PEO Tactical Missiles
Sensor to Shooter Timeline Equation

BG Mike Cannon
Operational Background

• THREAT TRENDS
  ➢ Asymmetric / Paramilitary
  ➢ Seeks cover in reinforced structures and vehicles
  ➢ Nonlinear battlefield
  ➢ Seeks sanctuary in urban and complex terrain

• DOCTRINE and TTP EVOLUTION
  ➢ Network centric warfare (Fires and Effects)
  ➢ Reduced collateral damage
  ➢ More efficient fires
  ➢ Reduced logistics/footprint
  ➢ Standoff range
  ➢ Scaleable effects
  ➢ Special purpose fires (non-lethal)
  ➢ Proliferation of targeting systems

• RULES OF ENGAGEMENT TRENDS
  ➢ Minimize collateral damage to protect:
    ✓ Noncombatants
    ✓ Religious and cultural landmarks
    ✓ Socio-economic infrastructure
  ➢ Conduct less-lethal operations
• **Total System Error** = $\sqrt{(\text{Target Location Error})^2 + (\text{Velocity Estimation Error} \times \text{Time})^2 + (\text{Delivery Error})^2}$

$$TSE = \sqrt{TLE^2 + [(VEE)T]^2 + DE^2}$$

• **Error sources**: Usually measured in ‘circular probable errors’, or ‘standard deviations in downrange and cross range’. Whatever measure is chosen, it must be common throughout the expression.

• **Target Location Error (TLE)**: The error associated with the sensor itself, whether radar, IR, LADAR, etc. Sensor developer responsibility.

• **Velocity Estimation Error**: Error associated with estimating the target velocity. Sensor developer responsibility.

• **Time**: Elapsed time beginning when sensor senses target and ending at munition (effector) function.

• **Delivery Error**: The accuracy with which the projectile or missile can be delivered to a desired aimpoint. Missile and launch platform developer responsibility.

**Total System Error for a stationary target:**

$$TSE = \sqrt{TLE^2 + DE^2}$$
NOMINAL SCENARIO: Observer with Global Positioning System (GPS) and a Laser Range Finder / Laser Designator (LRF / LD) observes a moving target on road, calls in mission, and a GPS / Inertial Navigation System (INS) missile equipped with a Semi-Active Laser (SAL) seeker is launched to a predicted aimpoint. Range from launcher to target is approximately 40 kilometers.

\[ T_{LE} = 10 \text{ meters} \]
\[ V_{EE} = 1.2 \text{ meters/sec} \]
\[ D_{E} = 10 \text{ meters (CEP)} \]

\[ T_{SE} = \sqrt{T_{LE}^2 + (V_{EE}T)^2 + D_{E}^2} \]
\[ T_{SE} = \sqrt{10^2 + (1.2 \times 280)^2 + 10^2} \]
\[ T_{SE} = \sqrt{100 + 112,896 + 100} \]
\[ T_{SE} = 336.3 \text{ Meters} \]

Assuming a SAL seeker with a Field of View of 13 degrees and sensitivity to start acquiring reflected energy from the LD at approximately 4 kilometers, the cross range dimension of the SAL basket will be greater than 900 meters, and the down range dimension greater than that.

BOTTOM LINE: The SAL seeker should be able to acquire the laser spot and guide the missile to impact on target, or Imaging Infrared (IIR) / Millimeter Wave (MMW) acquires, guides missile to target.
**SAL engagement**: Initial location provided by LLD. Final target engagement by SAL spot.

- **NETWORK Challenge**: How does observer know when to turn on laser?

**IIR / MMW engagement variant**: Initial target location and update by LLD. Final target engagement by IIR / MMW.

- **NETWORK Challenge**: How does observer know when to turn off laser?

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**In-Flight Update**:
- Reduces Time Variable
- Reduces moving TLE
- Reduces total TSE

**Man is in the Loop through munition impact.**
Non-Line of Sight
Sensor to Sensor Handoff

Network Challenges
- NCES versus legacy communication processes, data base storage, retrieval
- XML versus VMF, Link-16
- Inherent latencies versus point-to-point links
- Bandwidth
- Emerging Waveforms
- JTRS versus SINCGARS

Sensor to Sensor Handoff occurs through Sensor to Shooter pairing IAW Battle Command System Commander's Policies.

Other than at UAV Common Ground Station, Man is out of the Loop after missile launch.

IIR / MMW ATR acquires target, guides missile to target

Reduces Time Variable
Reduces moving TLE
Reduces total TSE

In-Flight Update

Launcher

UAV
Beyond Line of Sight
Sensor to Sensor Handoff

IIR / MMW engagement variant:
Initial location provided by LLD.
Final target engagement by IIR / MMW.

SAL engagement variant: Initial location provided by LLD. Target handoff to Shooter aircraft. Final target engagement by SAL

Initial target location obtained by:
• LLD
• Other
Phase 1: Inertial Navigation
The missile will navigate to the predicted target location using the IMU. Based on target type and other factors, the MMW and IIR will probably not be active during this phase.

Phase 2: MMW Detection
The MMW will come on line and begin processing detections. Detections will then be prioritized based on the target location and velocity.

Phase 3: ATA
The IIR will come on line and MMW and IIR will work together to determine which detections are most target like. This phase is where selection of a target or ATA takes place.

Phase 4: Terminal Track
The IIR will take priority and transition to target track on the most target like detection that best matches the target handover. The MMW will transition to backup tracking.

The key to Fire & Forget LOAL is merging the different sensor outputs including the IMU to increase the probability of target acquisition.
“WHAT CAN BE DONE TO REDUCE TOTAL SYSTEM ERROR?”

**TARGET LOCATION ERROR:** INS / GPS based systems provide accurate locations. **ROOM FOR IMPROVEMENT:** SMALL

**VELOCITY ESTIMATION ERROR:** Very accurate – a calculation based on the sensor’s ability to estimate a target velocity. Error is increased if velocity changes prior to munition function. **ROOM FOR IMPROVEMENT:** SMALL

**DELIVERY ERROR:** Very accurate INS / GPS based systems provide very low delivery errors. Capability for in-flight update reduces error even further. **ROOM FOR IMPROVEMENT:** SMALL

**TIME:** Biggest driver of the ‘total system error’ equation. **ROOM FOR IMPROVEMENT:** LARGE
- Many processes making up Battle Command time can be automated. Examples would be effects based weapon-target pairings and defeat criteria / target type.

- Some of the processes will not always lend themselves to automation. Measures related to rules of engagement, collateral damage, and fratricide are more likely to require human intervention, on a case-by-case basis.

- The operational scenario and the risks the Commander is willing to take, will drive which processes will be automated, and which processes will require human intervention.

*The more human intervention involved in the C2 process, the greater the TIME variable in the sensor-shooter timeline equation.*
## Division of Labor

### Sensor System Developers
- Develop reliable ATA/ATR
- Develop reliable / robust sensors
- Reduce sensor TLE
- Integrate sensors into network

### Weapons System Developers
- Develop multi-mode seekers
- Develop reliable ATA / ATR
- Improve IMU / INS / GPS systems to reduce delivery error
- Integrate platform / munitions into Network
- Develop more effective lethal mechanisms
- Improve propulsion reducing TOF

### Network System Developers
- Integrate communications
- Develop reliable / robust platforms
- Develop effective Battle Management System software
- Manage the Spectrum (manage / expand available bandwidth)
- Develop reliable long-range radios

### Operational / User Community
- Articulate requirements
- Develop appropriate TTP
- Staff / train Battle Command cells appropriately

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*Each can reduce the Time variable*
PEO Tactical Missiles Approach

- PEO TACTICAL MISSILE SYSTEMS UNDER DEVELOPMENT INCLUDE AUTONOMOUS AND MAN IN THE LOOP CAPABILITY.

- JOINT COMMON MISSILE – MMW RADAR / IIR / SAL SEEKER
- NLOS-LS PAM – IIR / SAL SEEKER / GPS
- NLOS-LS LAM – Loitering / LADAR seeker / Send and Receive Comms / GPS
- GMLRS – GPS
- APKWS – SAL SEEKER
- VIPER STRIKE / EAGLE EYES - SAL / IIR / MMW SEEKER
### APPLICABLE TECHNOLOGIES

<table>
<thead>
<tr>
<th>TECHNOLOGY</th>
<th>Maturity/ Resourcing</th>
<th>NLOS</th>
<th>CCWS</th>
<th>PFRMS</th>
<th>ARM</th>
<th>JCM</th>
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Resourcing:
- **GREEN**: (G) = Adequate Funding
- **AMBER**: (A) = Insufficient Funding
- **RED**: (R) = No funding
## APPLICABLE TECHNOLOGIES (cont)

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**Resourcing:**

- **RED** = No funding
- **AMBER** = Insufficient Funding
- **GREEN** = Adequate Funding

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**THE PEO HAS NO R&D BUDGET TO TRANSITION THESE TECHNOLOGIES**
Evolving Army Transformation
Current to Future Force - Accelerate fielding of select Future Force capabilities to enhance effectiveness of Current Force. Army Transformation is part of constant change.

CURRENT
- MLRS
- M270A1
- LONGBOW HELLFIRE
- HELLFIRE/PREDATOR
- ITAS
- HYDRA 70
- IBAS
- ATACMS
- JAVELIN

FUTURE
- NLOS LS
- JOINT COMMON MISSILE
- PAM
- LAM
- GMLRS
- LOSAT
- CKEM

Developing the Future Force while Simultaneously Spiraling Future Capabilities into the Current Force
-- “The Way Ahead”
What’s it all Mean?