Physical modelling of naval infrared decoys in TESS and SE-WORKBENCH-EO for ship self-protection

ITBM&S 2014, June 23-26
Outline

• Introduction to TTI and TESS™
• Overview of Naval IR Countermeasures (IRCM)
• Overview of TESS ASM(IR)+
• Decoy Modelling
  – Distraction decoys
  – Seduction decoys (launchers, cartridges, cloud)
  – Decoys in SE-WORKBENCH
• Engagement Analysis
• Way forward
Acknowledgements

Joint collaboration between

Okin SE

Synthetic Environment

TACTICAL TECHNOLOGIES INC
1988 - TTI is founded as a private company supporting Canadian Electronic Warfare (EW) research and engineering activities

1995 - TTI begins research and development of Tactical Engagement Simulation Software (TESS)

1998 – TTI makes first TESS sale to the international marketplace

2006 – Introduction of Anti-ship Imaging IR Simulator (ASMIR)

2007 – Introduction of Integrated Land Active Protection System (ILAPS)

2012 – Introduction of Surface-to-Air and Air-to-Air Imaging IR (SAAMIIR)

2014 – As of 2014, TESS products have been sold to government, research labs and operational support facilities in more than 20 countries around the world – representing multiple customers in many markets, repeat business and ongoing relationships
What is TESS™?

- Tactical Engagement Simulation Software (TESS)

- A suite of physics-based simulation software used to evaluate the effectiveness of electronic countermeasures against RF/IR guided weapons systems

- Based on open literature (unclassified)

- Developed in the MATLAB®/Simulink® framework

- COTS available in source code, semi-compiled and fully compiled

- Users can customize weapons/ECM systems by input parameters and/or modifying source code

- Products includes:
  - Master Interface (database),
  - Batch Runner,
  - Simulation Engine
  - Plotting, Scopes, 3D Visualization
TESS Application Areas

- Training
  - Radar & EW operator in-the-loop training
  - Electronic attack & protection training in concepts & physics

- Capability
  - System test & evaluation using HWIL

- Knowledge
  - Electronic attack & protection R&D

- Research & Test
  - TESS

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# TESS Product Line

<table>
<thead>
<tr>
<th>Element</th>
<th>Threat</th>
<th>TESS Suite</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><strong>TESS Suite</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Radar Guided</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Command Guided/AAA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Semi-Active Homing</td>
</tr>
<tr>
<td>Air</td>
<td>MANPADS</td>
<td>Pulse Doppler Homing</td>
</tr>
<tr>
<td></td>
<td>SAM</td>
<td>Track Via Missile</td>
</tr>
<tr>
<td></td>
<td>AAM</td>
<td>Multi-Function Surveillance Radar</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>IR Guided</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spinscan</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Conscan</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rosette, Quadrant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PWM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Imaging</td>
</tr>
<tr>
<td>Sea</td>
<td>ASM</td>
<td>Active Radar Homing</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Integrated Radar/IR Hard &amp; Soft Kill</strong></td>
</tr>
<tr>
<td>Land</td>
<td>RPG, ATGM</td>
<td></td>
</tr>
</tbody>
</table>

MANPADS – Man Portable Air Defense System
SAM – Surface-to-Air Missile
AAM – Air-to-Air Missile
ASM – Anti-Ship Missile
RPG – Rocket Propelled Grenade
ATGM – Anti-Tank Guided Missile
AAA – Anti-Aircraft Artillery
PWM – Pulse with Modulation

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  – Decoys in SE-WORKBENCH
• Engagement Analysis
• Way forward
Naval IR Countermeasures

Soft-Kill

- Multispectral obscurant smoke
- IR decoys
  - “Walkoff” effect
  - Flotation devices

Source: Rheinmetall Multi Ammunition Softkill System (MASS)
Naval IR Countermeasures

Hard-Kill Systems

Missiles

Radar-guided artillery

High energy lasers (future)

en.wikipedia.org/wiki/RIM-116_Rolling_Airframe_Missile

en.wikipedia.org/wiki/Close-in_weapons_system

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TESS ASM(IR)+ Master Interface (left), Simulink model, 3D displays, sensor views and signal viewers (right)
TESS ASM(IR)+

- Target Platform
  - 3 available vessels
  - Initial direction, speed, evasive maneuvers
- Countermeasures
  - Distraction/seduction decoys
  - Screening, walkoff or custom tactics
  - Repositionable fixed/trainable launchers
- Wind (speed and direction)
- Atmospheric Conditions (summer, winter, time of day)

- Threat Platform
  - Sea or air launched
  - Missile
  - Seeker (1 or 2 bands)
    - Imaging IR
  - Counter-Countermeasures
    - 2-color discrimination
    - Stiffneck
    - Sea skimming
  - Guidance
    - Proportional Navigation
  - Terminal Phase Maneuvers
    - Weaving
    - Let-down
  - Airframe
    - Cruciform (yaw-to-turn)
    - Planform (bank-to-turn)
Applications:

- Platform survivability, vulnerability studies
- Development of countermeasure tactics
  - Quantity, size, timing and direction of deployment
  - Number and location of launchers
- Performance analysis and tradeoff studies
  - Fixed vs trainable launchers
  - Location, coverage of launchers
  - Environmental conditions (wind, sea state)
- Development of tracking algorithms
- Development of counter-countermeasures algorithms
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Decoy Modelling

Distraction Decoys:

- Intended to prevent or delay ship acquisition by the IIR seeker at the start of the terminal phase
- Several decoys are deployed at various angles and range around the ship to “distract” the seeker
- Seeker must evaluate each object prior to locking on to a target
- In TESS, the active simulation starts with distraction decoys fully bloomed
Decoy Modelling

Distraction Decoys:

- Decoy deployment wrt ship $[D]^S$
  
  $LR = \text{Launch range}$
  
  $\varphi_L = \text{deployment angle wrt ship bow}$
  
  $DA = \text{deployment altitude}$
  
  $]^S = \text{ship frame of reference}$

- Wind influence $[S_W]^L$
  
  $V_W = \text{User defined wind speed}$
  
  $\varphi_W = \text{User defined wind direction}$
  
  $]^L = \text{Local North-East-Down (NED) frame}$

- Decoy horizontal motion $[D]^L$
  
  $[TM]^{LS} = \text{Ship to local NED transformation matrix}$

- Decoy vertical motion
  
  User defined descent rate

$$
[D]^S = \begin{bmatrix}
  LR \cos \varphi_L \\
  LR \sin \varphi_L \\
  DA
\end{bmatrix}
$$

$$
[S_W]^L = \int \begin{bmatrix}
  V_W^x \cos \varphi_W \\
  V_W^y \sin \varphi_W \\
  0
\end{bmatrix} dt
$$

$$
[D]^L = [TM]^{LS} [D]^S + [S_W]^L
$$
Seduction Decoys:

- Can be used to lure the IIR seeker’s tracking point away from the ship
- Can be deployed in a close group to create a temporary screen to hide the exact position of the ship
- Can contain sub-munition to create a “walkoff” effect followed by a final larger burst to keep the seeker track point away
- In TESS, seduction decoys consist of three primary subsystems:
  - Launchers
  - Cartridges (rounds)
  - Clouds
Decoy Modelling

Seduction Decoys:

- Launchers
  - User defined:
    - fixed or stabilized (az,el)
    - number and position on the ship
    - number of barrels/rounds per launcher
    - coverage in azimuth and elevation
Decoy Modelling

Seduction Decoys:

- Cartridges
  - Motion follows ballistic trajectory between ejection and detonation
  - Forces on the cartridges \([F_D]^C\) are due to drag and gravity:
    \[
    \begin{align*}
    F_D &= 
    \left[
    -\frac{1}{2} \rho v_x^2 C_D A_C - 9.81 \sin \theta_{CL} \\
    0 \\
    9.81 \cos \theta_{CL}
    \right]
    \end{align*}
    \]
    \(\rho\) is the air density at sea level,
    \(C_D\) is the drag coefficient,
    \(A_C\) is the cartridge cross-sectional area,
    \(\theta_{CL}\) is the elevation angle of the cartridge with respect to the horizontal plane.

]\(^C\) cartridge’s frame of reference.
Decoy Modelling

Seduction Decoys:

- **Cartridges**
  - Acceleration $[A_D]^C$ in cartridge frame:

  $$[A_D]^C = \frac{[F_D]^C}{m}$$

- Velocity $[V_D]^L$ in local frame following coordinate transformation $[TM]^{LC}$

  $$[V_D]^C = \int [A_D]^C \, dt$$
  $$[V_D]^L = [TM]^{LC} [V_D]^C$$

- Position $[S_D]^L$ in local frame

- Orientation $[\varphi_{CL}, \theta_{CL}]$ derived from the acceleration vector$^1$

  $$[\varphi_{CL}, \theta_{CL}] = \begin{bmatrix} \int \frac{A_y}{V \cos \theta_{CL}} \, dt \\ \int \frac{A_z}{V} \, dt \end{bmatrix}$$
Decoy Modelling

Anatomy of a decoy

- Burning particles
- Smoke trail
- Dense, hot particle core
- Dispersed, cooler particles

Naval IR decoys in the visual² (left) and the IR³ (right) spectrum
Decoy Modelling

Anatomy of a decoy

- Decoy clouds in SE-WORKBENCH

- Burning particles
- Smoke trail
- Dense, hot particle core
- Dispersed, cooler particles

Naval IR decoys in TESS ASM(IR)+ generated in SE-WORKBENCH
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Engagement Analysis

Decoy deployment

Real decoy deployment observed from a stationary IR camera

Dense, hot particle core
Thermal reflection on the sea surface
Remaining smoke columns

Dispersed, cooler particles
Thermal reflection on the sea surface
Engagement Analysis

TESS ASM(IR)+: Stationary observer
Engagement Analysis

TESS ASM(IR)+: Missile launch, no countermeasures
Engagement Analysis

TESS ASM(IR)+: Missile launch, with countermeasures (screen)
Engagement Analysis

TESS ASM(IR)+: Missile launch, with countermeasures (walkoff)
Engagement Analysis

TESS ASM(IR)+: Missile launch, wind effects on deployment
Engagement Analysis

TESS ASM(IR)+: Missile re-acquisition, ineffective deployment
Engagement Analysis

Deployment algorithm optimization

- 3 generic deployment tactics using TESS Batch Runner
- Blue regions indicate effective decoy deployment (low $P_K$)
- Red regions indicate ineffective decoy deployment (high $P_K$)

Generic decoy deployment tactics in order of effectiveness (blue regions) from left to right
Way Forward

- Complete coupling of ASM(IR)+ and SE-WORKBENCH
- Addition of user-defined automatic decoy deployment algorithm based on system, engagement and environmental parameters
- Addition of generic target recognition and tracking algorithms based on machine learning approaches
- Addition of a 2\textsuperscript{nd} missile system
- Addition of ship exhaust signature using SE-WORKBENCH
- Modifications to the user interface to support new functionality provided by SE-WORKBENCH
- Expected availability of TESS ASM(IR)+ by the Fall 2014
Reference


<https://www.youtube.com/watch?v=CoduG_AkQeQ&index=7&list=PLFE88E1F348AB011E> (21 May 2014).

<https://www.youtube.com/watch?v=vq7qTssx0Kw&list=PLFE88E1F348AB011E&index=10> (21 May 2014).

<https://www.youtube.com/watch?v=WPqSZh3QGac&list=PLFE88E1F348AB011E> (15 May 2014).
Thank you.
Questions?