Implementation of Intensity Ratio Change and LOS Rate Change Algorithms for Imaging Infrared Trackers

TACTICAL TECHNOLOGIES INC

www.tti-ecm.com

Presentation Outline

1. Introduction
2. IRCCM Algorithms
3. Experimental Setup
4. Batch Run Results
5. Discussion
6. Conclusion

Introduction

- Tactical Technologies Inc. (TTI) was established in 1988 as an independent EW/ECM product development and engineering support organization.

- TTI's offerings include a broad range of modeling and simulation based analytical tools (TESS™), technology and services related to:
  - Platform Survivability
  - Electronic Protection/Attack
  - Radar guided weapons
  - EO/IR guided weapons

Introduction

Tactical Engagement Simulation Software (TESS™) COTS		
Air (RF) Command Guided Semi-Active Homing Active (Pulse Doppler) Track Via Missile Anti-Aircraft Artillery	**Air (IR)** Spin Scan Con Scan Rosette Quadrant Imaging	**Active Protection System (IR & RF)** ATGM RPG
Sea (RF) Active Homing	**Sea (IR)** Imaging	**Multi-Function Surveillance Radar**

Introduction

Goals

- Implement IRCCM algorithms in a generic IIR seeker based on:
  - Target Intensity Change (IR Signature)
  - Target Kinematic Behavior (Motion)
- Gain better understanding of how threat systems reject countermeasures

Requirements

- Based on documented [non-imaging] IRCCM techniques
- Open literature and easily verifiable
- Implemented using the Mathworks® product line

IRCCM Algorithms

TACTICAL TECHNOLOGIES INC

Overview

Intensity Ratio Change (IRC):

- Compares the intensity of a detected object to the historical intensity average of a reference object.
- If the intensity ratio is greater than a pre-defined threshold, the object is identified as a probable decoy/flare.

$$IRC_N(i) = \frac{P_N(i)}{\overline{P_N^o}} \qquad \overline{P_N^o} = \frac{\sum_{K=N-J}^{N} P_K^o}{J}$$

IRC = Intensity Ratio Change
N = Current time-step
i = Track Id
P_N = Detected intensity

$\overline{P_N^o}$ = reference object's average intensity
J = IRCCM memory time (# of time-step)

IRCCM Algorithms

Overview (cont.)

Line-of-Sight Rate Change (LRC):

- Measures the average azimuth ($\bar{\dot{\theta}}$) and elevation ($\bar{\dot{\phi}}$) rates of a detected object (with respect to a reference object)
- If the azimuth or the elevation rate is greater than a pre-defined threshold, the object is identified as a probable decoy/flare.

$$\bar{\dot{\theta}}(i) = \frac{\sum_{K=N-J}^{N} \theta_K(i) - \theta_{K-1}(i)}{J \cdot \tau} \qquad \bar{\dot{\phi}}(i) = \frac{\sum_{K=N-J}^{N} \dot{\phi}_K(i) - \dot{\phi}_{K-1}(i)}{J \cdot \tau}$$

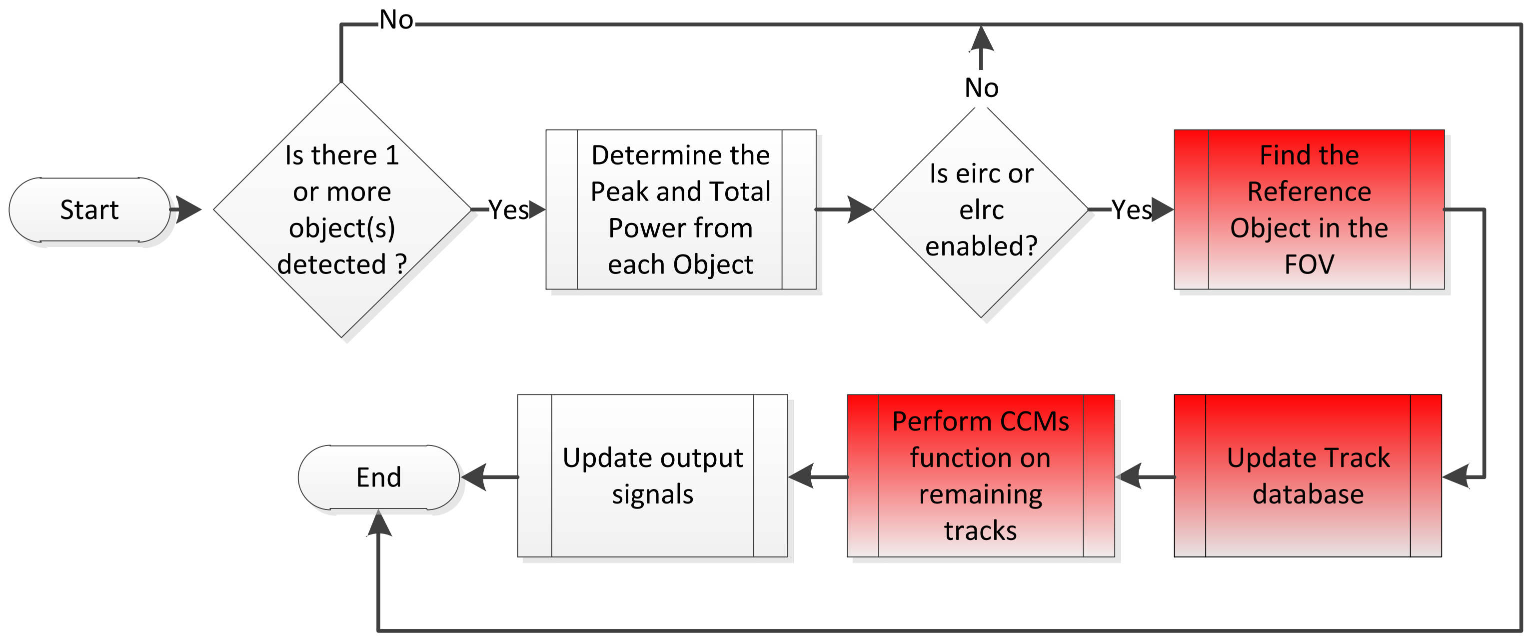
θ = Separation angle between ref. object and i^{th} object
N = Current time-step
i = Track Id
J = IRCCM memory time (# of time-step)

ϕ = reference object's average power
τ = simulation time-step

IRCCM Algorithms

TACTICAL TECHNOLOGIES INC

Top Level IRCCM Logic Diagram



Track Database

Time Stamp	Object Size	Horiz. Position	Vertical Position	Horiz. Velocity	Vertical Velocity	Pred. Horiz. Position	Pre. Vertical Position	Total Power	Peak Power

Experimental Setup

Purpose

- test the robustness and effectiveness of the algorithms
- Identify strengths and weaknesses in the algorithms

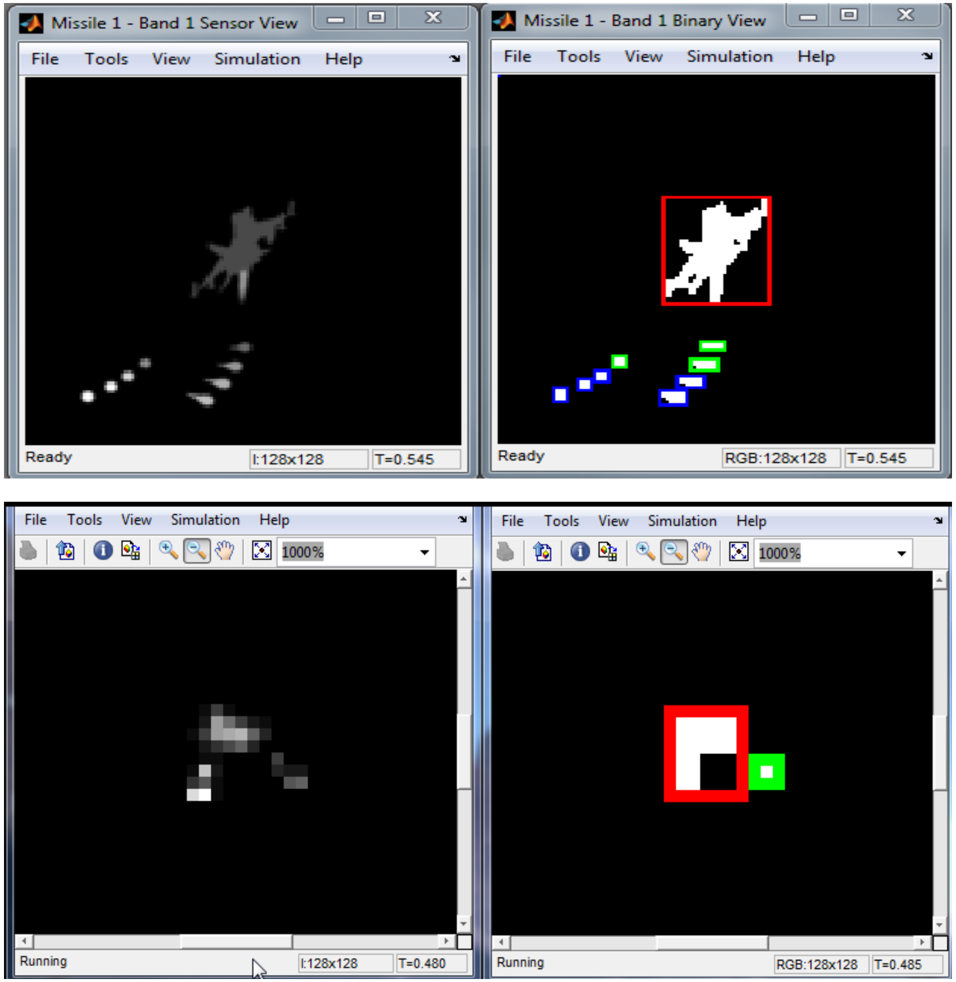
Methodology

- simulate dynamic engagement between an IIR-guided threat system and a target platform employing expendable countermeasure as self-protection
- generate 1000’s of runs with varying angle of arrivals to represent surface-to-air and air-to-air engagements
- record key engagement parameters to produce effectiveness plots
- modify algorithm parameters to optimize and assess the impact on the engagements

Experimental Setup

Target Tracking

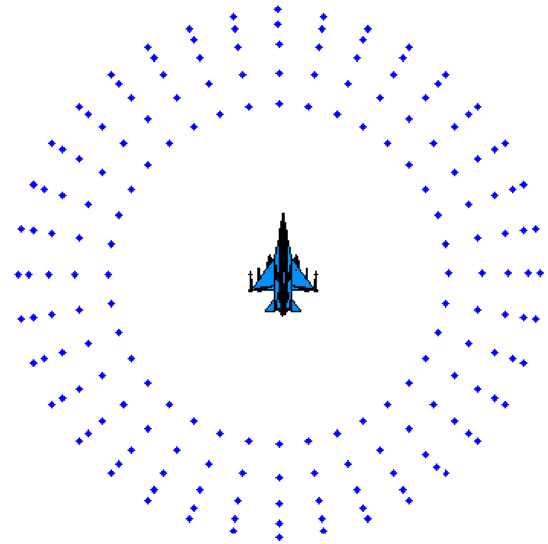
- IIR seekers may use feature/pattern recognition algorithms to track targets (top).
- At longer ranges (bottom), such features are not always discernible and may require alternative methods (perhaps based on intensity).
- Proposed algorithms were tested against targets at longer ranges

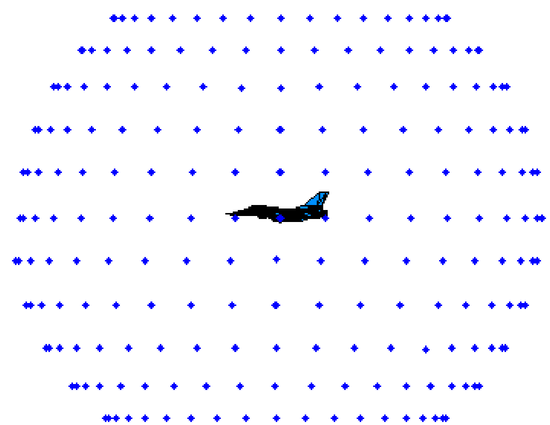


Experimental Setup

Engagement Geometry

- **Range:** 3000 m
- **Azimuth:** 0º to 360º
- **Elevation**: -50º to -50º
- **Az/El Increments**: 10º





Experimental Setup

Subsystem Parameters

Target Platform	
Platform Type	Fast Jet
Length	14 m
Wing span	9 m
Velocity	250 m/s
Maneuver Time	none
Normal Acceleration	0 g

Flare	
Approx. max diameter	0.3 m
Growth Time Constant	0.1 sec
Sustain Time	4 sec
Decay Time Constant	3.5 sec
Number of flares	8
Orientation [az el]	4 x [135 -30] 4 x [-135 -30]
Deployment Timing	[0.1 0.2 0.3 0.4] sec after the start of the simulation

Experimental Setup

Subsystem Parameters

Airframe	
Length	1.45 m
Diameter	0.1 m
Wing Span	0.17 m
Mass	9.2 kg
Prop. Nav. Coef.	3
Max. Acceleration	30 g

Seeker	
Servo Bandwidths	10 Hz
Gimbal Limits	60 deg
Field of View	4 deg
Detector Array	128x128
Detector Sampling Rate	200 Hz
IRCCMs	IRC / LRC

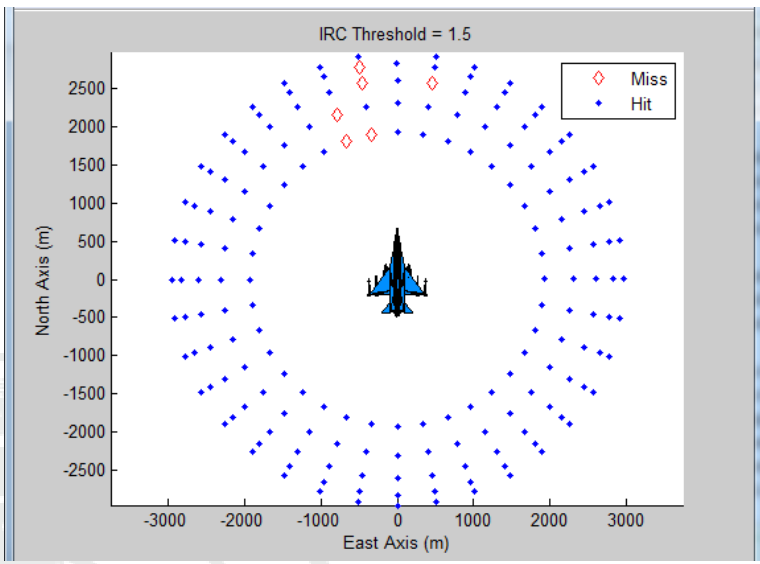
Measure of Effectiveness

- Miss Distance (m)

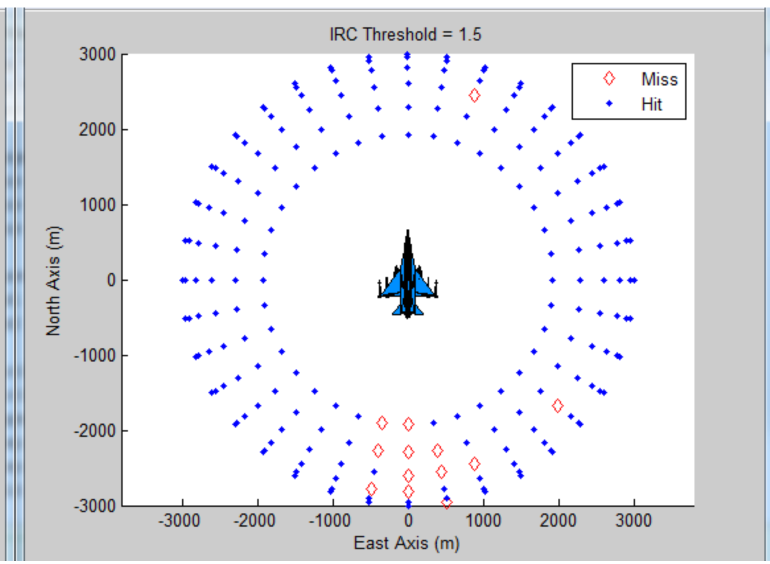
Batch Run Results

Batch Run #1: Intensity Ratio Change Algorithm

Input Parameters		Results	
IRC Threshold	1.5	Total Number of runs	396
IRCCM Memory Time	1 sec	Miss	19 (5%)
Flare Hold Time	0.3 sec	Hit	377 (95%)



Surface-to-Air

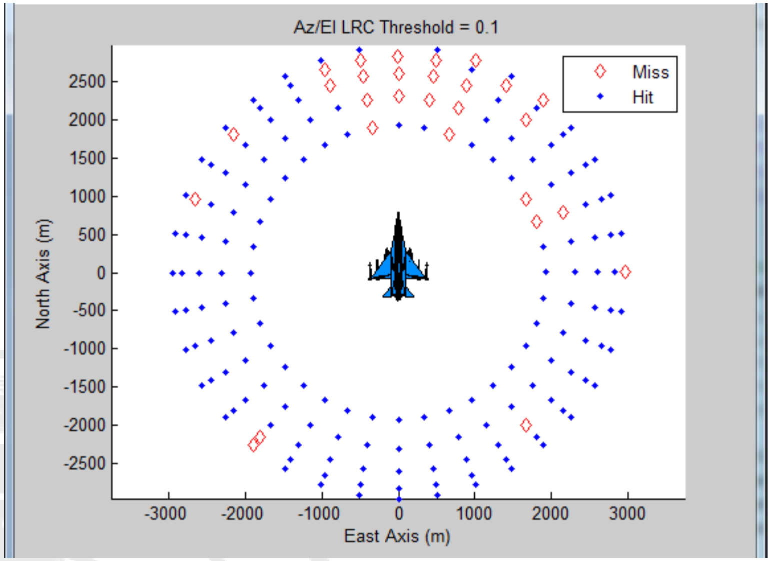


Air-to-Air

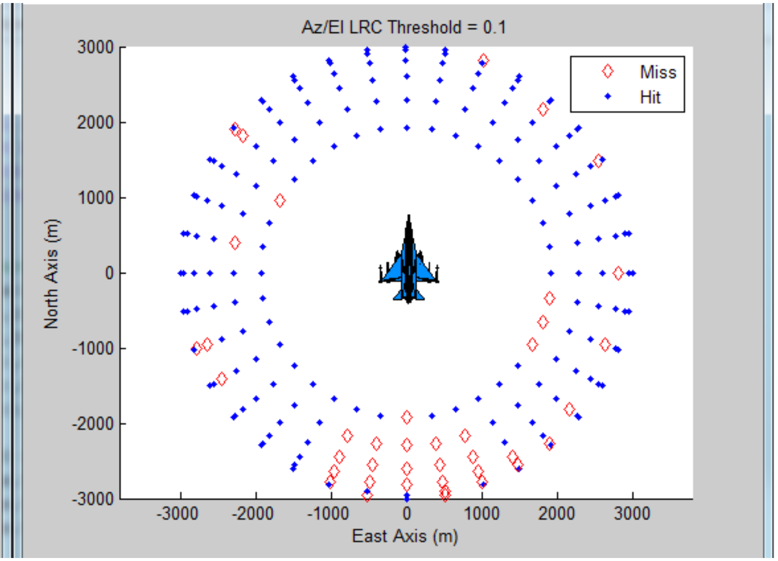
Batch Run Results

Batch Run #2: LOS Rate Change Algorithm

Input Parameters		Results	
LRC Threshold [Az El]	[0.1 0.1] deg/s	Total Number of runs	396
IRCCM Memory Time	1 sec	Miss	67 (17%)
Flare Hold Time	0.3 sec	Hit	329 (83%)



Surface-to-Air



Air-to-Air

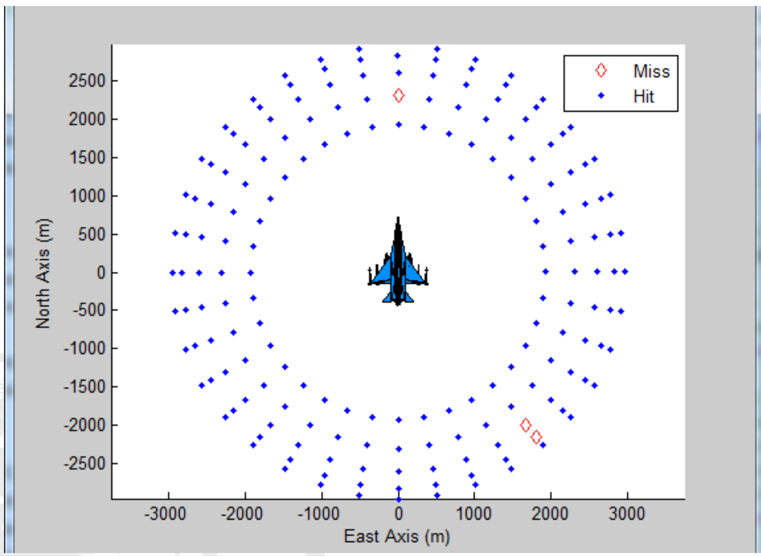
Batch Run Results

TACTICAL TECHNOLOGIES INC

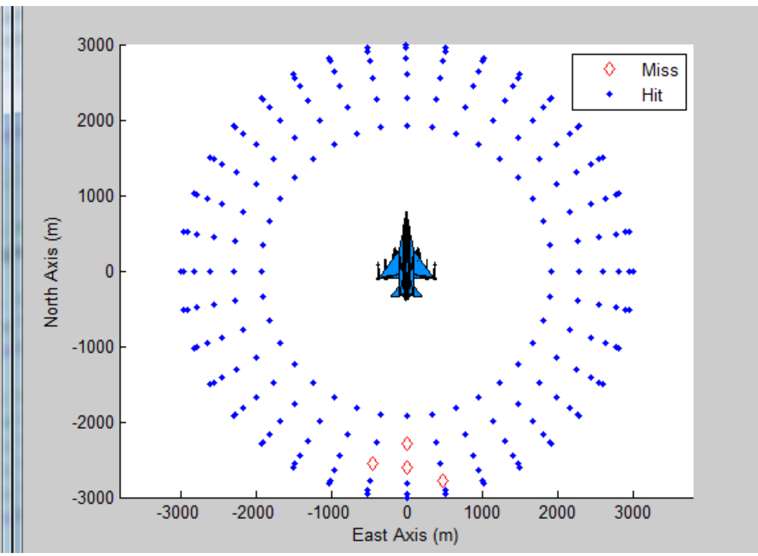
Batch Run #7: Combined IRC/LRC Algorithm

Input Parameters	
IRC Threshold	1.1
LRC Threshold [Az El]	[0.1 0.1] deg/s
IRCCM Memory Time	1 sec
Flare Hold Time	0.3 sec

Results	
Total Number of runs	396
Miss	8 (2%)
Hit	388 (98%)



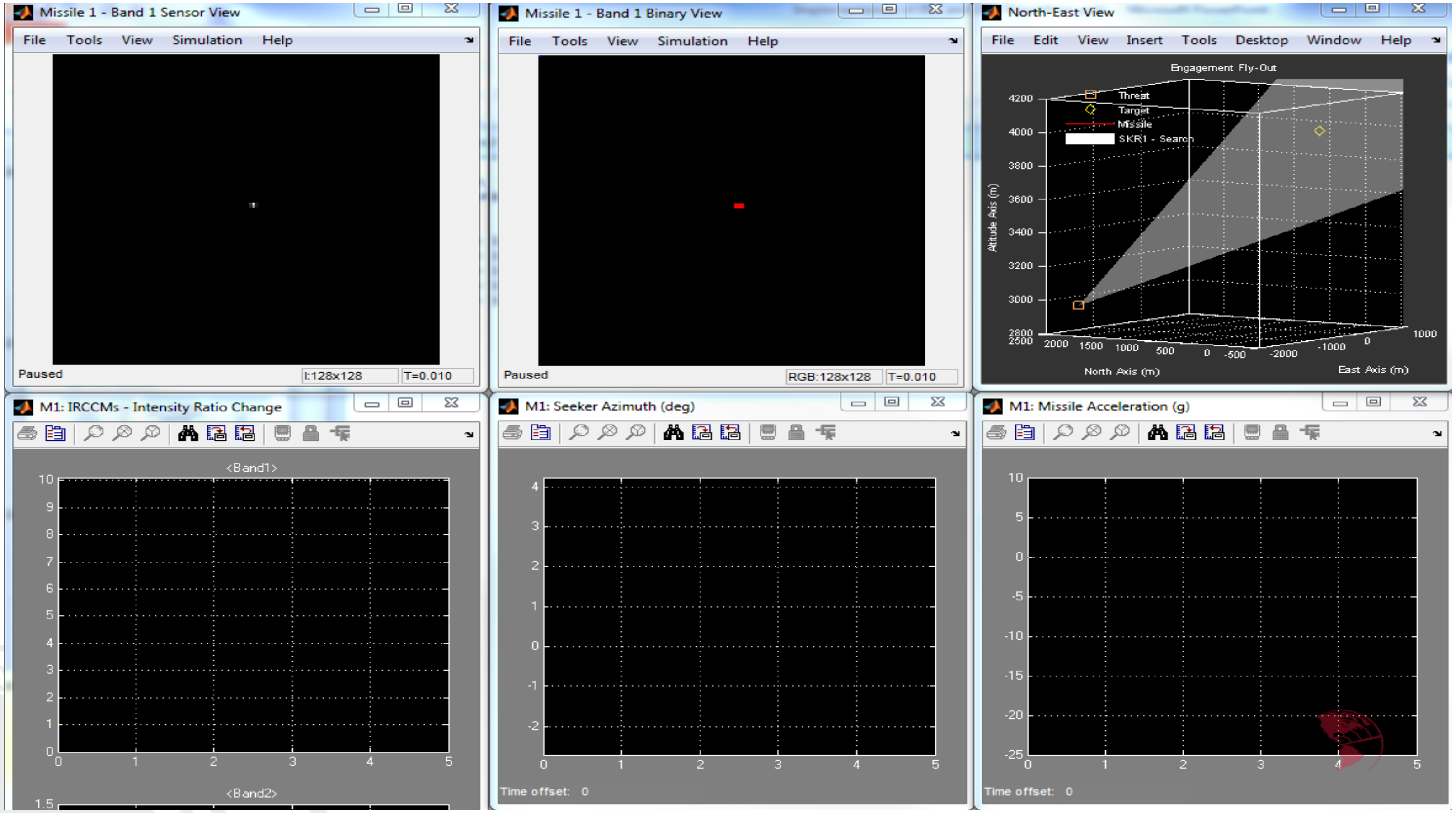
Surface-to-Air



Air-to-Air

Discussion

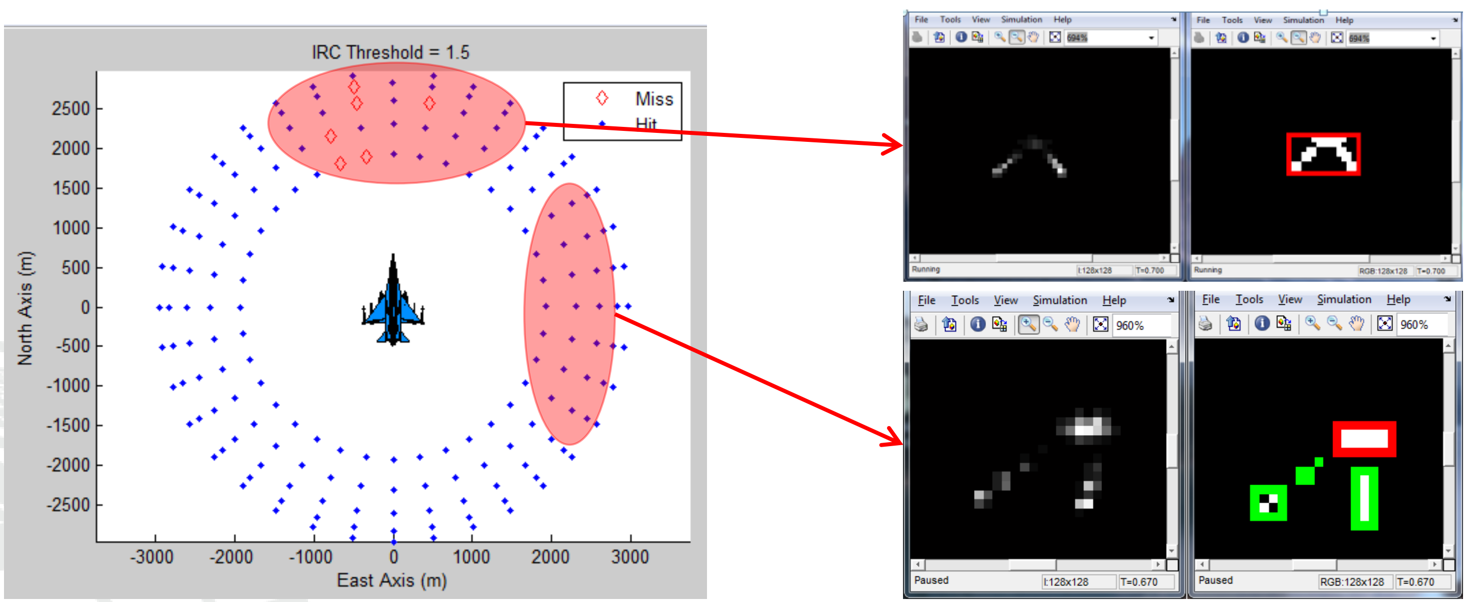
Flare Rejection Using Intensity Ratio Change Algorithm (.avi)



Discussion

Impact of flare deployment in the apparent close-proximity to the platform.

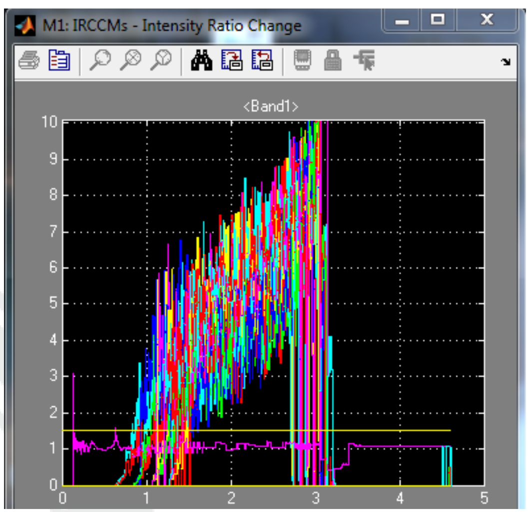
- In many head-on and tail chase engagements, the flare deployment appears to be very close (sometimes overlapping) the target platform due to flare deployment angle and the threat's angle of arrival.

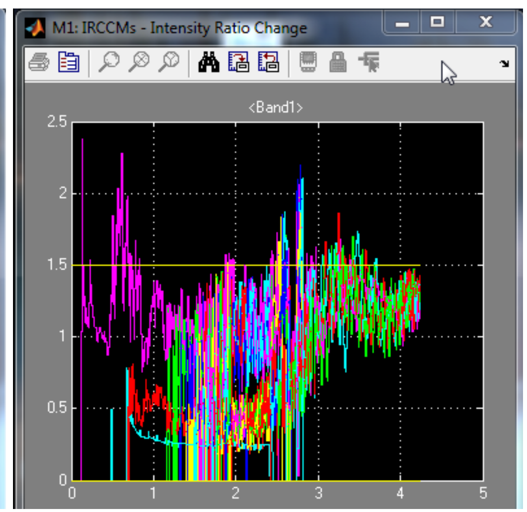


Discussion

Impact of flare deployment in the apparent close-proximity to the platform (cont.).

- This interferes with the intensity ratio calculation.
- The intensity of the detected objects is compared to the intensity of another flare (right) instead of the target platform (left).
- The ratio is below the threshold and the algorithm can not discriminate the target from the flares.

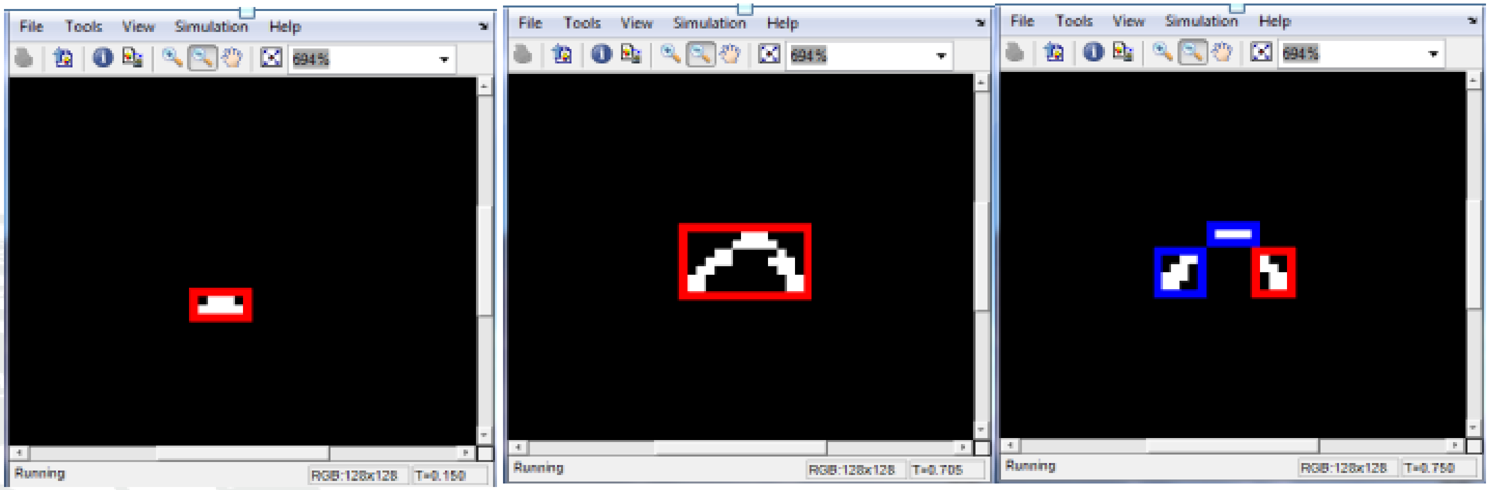




Discussion

Impact of flare deployment in the apparent close-proximity to the platform (cont.).

- The target's changing features (size, aspect ratio and centroid location) interferes with the algorithm's ability to correctly identify the reference object from one time-step to the next.
- In some cases, the algorithm mistakenly classifies the reference object as a potential flare (blue boxes)



Conclusion

- In the conducted tests, the algorithms successfully discriminated the target from the flares 98% of the time.
- The ability to correctly identify the reference object from one time-step to the next is key to successfully rejecting false targets.
- Flares deployed in the direct line-of-sight between the target and the threat can interfere with the detection of the reference object (change in intensity, size, aspect ratio and centroid).

Thank you.

Questions?

TACTICAL
TECHNOLOGIES INC

www.tti-ecm.com