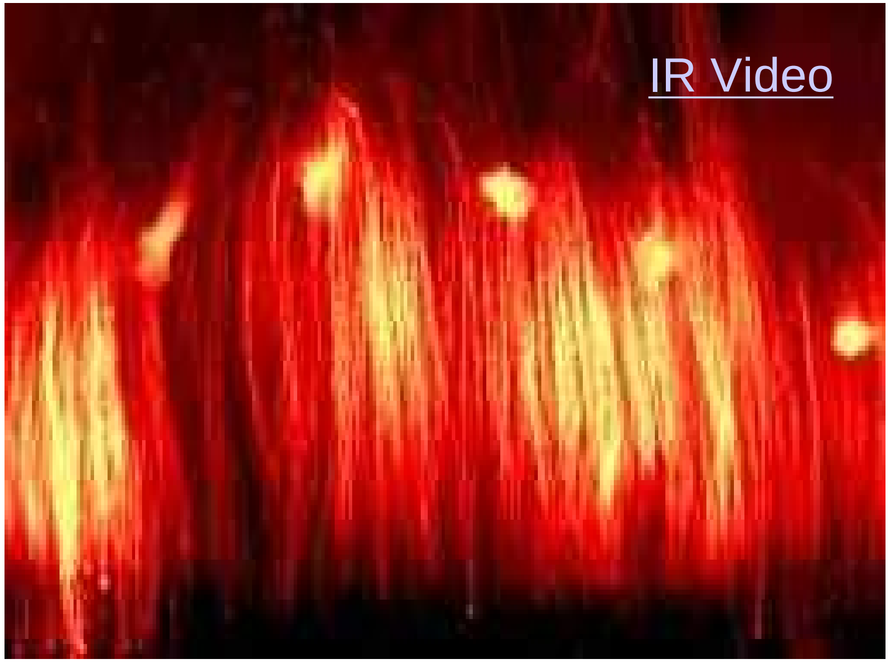


Important IRCMs

§ 2. Flare Decoys

MASS (Multi-Ammunition Softkill System - Rheinmetall) consists of a trainable launcher with 8 magazines and 32 OMNI TRAP rounds. Claimed performance: effective against seekers from UV to LWIR, “walk-off” principle, also effective against LBR missiles.





IR Video

Important IRCMs

§ **Flare Decoys**

TALOS (Kilgore part of Chemring) is a multi-burst walk-off IR seduction decoy. Five sub-munitions are sequentially launched to create the walk-off pattern. The resulting clouds of burning red phosphorous leaves and emissive smoke provide a IR signal with good spectral ratios. Claimed good features are: Fast rise time, long duration, high IR intensity, large area, coverage in 3-5 μm & 8-14 μm bands, “walk-off”, effective against hotspot & IIR (TC) seekers.

Important IRCMs

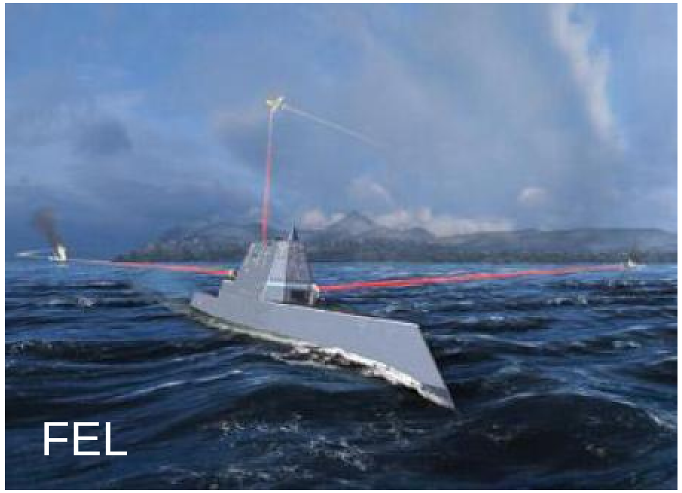
§ **IR Flare Decoys Trends**

- Large area roughly resembling the shape of a ship
- Multi-submunition deployment to create “walk-off” pattern
- Long duration (> 40 sec)
- Spectrally balanced (effective against “multi-colour” missiles), simulating ship spectral IR signature
- Correct spatial deployment (low enough to simulate a surface target)
- No large ignition spikes

EO EW

§ **3. Directed Laser CM Systems (DIRCMs) /1**

- Jam, damage or destroy the threat/sensor depending on the laser power.
- US plans to develop a 10 KW class free-electron laser (FEL) for ships (Boeing/Raytheon). Eventually upgrade to 100 kW and Megawatt system. Advantages: all electric laser, running of ship power, tunable in wavelength and power, ultra-fast & precise
- The ATL (advanced tactical laser) is an operational 100 kW chemical laser (COIL) on a C130-Hercules. The laser can destroy targets at 20km from 10 000 ft & operates at 1.3 um. Another advantage is that it will be difficult to prove that this weapon was used to destroy targets. Boeing recently (2009) received a contract for extended user evaluation on the ATL.



EO EW

§3. Directed Laser CM Systems (DIRCMs) /2

Trends

- Tunable lasers (preventing CMs at fixed frequencies)
- LWIR (8-12 um) lasers to counter LWIR FLIR surveillance
- Megawatt lasers on ships might be the future

END