



Technology Work Session for the South African Army; Hosted by the CSIR

Battle Space Awareness and Sensors



Optical Sensors for SA Army Applications

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Outline of presentation

- **SA Army Optical Sensors Challenges**
- **International Optical Sensor Perspective/Trends**
- **Owning the EM spectrum:**
 - **Ultraviolet**
 - **Visible**
 - **Infrared**
 - **Terrahertz**
- **Sensor Support:**
 - **Image Processing**
 - **Optical Displays**
 - **Test and Evaluation**
 - **Cognitive Computing**
- **Recap:**
 - **Risks**
 - **SA Army Applications**

SA Army Optical Sensors Challenges



- Dismounted soldier:
 - Spectrum allocation & management

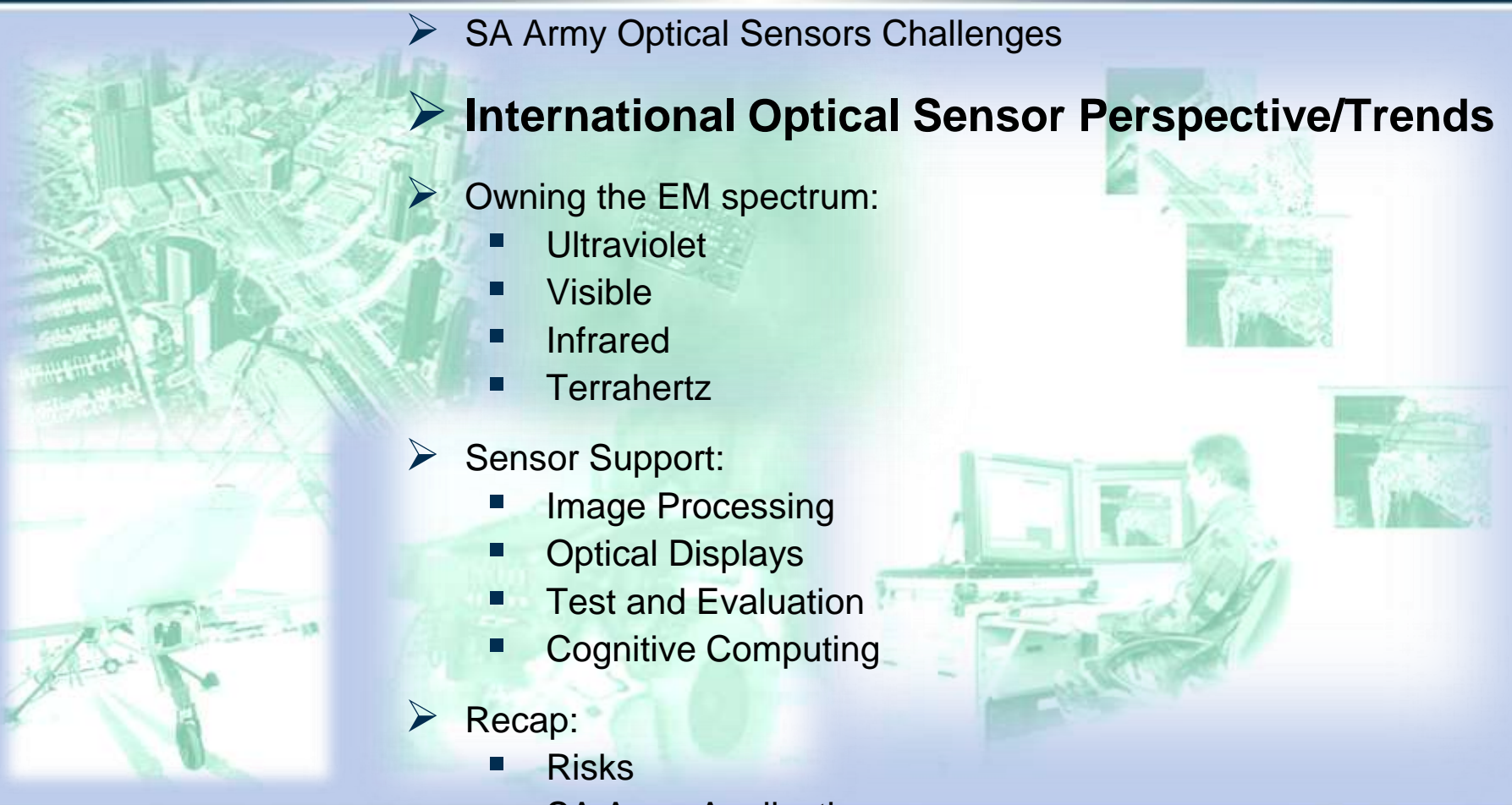
- Integrated Systems Solutions:
 - Limited view in the Urban Battle Space.
 - Validate/integrate use of all available assets.
 - Establish efficacy of the doctrine
 - Command System/Army Headquarters

- Sensor weight versus mobility
- Energy efficient sensing
- Legacy sensors, latent sensors
- System Performance



International Optical Sensor Perspective/Trends

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International Perspective & Trends



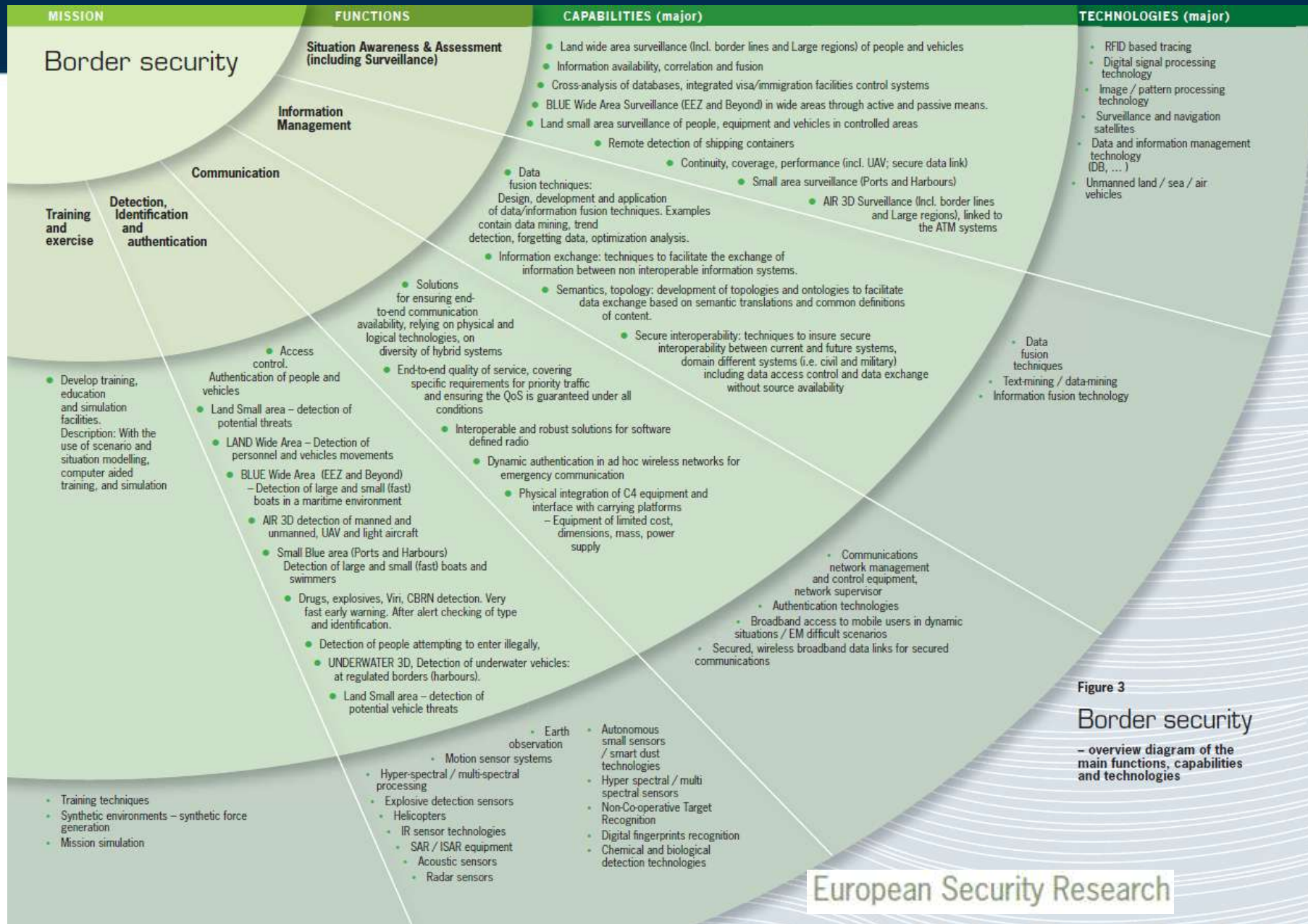
C4ISR

Command, Control, Communications, Computers,
Intelligence, Surveillance and Reconnaissance



International Perspective & Trends

EU



International Perspective & Trends

(Forecast International, 2011)

Biological Threat Detection:

Standoff Systems, Chemical/Smoke&Equipment Defeating Technology, Nuclear Detonation

Night Vision:

Advanced Technology Combat Vehicles, Advanced Technology Airborne Systems, Panoramic Goggles

Range and Wide Angle:

Driver Wide-Angle Indirect View Observation Systems, Long Range Advanced Scout Surveillance System, Integrated Rifle Sights, Enhanced Reconnaissance Infrared Cameras

Display:

Digital High-Definition Video, Integrated Helmet Assembly Subsystems

Counter Measures:

DIRCM, Advanced Threat IRCM, Tactical Aircraft DIRCM

Fire Control:

Advanced Targeting Forward-Looking Infrared, Fire-and-Forget Seekers

Sensor Networks:

Sensor Fusion Technology, Distributed Common Ground Systems, Common Missile Warning System,


Tactical:

Tactical Targeting Network Technology, High Energy Laser Systems, Advanced Responsive Tactically-Effective Imaging

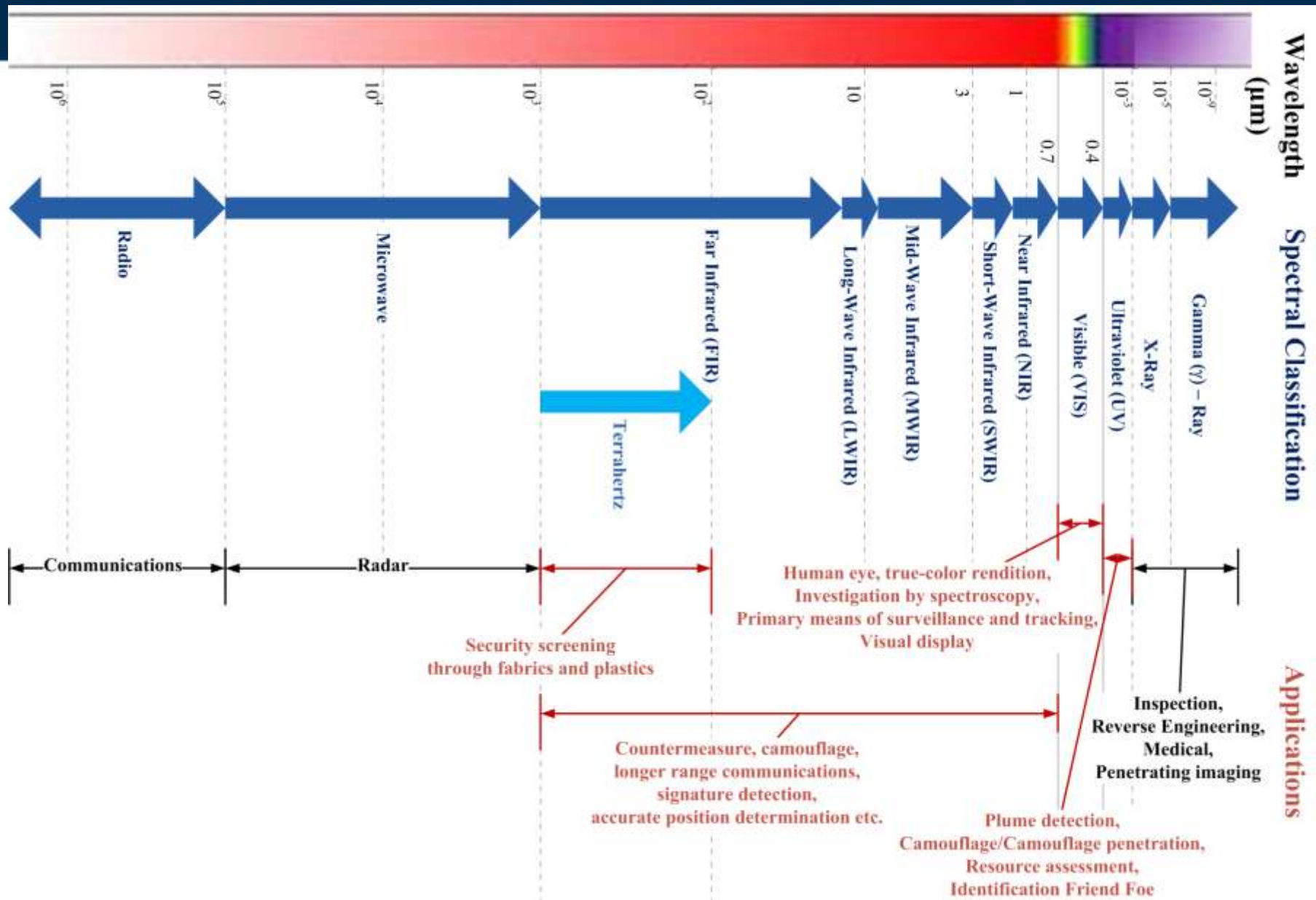
Communications:

Free Space Optical (FSO) Communications, Optical Information Processing

Dedicated test, evaluation and calibration

- 
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The Electromagnetic Spectrum



UV Exploitation



- UV sensors can be effectively used to detect camouflaged land-based deployment of visible personnel or equipment.

UV Exploitation

(UVR Defense Tech, 2010)



- Concealment by UV Reflection Camouflage materials.

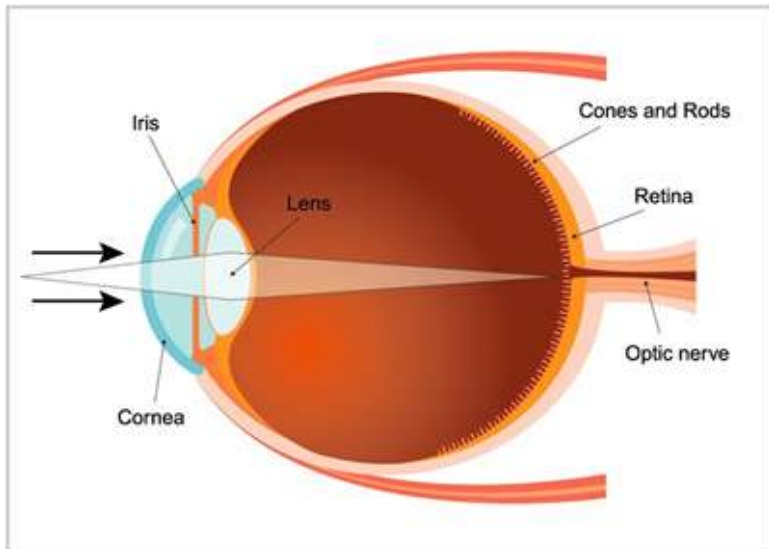
UV Exploitation



➤ Other army applications:

- laser covert communication in urban environments
- equipment and personnel decontamination
- sanitisation
- biosensors for rapid detection of infectious organisms
- water purification
- protective military eyewear.

VIS: The Human Eye



- The human eye is a sophisticated sensor.
- An important instrument possessed by the Army.
- Capability depends on the intensity, contrast and 'colour' mixing of the incoming light.
- There is a limit to the detail one can see with the unaided eye.

VIS Ocular Exploitation



- Depending on light source and duration:
 - Eye strain, tiredness and headaches
 - Poor visual clarity
 - Scotopically rich lighting may reduce fatigue/glare

- Deceive the human eye by camouflage:
 - Increase survivability
 - Decrease Probability of Detection
 - Identify Friend or Foe
 - Thermo-chromic materials

- Laser Dazzling:
 - escalation of force option
 - tactical: temporarily flash blind
 - vulnerability to accidental and malicious exposure



VIS Ocular Exploitation

- Human visual cognitive system is opportunistic:
 - take clues from environment for decision-making
- Human eye is easy to fool:
 - camera systems (with human observing a display) is more difficult to fool



VIS+ Long Range Surveillance

- Soldiers need to acquire information about targets beyond the immediate environment
- Enablers for the eye to “see” things that would otherwise be impossible

Cyclone daytime surveillance, 13km





- High Resolution Digital Video
- 4000 x 1000 Pixels @ 20 frames/second
- 90° and 360° panorama
- Instantaneous Wide Area Situational Awareness



Challenges

- Manipulation and misuse
- Basic rules of Soldier conduct



- Soldiers need to know that the enemy is watching
- “Just because you delete it, doesn't mean 1,000 people haven't already seen it”

(Capt. Steve Szymanski, February 2012)



➤ Need:

- high-fidelity detection
- minimal false alarm rates
- without adding to already significant soldier combat loads

➤ Trend:

- Brain-Machine Interface
- Composite software/human-in-the-loop system

➤ Application:

- Foreseen to significantly improve soldier situational awareness in a variety of operations, including reconnaissance, force protection surveillance and standard infantry tactical fighting.

➤ Impact:

- Quick alert from control center – DO NOT SHOOT!
- No need to entire volatile zone (send in the robot).
- Can be controlled.
- Can control.



VIS+ Image Intensifiers/Night Vision Devices

- RSA battalion needs to “own the night” for successful border controlling and peace-keeping.
- Enabler: Night vision devices (NVDS).

- NVD possible challenges:
 - Can impede adaptation.
 - Effectiveness degradation by heavy rain, snow, fog or smoke.
 - Uncomfortable to use.
 - Negligent disuse ⇒ increased risks
(leads to poor capability to effectively combat in the night)

- NVD on the plus side:
 - Evolved into light weight optical devices.
 - Becoming more affordable.



VIS+ Image Intensifiers/Night Vision Devices

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- Enabler: Night vision devices (NVDS).

NVD	Characteristics	3 rd Generation: Detection Range
Single Tube Goggles	Weight: 269 – 1700 g Magnification: 1 – 6	Human Detection Starlight: 375m Human Detection Moonlight: 650m Boat Detection Starlight: 800m Boat Detection Moonlight: 1500m
Twin Tube Goggles	Weight: 450 – 2100 g Magnification: 1 – 6	
Helmet mounted/integrated Goggles	Weight: 450 – 2100 g Magnification: 1 – 6	
Day/Night Weapon Sights	Weight: 830 – 2100 g Magnification: 2.5 – 8.5	
Night Weapon Sights	Weight: 850 – 3670 g Magnification: 1 – 6.2	
Night Observation	Weight: 330 – 15900 g Magnification: 1 – 11.6	

VIS+ Image Intensifiers/Night Vision Devices

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<http://www.atncorp.com>



GENERATION 1



GENERATION 2



GENERATION 3

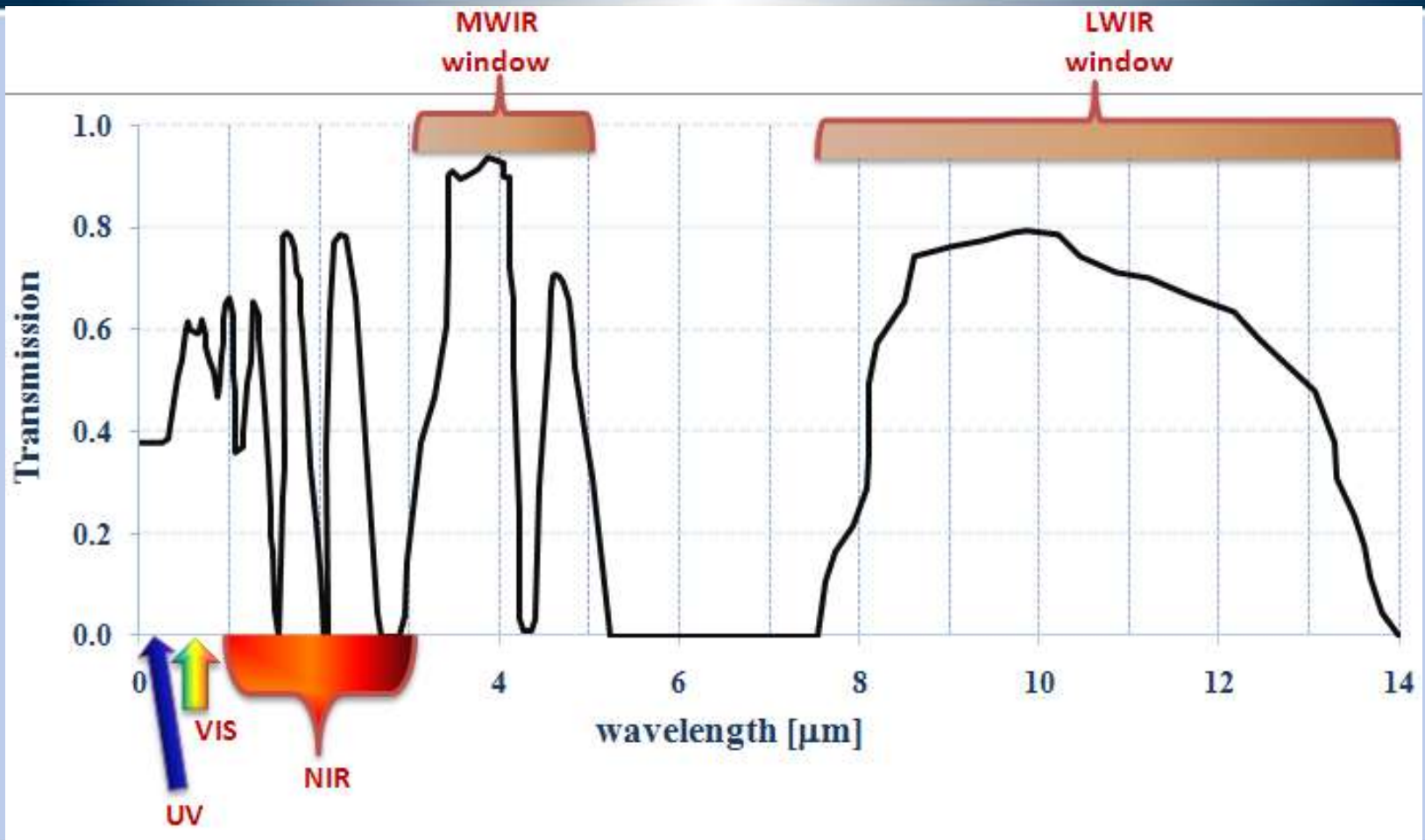


GENERATION 4



- White phosphor technology (WPT™)
- night time scenes appear more natural
- degree of detail
- overall contrast
- depth perception

Infrared (IR)



IR Imaging Systems

- Operate in the NIR, SWIR, MWIR and LWIR atmosphere transmission windows.
- Combinations of detectors and spectral filters define the operating region to conform to a spectral window to maximize sensor performance against the targets and to minimize background contributions.



At night, $\sim 1/4$ phase moon, 65% overcast, minimal night-time light pollution

Source: Night Vision and Electronic Sensor Directorate, 2010

NIR and SWIR Cameras

- Nearly all of the night sky light is in the SWIR band



- Example (sInfraRed, 2011):
 - Nightvision with SWIR XEVA 1.7 320 TE1
 - at midnight
 - partly cloudy
 - few stars
 - no added illumination



- Cameras: light weight, with low power requirement.
- In the absence of natural SWIR light, a covert and eye safe source can be used to “light up” targets.

NIR and SWIR Cameras

VIS

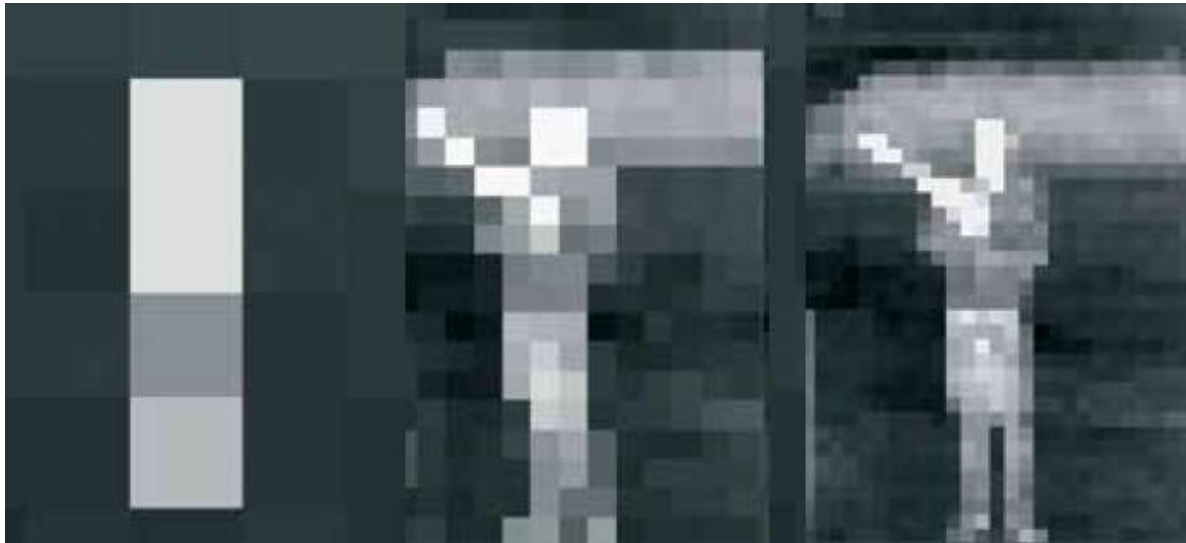
SWIR



MWIR and LWIR Cameras

- Thermal Cameras give Intelligence Surveillance Reconnaissance capabilities to the Army
- Need to be able to “see” thermal emissions.
- Need to “see” through obscurants such as dust, rain, smoke.
- Need to “see” over long and wide ranges.
- Need to know target range for:
 - Detection, Recognition, Identification

FLIR Technical Note, TN_1108_0002_EN



Detection:
Something is there.

Recognition:
A person is there.

Identification:
The person is holding a rifle.

MWIR and LWIR Cameras

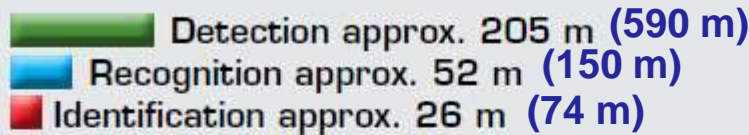
Range performances for SR-, F-, PT-, and outdoor D-Series with 320x240 pixels detector



(Vehicle, 2.3 m)

Detection, Recognition, Identification of Human Target

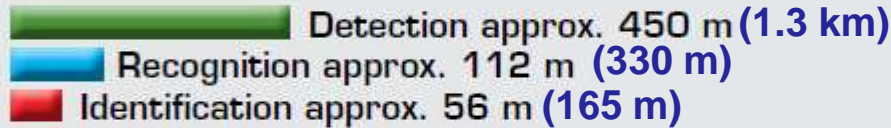
9 mm lens



13 mm lens



19 mm lens



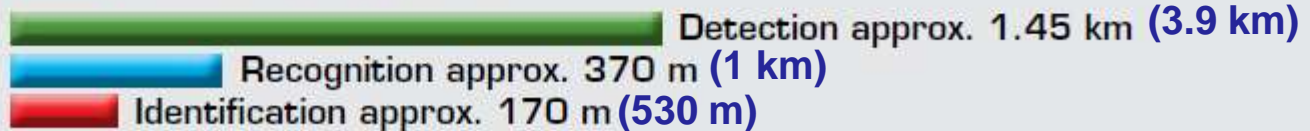
35 mm lens



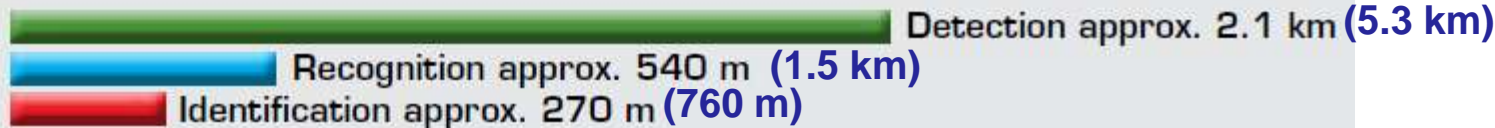
50 mm lens



65 mm lens



100 mm lens



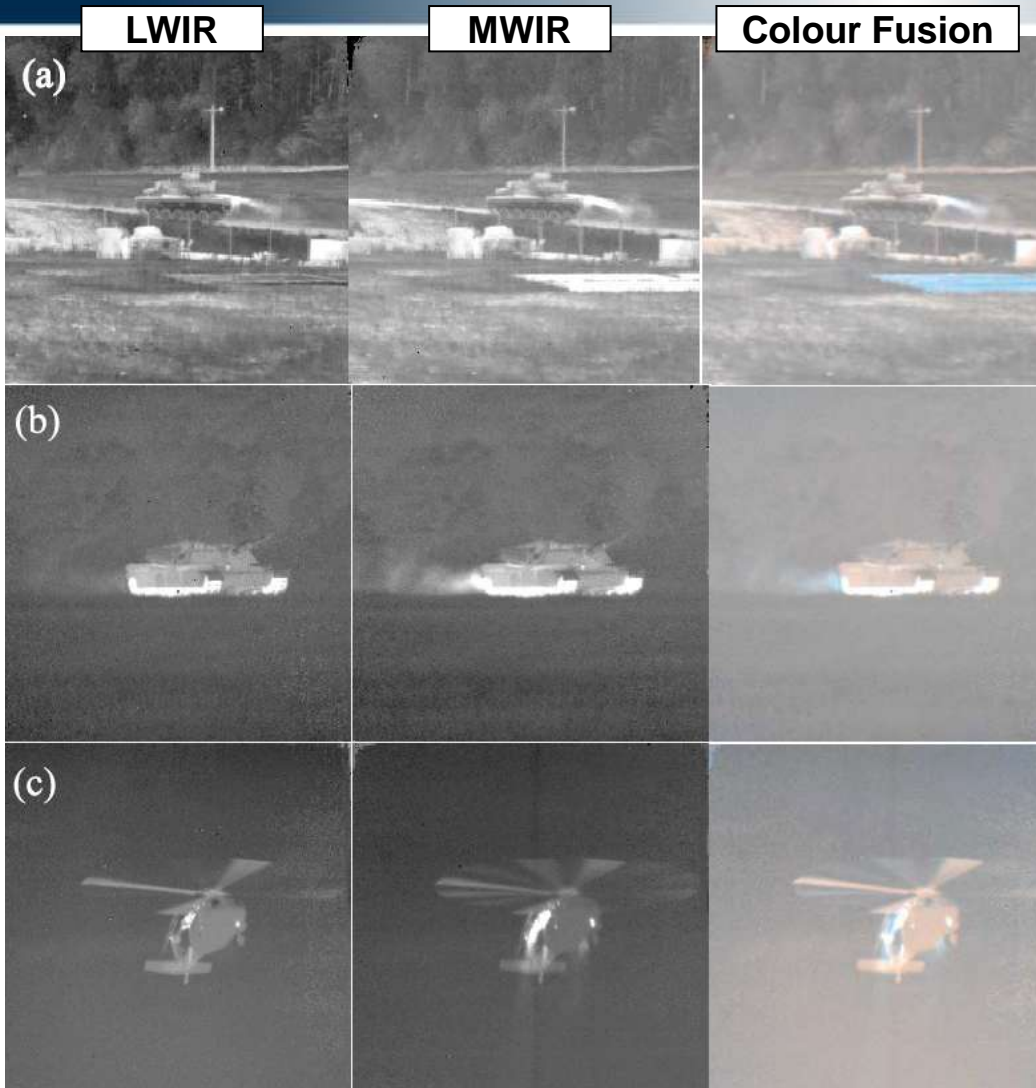
MWIR and LWIR Cameras

Actual range may vary depending on camera set-up, environmental conditions, user experience and type of monitor or display used.

Assumptions:

50 % probability of achieving objective at specified distance given 2°C temperature difference and 0.85 / km atmospheric attenuation factor. A vehicle is 1.25 °C delta T.

MWIR and LWIR Cameras

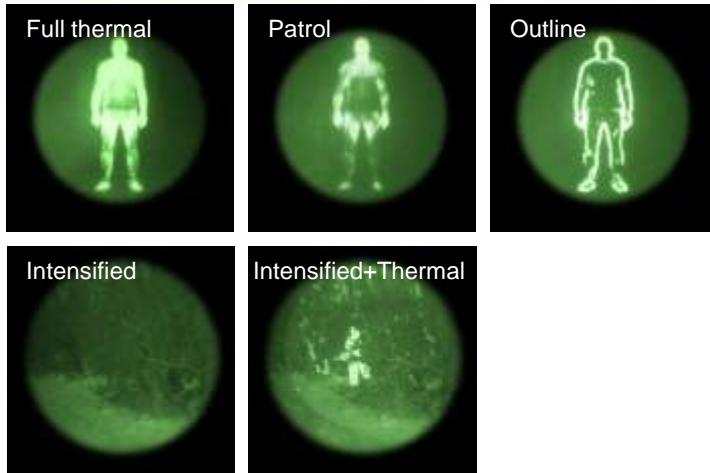


- Images acquired with a dual band QWIP FPA for three targets.
- Exhaust fumes is seen best in the MWIR (blue in the fused image)
- Body of the target is more prominent in the LWIR (red in the fused image)
- Fused systems:
 - enhance situational awareness on the battlefield
 - under diverse conditions

MWIR and LWIR Cameras

The Clip-On Thermal Imager (COTI)

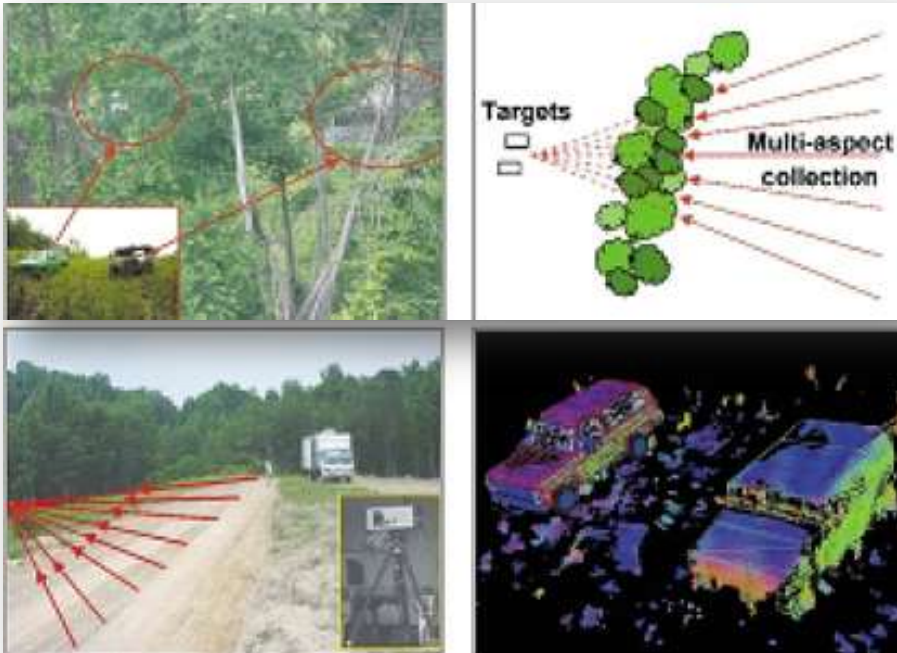
Vectronix AG, TACS-M



- See LWIR signals with existing night-vision devices
- Modular: attach thermal imager directly in front of the existing scope.
- Can “see” residual heat signatures
- Three modes: full thermal, patrol, and outline
- Application examples:
 - border patrol, helping fire fighters “see” in smoke-obscured environments.

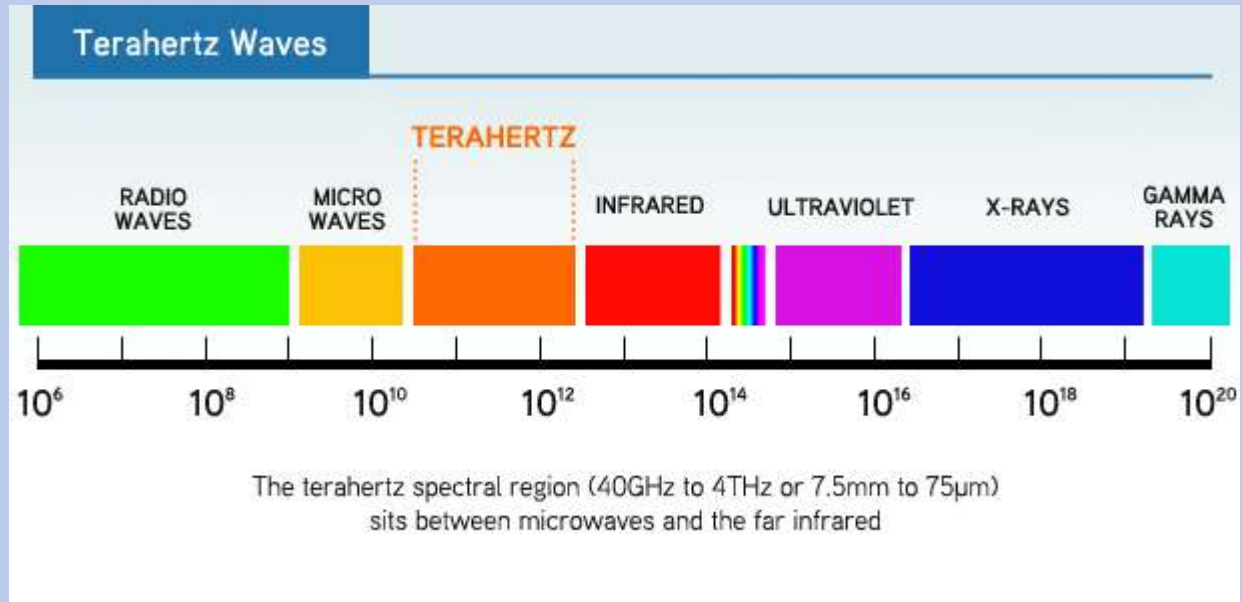
IR Countermeasures

- IR camouflage examples:
 - BAE Systems - ADAPTIV
 - Eltics - Black Fox
- Need sensors to detect against mimicry IR
 - Passive Detectors (laser devices)
- DIRCM, LIDAR

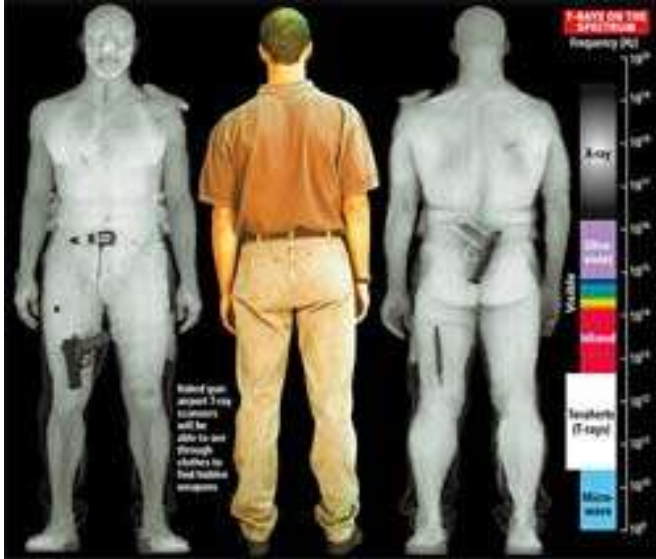


LIDAR: Laser pulses pass through gaps in dense foliage, reflect off the test targets and return to the sensors. The returned pulses are combined to reveal an image of a Humvee and a Chevy Blazer. (DARPA, 2003)

Terahertz



Terahertz (THz)



- Attractive for security applications:
 - materials of interest have very distinct signatures in the THz band
 - passive standoff detection and identification.
 - weapons, explosives, liquids, gels, ceramics, narcotics ...
- Systems can operate by transmission or reflection.
- Strongly absorbed by the Earth's atmosphere, so the range of applications in long-range and open environments may be limited.
- As yet, no official standard regarding exposure to THz radiation.
- No conclusions on risk of potential damage to biological activity

Sensor Support

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Sensor Support

- A sensor is meaningless without support.
- Support includes:
 - Platform.
 - Platform stability.
 - Image processing for rapid visual identification.
 - Displays
 - Test and evaluation for reliability.
 - Multi-sensor information fusion for intelligence.

Sensor Support: Image Processing

- Increasingly important role in defence systems:
 - need for autonomous operation (target detection and tracking)
 - need to make greater use of a diverse range of sophisticated sensors (target ID)
- Images and videos are rarely recorded in ideal conditions and must be processed in real-time to account for factors such as:
 - limited resolution, noise artefacts, camera shake and atmospheric distortion
- Image processing is used to fuse multi-band images
- Image processing is used for rapid target recognition

Sensor Support: Image Processing



Depending on the time of day and line of sight, long range surveillance is also plagued by distortions due to atmospheric turbulence. Digital image de-warping developed by CSIR is applied to correct the scintillation as shown above.

Sensor Support: Test and Evaluation



- Sensor and system characteristics and performance can deviate from specifications.
- Specifications may be incomplete.
- Yet – reliable electro-optic systems remains a primary requirement for all military surveillance applications.
- Quality of the output image is the most important criterion for evaluation of operation.
- Testing of systems against the backdrop of field environments is a very difficult task.
- ARMSCOR, the SANDF designated Government Quality Assurance Authority, is responsible for assuring a comprehensive service in Quality.
- Laboratories with proper measuring systems (and reference targets) are used.




Sensor Support: Cognitive Computing



U.K. Ministry of Defense, 2011

- The modern battlefield is now a network of networks of “data-rich” soldier systems.
- Large volumes of information and data must be fused, and in real-time:
 - ↔ military can achieve effective integration of views on a situation.
 - ↔ quicker response with elimination of errors caused by single element failures.
- Military Cognitive Computing the new generation of machine learning technology:
 - Automatically adjust to new environments and new users
 - Help commanders maintain the battle rhythm
 - Help commanders adapt to new enemy tactics
 - Adapt to evolving situations and priorities
 - Accelerate incorporation of new personnel into command operations
 - Make more effective use of resources.
- The ultimate **goal of a military cognitive computing tool** is to create sets of sophisticated decision support systems that will improve mission efficiency and help **keep observe-orient-decide-act loops faster than the enemy's.**

- 
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Recapping: Risks

- Education and training:
 - Become more technologically adept
 - More effective in the collection, transfer and analysis of information within and between organizations.
 - Understand the performance of each optical sensor
- Test and Evaluation of sensors:
 - assurance of performance
 - Informed decision making on lifetime, repair, replacement.

SPOT CHECKS OF INDIVIDUAL UNITS

Source: C²NVEO, Study on AN/PVS-5 goggle tubes,

UNIT DESIGNATION	UNKNOWN	1ST MARINE BRIGADE	25TH INFANTRY DIVISION
TYPE OF UNIT YEAR	AIR 1979	GROUND 1984	BOTH 1984
TOTAL SYSTEMS IN UNIT	73	125	369
SYSTEMS IN USE	73	33	369
TOTAL TUBES	180	290	930
TUBES IN USE	146	66	792
FAILED TUBES PER YEAR	53	40	138
TOTAL HOURS TUBES USED	143,032	69,498	205,920
MEAN TIME BEFORE TUBE REPAIR	2,699	1,737	1,492

Recapping: Optical Sensors for SA Army Applications

- No one sensor has the complete picture.
- The SA Army can own the EM Spectrum for C4ISR with the suite of modern sensors.
- More so: SA Army can have the tools to recognise/identify and track vehicles, people, and materials amongst clutter during the day and night.
- South Africa has joined the Space Race and as such will need to safe-guard its future space assets.
- Keeping up with technology trends:
 - Builds the SA Army's knowledge of advanced, up-to-date optical solutions.
 - Enables development of countermeasures.
- In-service sensors must undergo routine test and evaluation.
- Prospective procurements must undergo stringent performance evaluation.
- Lesson from Norwegian Youth Camp Attack:
 - **Be aware and ready even if we feel safe.**

Thank You

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