Government Solutions to the Optics of ISR

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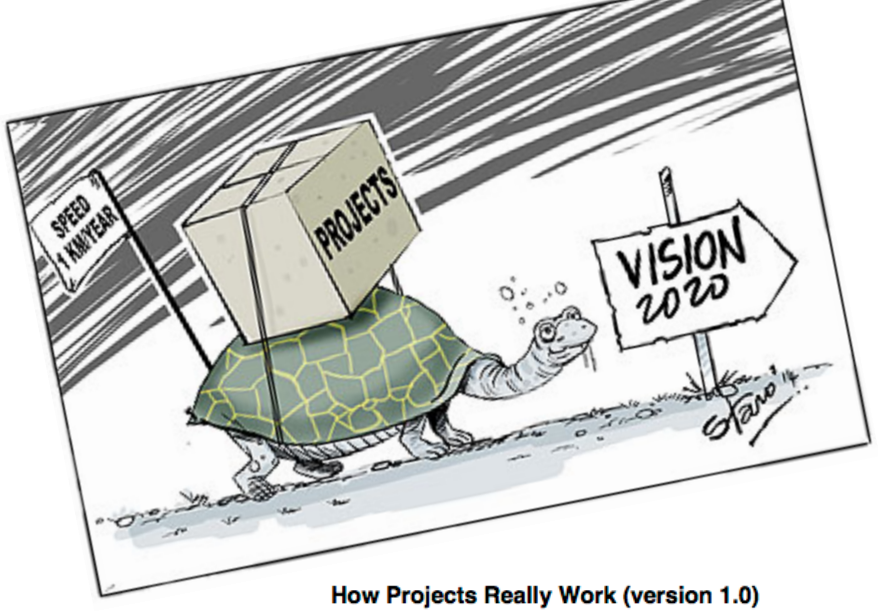
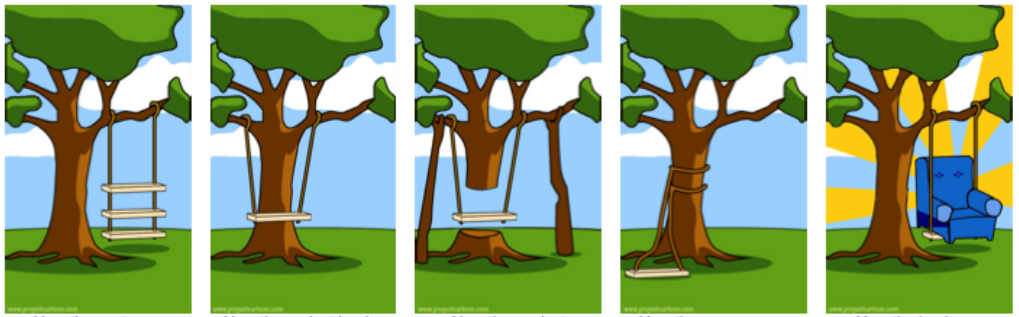
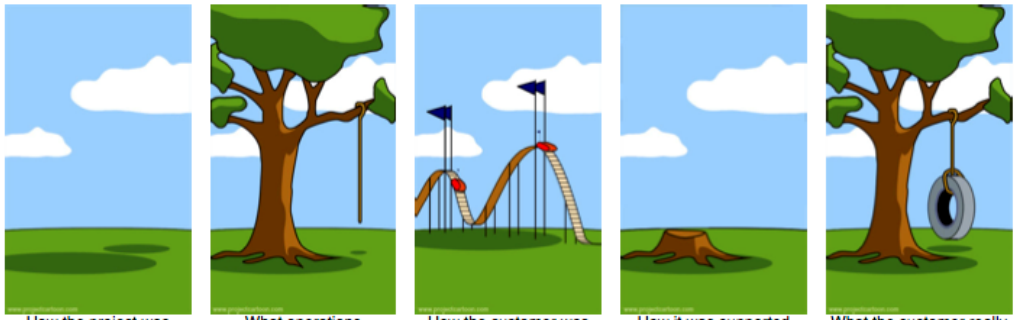
Approved for Public Release



How Projects Really Work (version 1.0)



How the customer explained it | How the project leader understood it | How the analyst designed it | How the programmer wrote it | How the business consultant described it



How the project was documented | What operations installed | How the customer was billed | How it was supported | What the customer really needed

What does Intelligence, Surveillance, and Reconnaissance (ISR) see?

- Modeling and Simulation (militarily speaking)
  - Modeling the Physical (how does it work?)
  - Simulating the Execution (how do you use it?)
- All through the eyes and brain of a human operator
- Military wants to see better and farther

Research on Human Perception

- Visual analytics – field of study that examines the human ability to process visual data, images, and also other interconnected information[1]

- Human brain is trying to derive meaning from a electronically presented image

- Usually interested in objects or people and trying to understand what they are doing (i.e. the “Target”)

1. Keim, D., Andrienko, G., Fekete, J. D., & et al. (2008). Visual analytics: definition, process, and challenges. In J. S.-D. A. Kerren, Information visualization - human-centered issues and perspectives (Vol. 4950, pp. 154-175). Berlin: Springer.

Target

- According to Joint Publication 3-60 "Joint Targeting," there are 5 categories of characteristics by which targets are detected:
  1. Physical Characteristics – shape, size, number, dispersion, EMS signatures, etc.
  2. Functional Characteristics – what it is doing in the environment? Is it normal? Status (75% functional?)
  3. Cognitive Characteristics – how target thinks, exercises control functions, processes information
  4. Environmental Characteristics – environments effect upon the target – like weather, proximity to noncombatants, etc.
  5. Time Sensitivity – is it doing something that requires immediate action? Like attacking friendly forces?

Target

What can be replicated in a simulation or by a model? Everything else is very subjective and depends on the human brain

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Target Task Performance (TTP) Metric

- Within the US Army's sensor performance models – TTP metric is used to predict task performance of detecting and identifying a specific target[2,3]

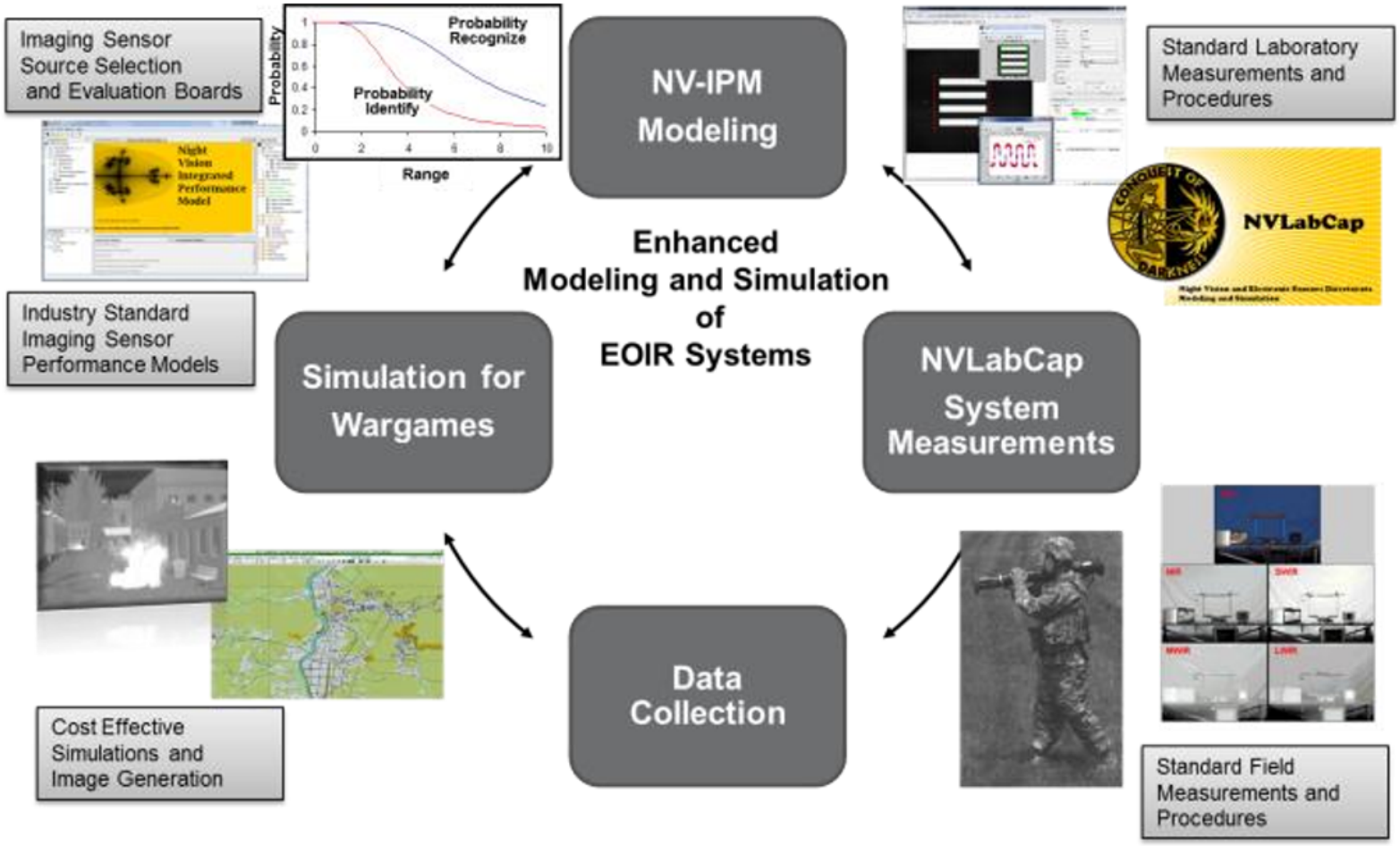
$$\mathrm{TTP}_x = \int_{\xi_{\mathrm{cut,on}}}^{\xi_{\mathrm{cut,off}}} \sqrt{\frac{C_{\mathrm{tgt}}}{\mathrm{CTF}_{\mathrm{sys}}(\xi)}}\, d\xi, \quad \Rightarrow \quad P(R) = \left(\frac{V(R)}{V_{50}}\right)^{1.5} \Big/ \left\{1 + \left[\frac{V(R)}{V_{50}}\right]^{1.5}\right\},$$

- Determined by experiments in which operators look at screens

- Used to create Receiver Operator Characteristics (ROC) curves for every sensor in inventory (and contenders)

2. Preece, B. L., Olson, J. T., Reynolds, J. P., Fanning, J. D., & Haefner, D. P. (2014). Human vision noise model validation for the U.S. Army sensor performance metric. Optical Engineering, 53(6).
3. Vollmerhausen, R. H., Driggers, R. G., & Wilson, D. L. (2008). Predicting range performance of sampled imagers by treating aliased signal as target-dependent noise. *Journal of Optical Society of American Association, 25*(8), 2055-2065.

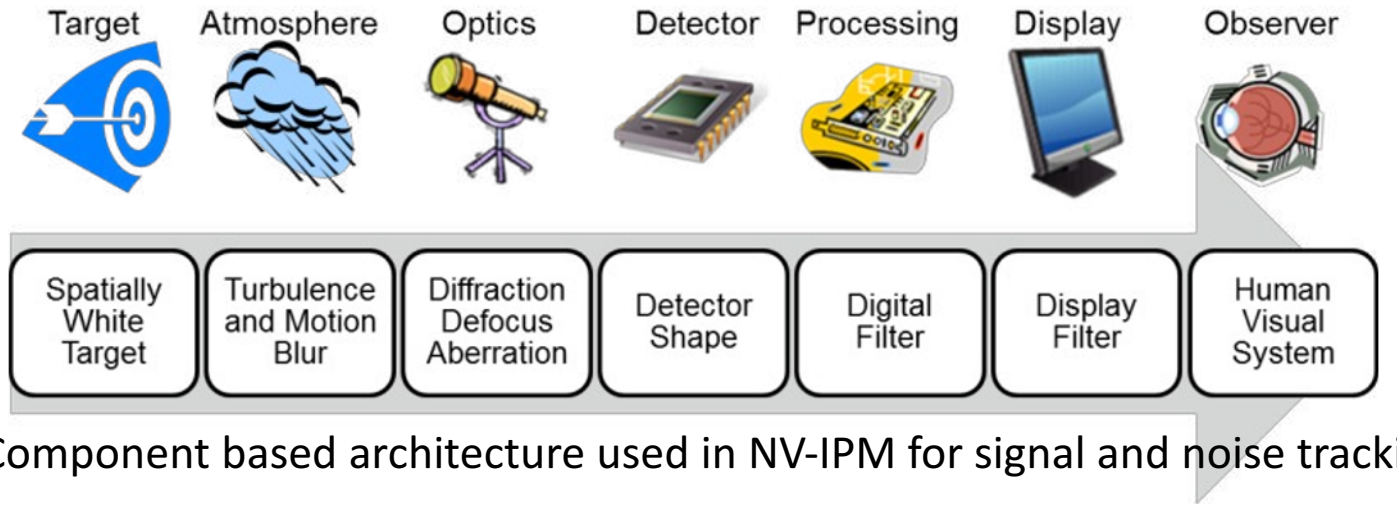
Electro-Optical/Infrared (EO/IR) Imaging System



Jonathan G. Hixson ; Brian Miller ; Christopher May; Enhanced modeling and simulation of EO/IR sensor systems. Proc. SPIE 9478, Modeling and Simulation for Defense Systems and Applications X, 947807 (May 22, 2015); doi:10.1117/12.2179374.

Night Vision Integrated Performance Model (NV-IPM)

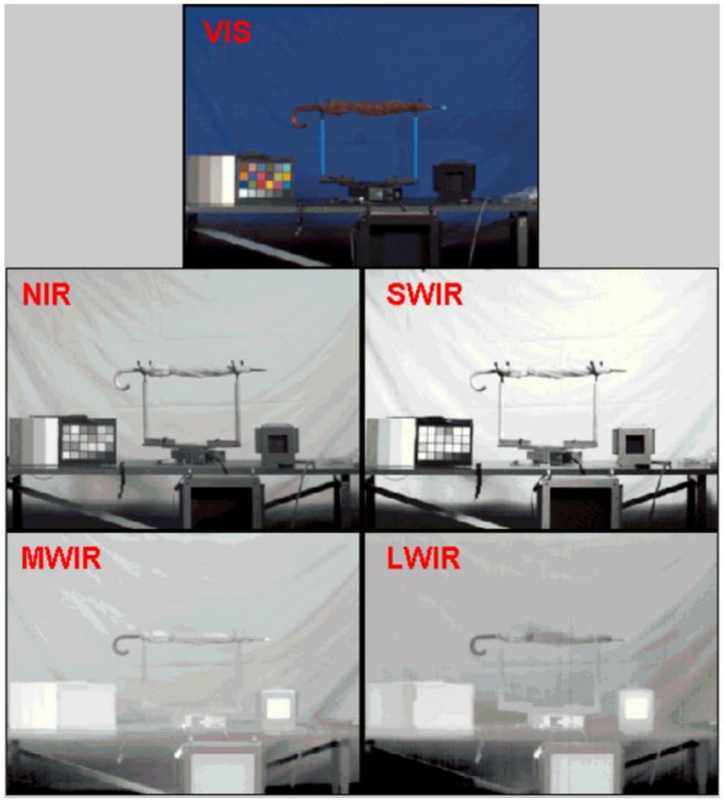
Designed as a means of predicting imaging system performance to support engineering level trades and analyses in support of sensor acquisition.



Component based architecture used in NV-IPM for signal and noise tracking

NVLapCap

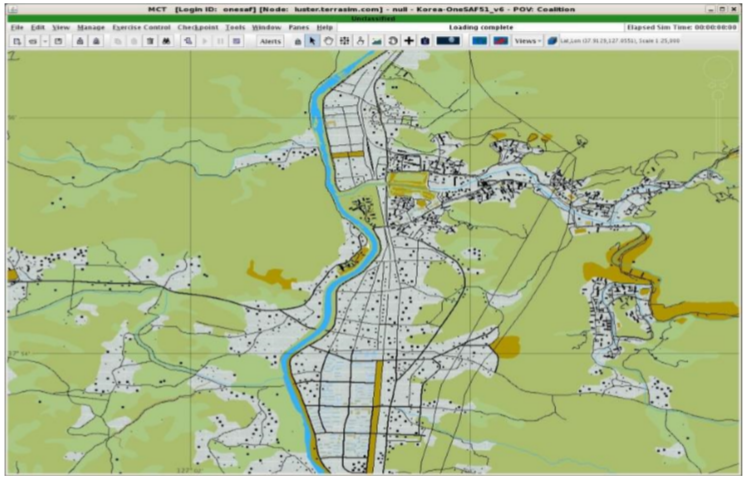
- Sensor measurement enables refinement of the theoretical modeling inputs used during the beginning of the system design process.
- Used to refine sensor performance predictions.
- Developed to not only captures sequential frames from thermal and visible sensors, but it also can perform measurements of signal intensity transfer function, 3D noise, field of view, and Modulation Transfer Function (MTF).



MTF - the fundamental measurement of an imaging systems resolution

Simulation - Predicting

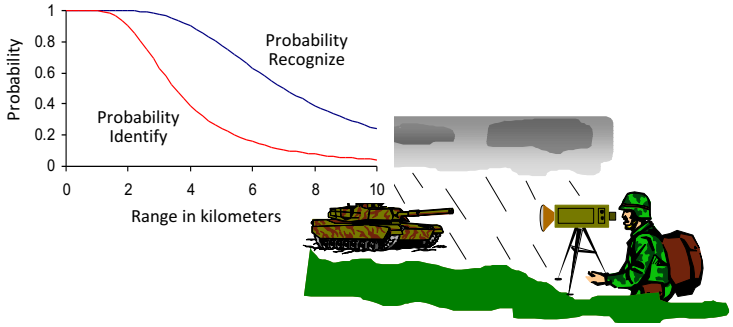
- The last step is predicting operational performance which is conducted within a simulation
- Sensor performance modeling allows simulations to statistically quantify the performance of an individual sensor against an individual target
  - Using force-on-force simulation enables us to apply that data to an operational scenario to predict how a change in sensor technology may affect battlefield results
  - Tying the technology improvement to quantifiable change in actual battlefield performance gives better data to decision makers



How is it used?

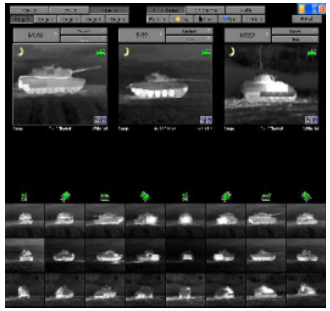
Sensor Performance Modeling

Development of EO/IR sensor models to predict range performance



Training Applications

Development of EO/IR signature training applications



Night Vision Image Generator (NVIG)

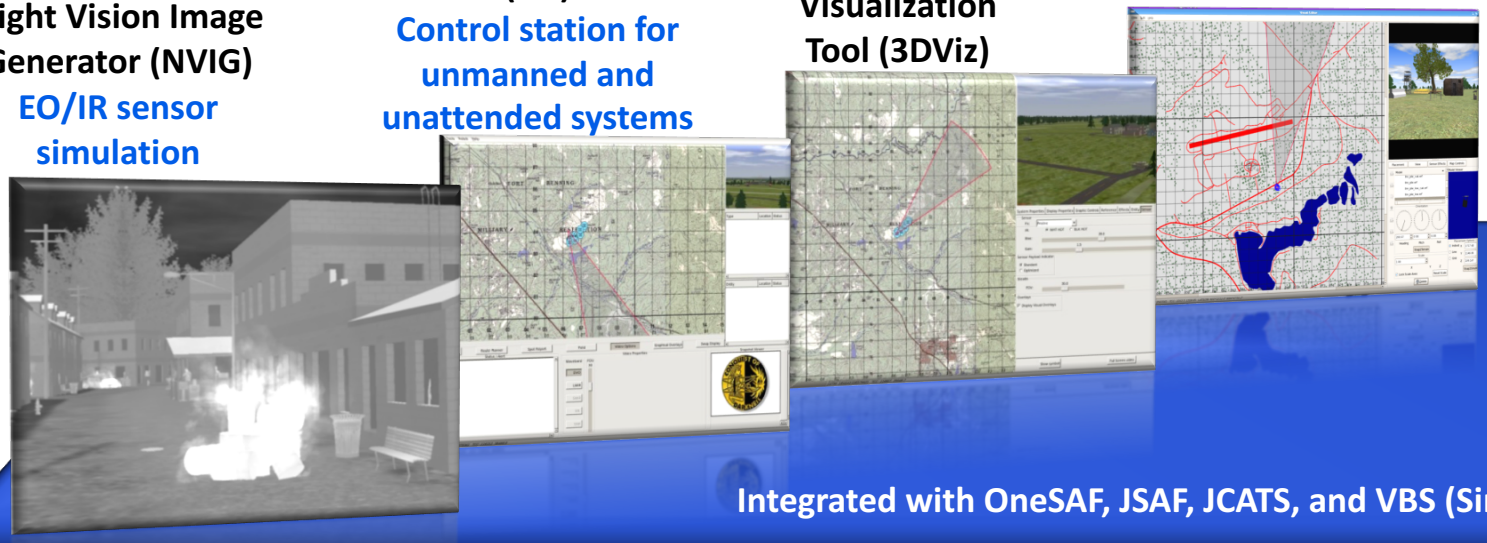
EO/IR sensor simulation

Universal Controller (UC)

Control station for unmanned and unattended systems

3-D Visualization Tool (3DViz)

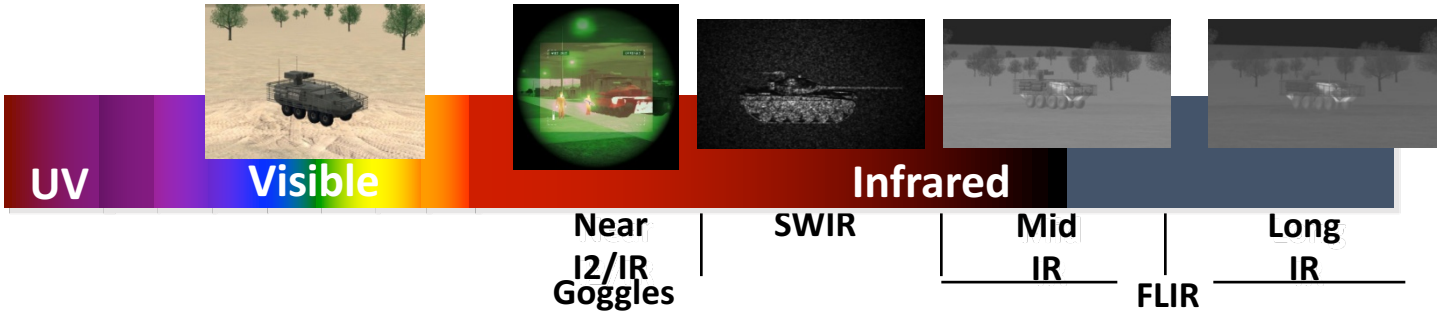
Visual Terrain Editor



Integrated with OneSAF, JSAF, JCATS, and VBS (Simulations)

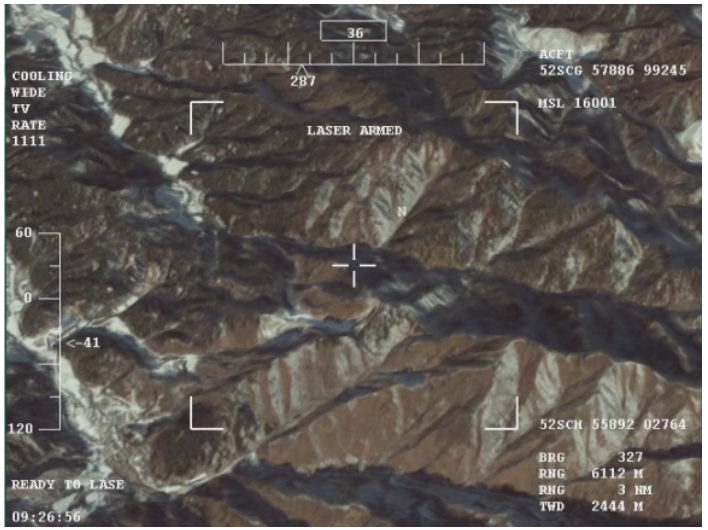
Night Vision Image Generator (NVIG) EO/IR sensor simulation

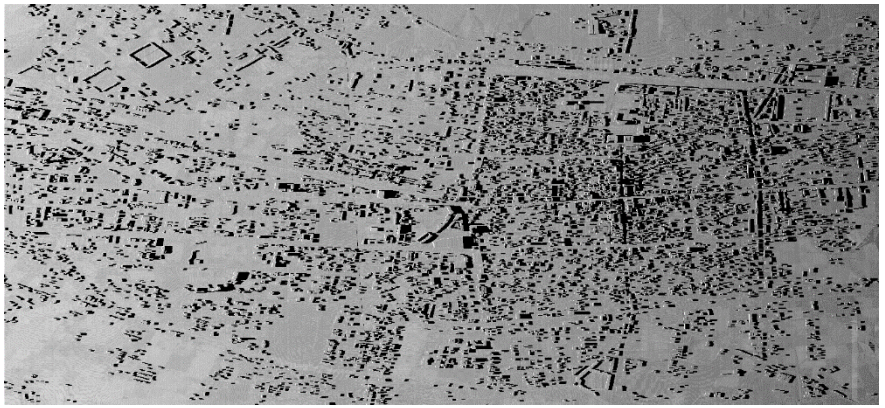
- **Night Vision Image Generator (NVIG) is:**
  - US Army developed Synthetic image generator
  - Real-time
  - Multispectral, with physics based sensor and environmental effects
  - A software application that is embedded in the NVESD sensor simulation toolset.
- **Used for:**
  - **Research and development** of infrared (IR) and electro-optical sensors and mine / counter-mine technology
  - **Experimentation** via man-in-the-loop (MITL) wargames throughout the US Army Battlelabs and Schools
  - **Soldier Training** for various infrared (IR) and electro-optical sensor systems; Mission Command collective training exercises for battle staffs.
- **Uses real-world, high dynamic range signature data to create realistic virtual targets; validated via field test, perception studies and AMSAA review**



Multi-INT Simulation

- **Configurable Aerial Platforms**
  - Unattended: (MUSE)
  - Manned: Commercial Crew Procedural Trainer (CPT)
- **Configurable Sensor Payloads**
  - EO/IR (NVIG): STANAG 4609
  - GMTI (MUSE) and Tracks: STANAG 4607 / NATO-EX
  - LiDAR (In Progress): LAS / LAZ
  - SAR (NVIG): NITF
- **Standard Maneuver "Drivers"**
  - SAFs, ViPRS, …



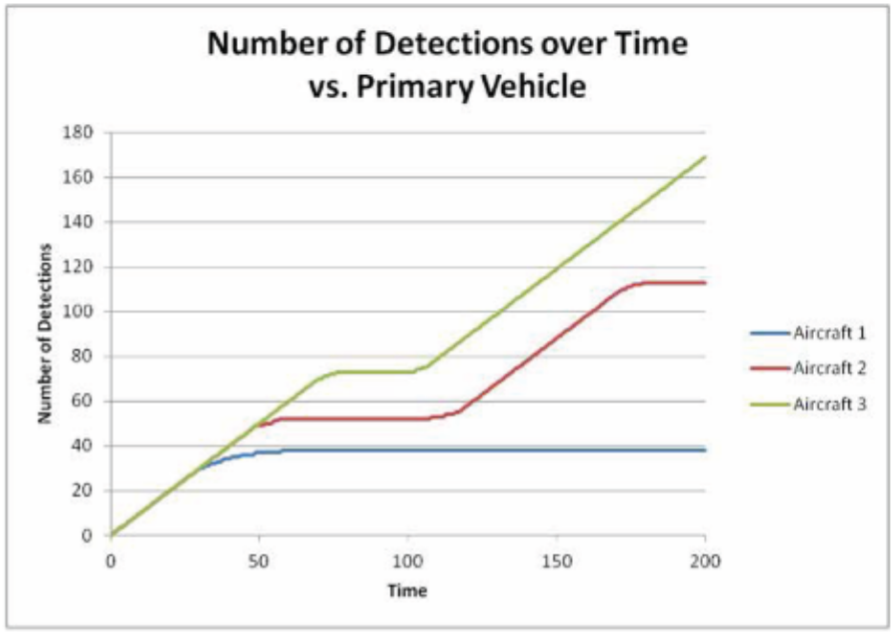


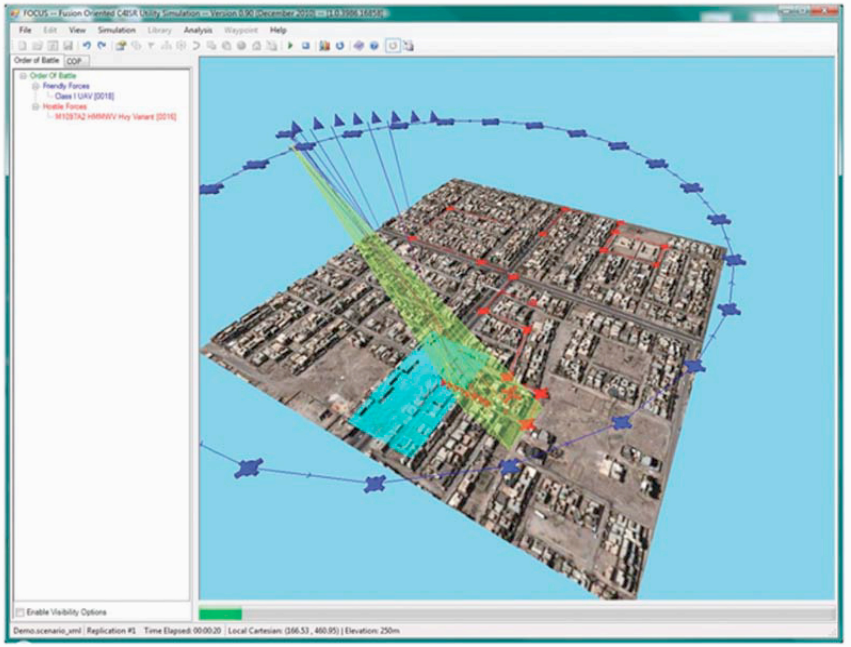
GMTI – Ground Movement Target Indicator
SAR – Synthetic Aperture Radar
LiDAR – Light Detection and Range

MUSE – Multiple Unified Simulation Environment
SAF – Semi-Automated Forces
VIPRS - Vignette Planning and Rehearsal Software

FOCUS

- Fusion Oriented Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) Utility Simulation = FOCUS
- Based upon the Acquire-Targeting Task Performance (TTP) Metric





Government Solutions

- Reuse software programs and leveraging other efforts
- Access to data (most of it classified – hard to get)
- Build to the strictest guidelines (analysis) and then have the capability to adjust parameters
  - Important if processing power or bandwidth is limited
- Reduces costs and development efforts
- Improves combat readiness

Future pathways

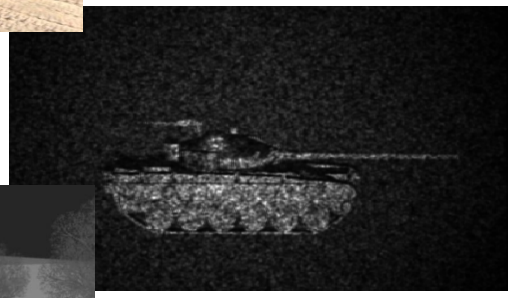
- Government will evolve – understand the evolution pathways
- Government looks for revolutionary ideas or new ways to use information (reference #1)
- Risk – how will it be mitigated and controlled? Where is data coming from?

Questions?

Night Vision Image Generator (NVIG) EO/IR sensor simulation

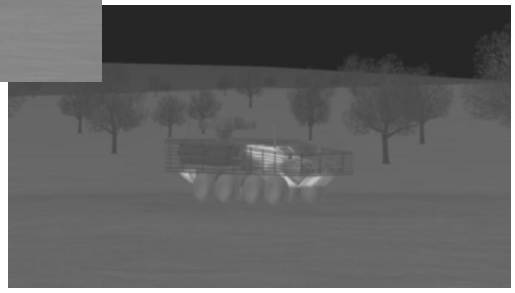
- **Multi-Spectrum**
  - Visible
  - Long Wave Infrared (LWIR)
  - Mid Wave Infrared (MWIR)
  - Short Wave Infrared (SWIR)
  - Image Intensification (I2)
  - Synthetic Aperture Radar (SAR)
- **Physics Based Sensor Effects**
  - Noise and Blur
  - Brightness and Contrast
  - Polarity
  - Electronic-Zoom
- **Environmental / Effects**
  - Atmospheric Attenuation
  - Shadows / Solar Loading
  - Weather (Rain, Snow, Fog)
  - Smoke and Fire
  - IR Blooming
  - Dynamic Terrain

Visible



Short Wave Infra-Red (Active)

Mid Wave Infra-Red

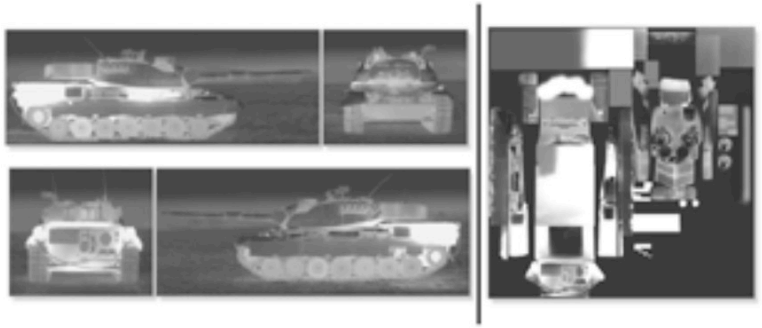


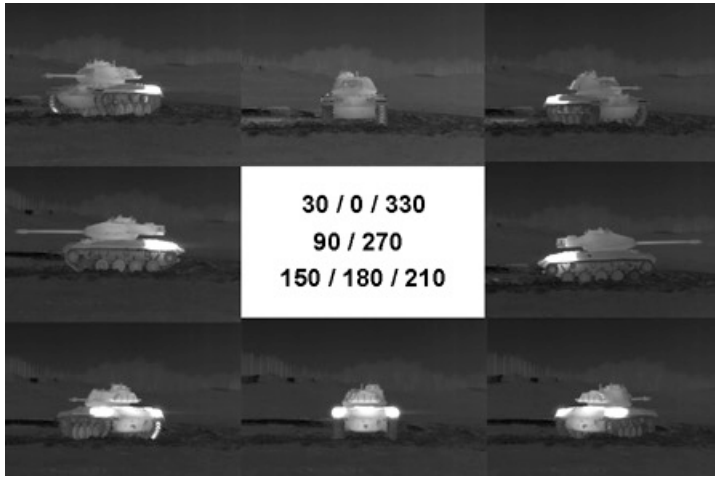
Long Wave Infra-Red

Night Vision Image Generator (NVIG) EO/IR sensor simulation

Recent Improvements

- Texel based material classification system
  - Manipulated single pixels
- Engine Cooling and Heating
  - State of the target will change over time
  - Dependent upon environmental conditions
- Proximity Heating and Cooling
  - Target will impact the environment around it
  - Based on thermal dissipation
- New models added (based on recent conflicts)
  - Next step is gathering data on UASs
  - Also added human beings with equipment
- Shade Optimization
  - Upgrades to better utilize GPUs
  - Improve performance





Streaming Video

- **Ability to stream real-time video generated from any NVIG**
  - Stand-alone NVIG or Embedded with application (3DViz, Universal Controller, USS, USSV, …)
  - Live Streaming or save to File
  - Supports multiple video feeds per NVIG viewport (e.g. save and stream)
- **Multiple transport mechanisms to get from generator to subscriber**
  - UDP or RTP Mode – IG sends stream directly to subscriber via unicast or multicast group (Preferred)
- **Numerous video codecs and formats**
  - H264, MPEG2, JPEG2000 via MPEGTS or Real Time Protocol (RTP) (low latency, multicast)
  - Flash over SWF, MSMPEG4V2 over ASF (greater latency, http delivery)
  - File formats, AVI, MP4, …
- **Ability to transmit the metadata associated with each video stream**
  - Metadata embedded in video (Overlays, HUD)
  - EIA-708 Closed Captions in MPEG2 or H264 Video
  - MISB601 / STANAG 4609: Key – Length – Value (KLV) in MPEGTS or RTP

NVESD's Video Mux