Ground Moving Target Tracking and Exploitation Performance Measures

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Abstract Ground Moving Target Indication provides a unique source of information for the exploitation of surface and low flying aircraft at long range, in all weather, providing situation awareness, targeting, and intelligence information. While airborne moving target indication and fire control radars have been around for a long period of time, it has been only the last decade when Ground Moving Target Indication (GMTI) data has been collected and used to prosecute mobile surface targets. This presentation addresses the use of GMTI data from providing intelligence information to the analysis and leads to the challenges associated with doing long-term track maintenance. The intelligence community has been expressing interest in GMTI data since 1999 when investments were made to develop the first exploitation capability that focused on products from Joint STARS GMTI data providing a web based capability to process and exploit Joint STARS data via a Network Centric Architecture. At the same time, DARPA and AFRL were pursuing the Long Term Track Maintenance challenge performing multi-platform command and control, horizontally fusing multiple sensors with weapons for a long-range precision fire control system. The focus of this presentation is to cover performance metrics. The metrics will be associated with operators-in-the-loop evaluations looking at intelligence and analysis for the find, fix, track, and assess portion of the weapon. The second set of metrics focus on long-term track maintenance evaluations. Track accuracy and persistence in time critical targeting, which address the track, target, and engage portion of the weapon chain. Programs to be discussed include the Moving Target Information Exploitation System (MTIX) program with respect to intelligence products, the Multi-Platform Tracking Exploitation (MPTE) and the Affordable Moving Surface Target Engagement (AMSTE) programs with respect to Long Term Track Maintenance and Precision Fire Control.

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Ground Moving Target Tracking and Exploitation Performance Measures

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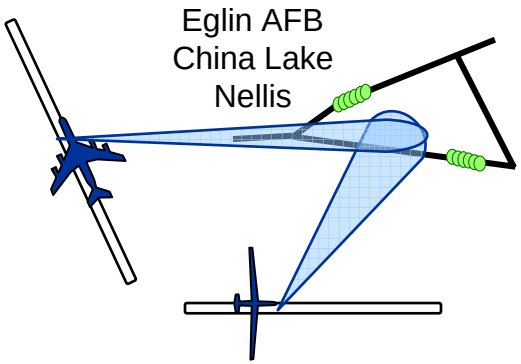
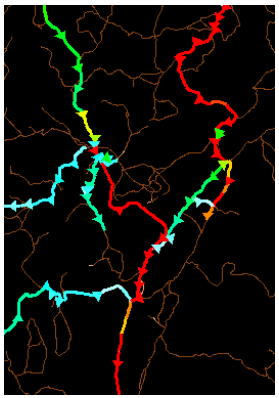
Outline



Multi-Platform Tracking & Engagement

- **Ground Moving Target Tracking**
  - **Performance Measures for Tracking Targets**
  - **Sources of Analysis**
    - **Multi-Platform Tracking Exploitation (MPTE)**
    - **Affordable Moving Surface Target Engagement (AMSTE)**
  - **Well Defined Metrics**

Korea
OIF



Flow Analysis
MTI Change Detection

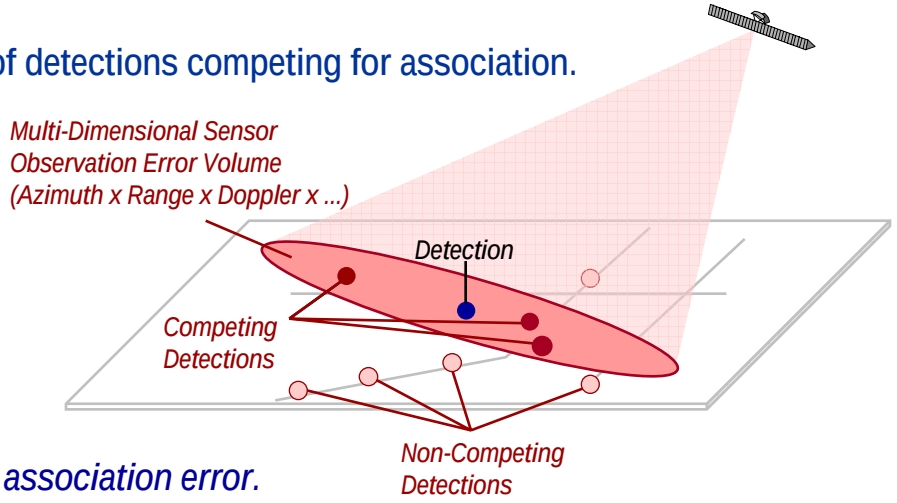
- **Ground Moving Target Exploitation**
  - **Exploitation MOPs/MOEs (use of the data and performance of the systems)**
  - **Moving Target Information Exploitation (MTIX) Features**
    - **OIF, Korea, DCGS**
  - **Metrics Maturing**

Indicators of Association Complexity

1) Normalized Target Density – Number of detections competing for association.

Dependencies

- Observation Error Volume
  - -Dimensionality
  - -Measurement Errors (σ)
  - -Vehicle/Sensor/ROI Geometry
  - -Sensor distance from ROI
- Number of Nearby Confusers
  - -Density of Targets
  - -False Alarm Rate
  - -False/Branch Track Rate

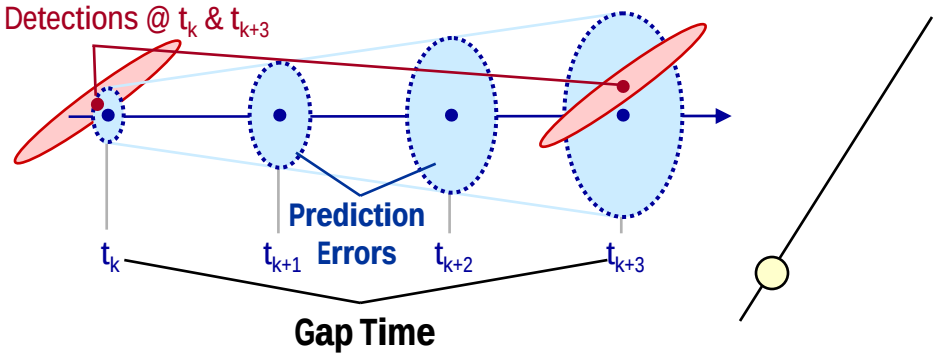


NTD quantifies the measurement error contribution to association error.

2) Gap Time – Time between a target's detections. (Amount of time to extrapolate track and track error.)

Dependencies

- Sensor
  - -Revisit rate
  - -Probability of Detection
  - -Clutter cancellation technique (MDV)
  - -Sensor availability
- Environment
  - -Terrain blockage
  - -Target speed relative to mainlobe clutter
  - -False/branch track rate



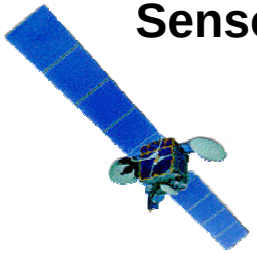
Gap Time quantifies the prediction error contribution to association error.

AMSTE managed this asymetrically (revisits when needed)

System of Systems designs must drive down Gap Time and Normalized Target Density

Intel and Analysis Metrics

Operator-In-The-Loop Experimentation



Sensor Configurations

21 Ball Low Earth Orbit Constellation
8 Ball Wolf Pack 8/1/1
10 Ball Mid Earth Orbit Constellation

Scenario Volume

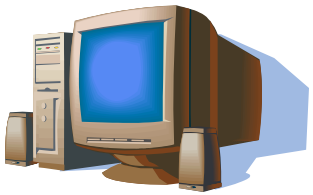
160 Vehicle “Davison Challenge”
2 Convoys plus background traffic

10,000 Vehicle RT-1
25 Convoys plus background traffic

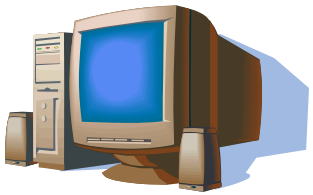
140 Vehicle Korea
4 Convoys plus background traffic

15,000 Vehicle RT-2
34 Convoys plus background traffic

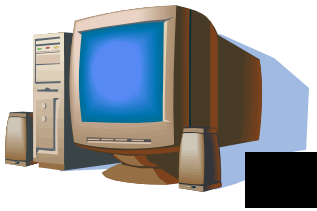
Experience Operators



MTIX
Operator
Auto Assisted Tracker



JSWS
Operator
No Auto Tracking



MATrEx
Operator
Auto Only Tracker

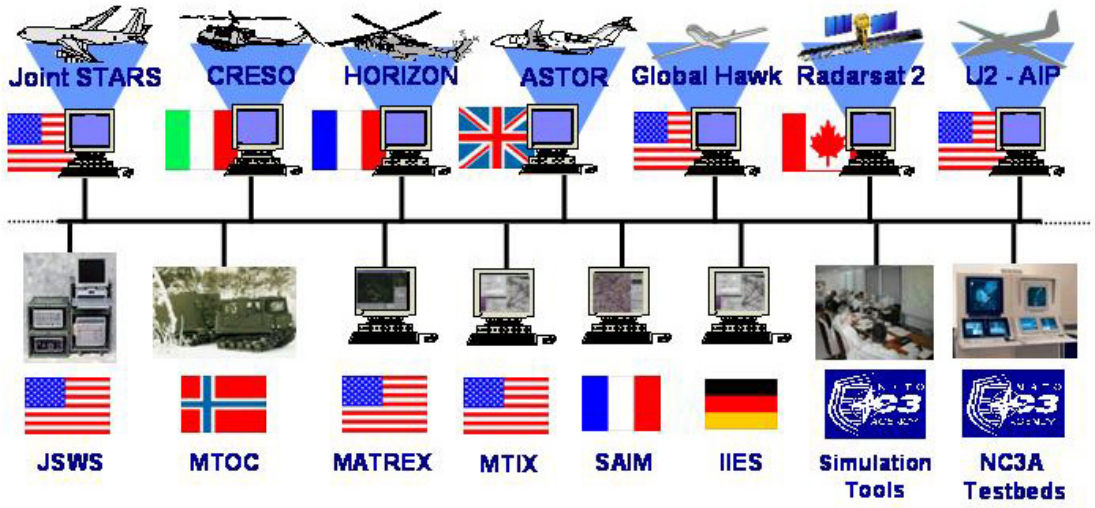
Metrics

Link 16 Messages
Recorded for Post Processing

Border Crossings
Convoy Following
Volume of Coverage
Tracklets

AFRL Developed Simulations, Models, and Metrics

Simulation Exercise



October 2003 Exercise

Location: NC3A The Hague, NE

Experience Army and AF Operators

Robust 2 Week Scenario

NC3A Dev. Hostile & Friendly Targets

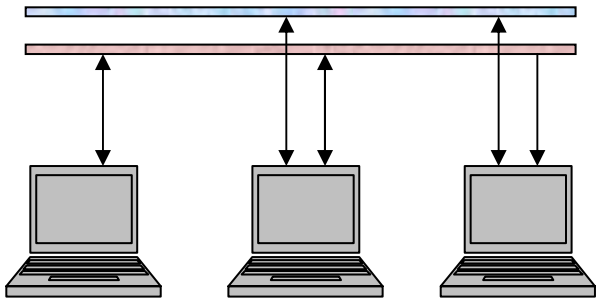
AFRL Dev. Civilian Targets

TTPs and CONOPS

Operators Nominated Link 16

Use of J3.5 Message Set

AFRL SETUP



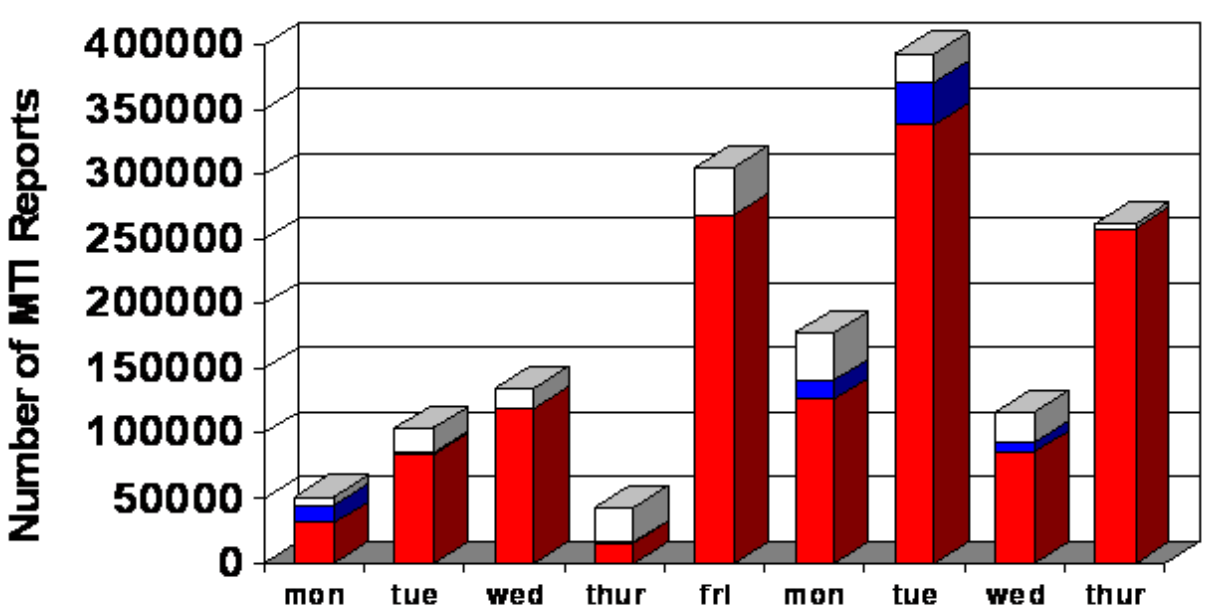
Data logged for post analysis:

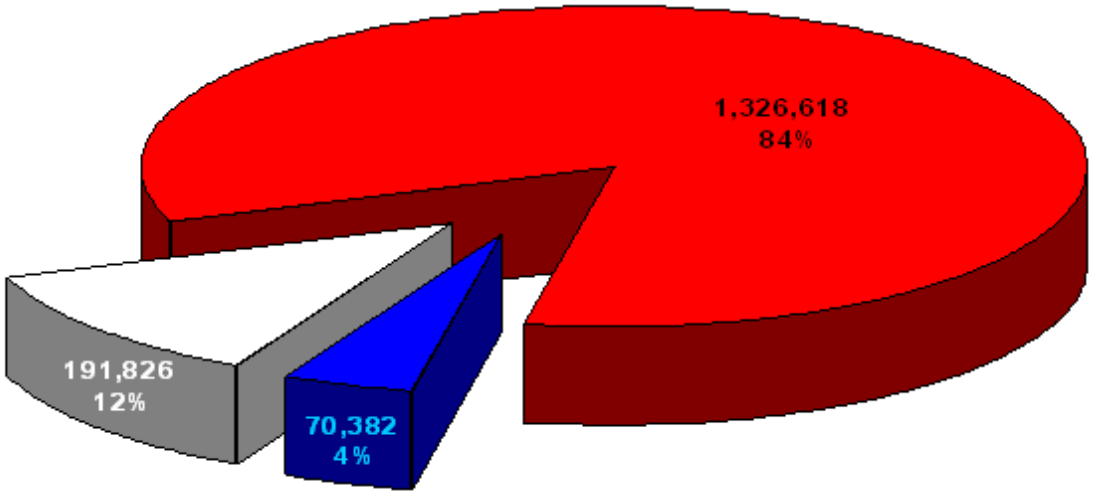
All DIS entity states

- **PDU timestamp vs. time received**
- **Compressed and stored as NRTTDF**

- **All NatoEx GMTI, FreeText, and RSRs**
- **All JTIDS J2.2 (Ownship) and J3.5 (Track) messages**

Total GMTI reports – all sensors





GMTI on Civilians

GMTI on Friendlies

GMTI on Hostile Targets

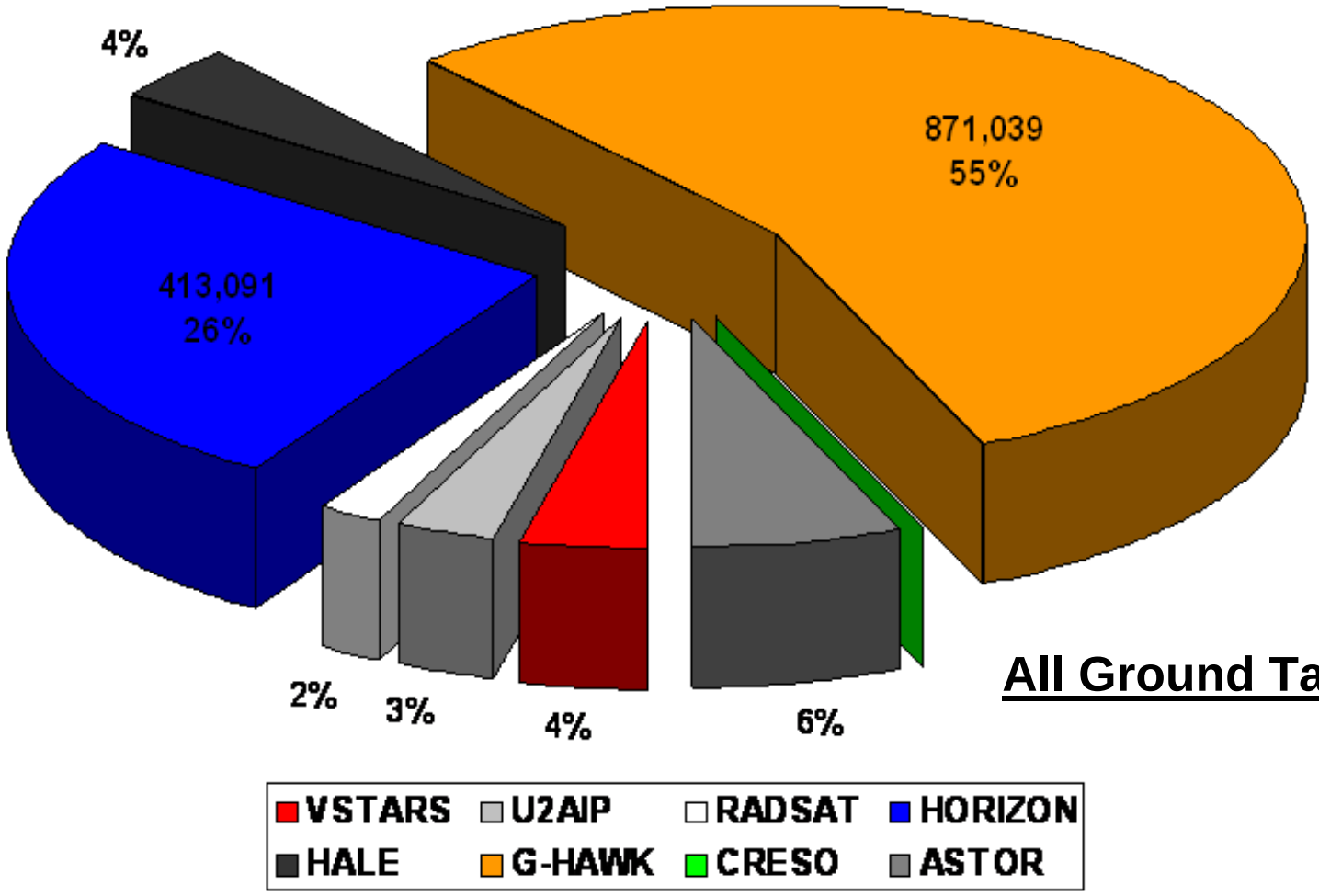
- Based on all sensor data combined
- Does not include false alarms or MTI on airborne targets

Total 1.5+ million GMTI reports

Does not include MTI that did not associate with ground targets.

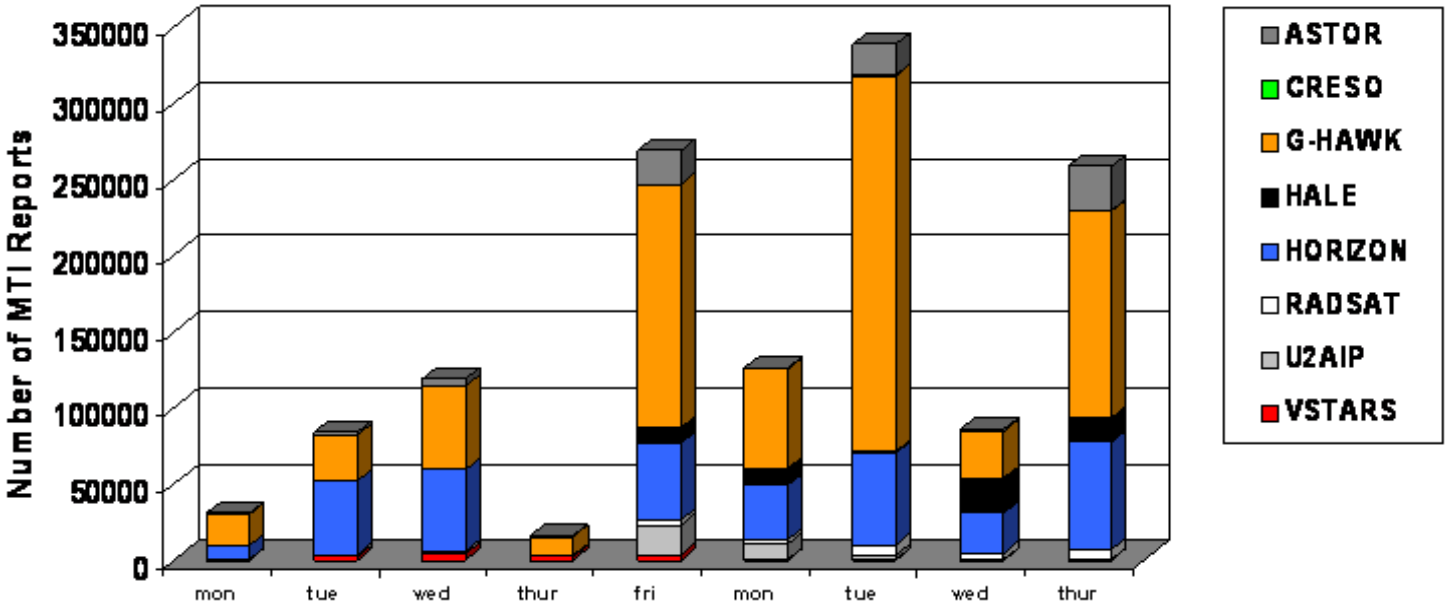
Based on truth id set by sensor simulations.

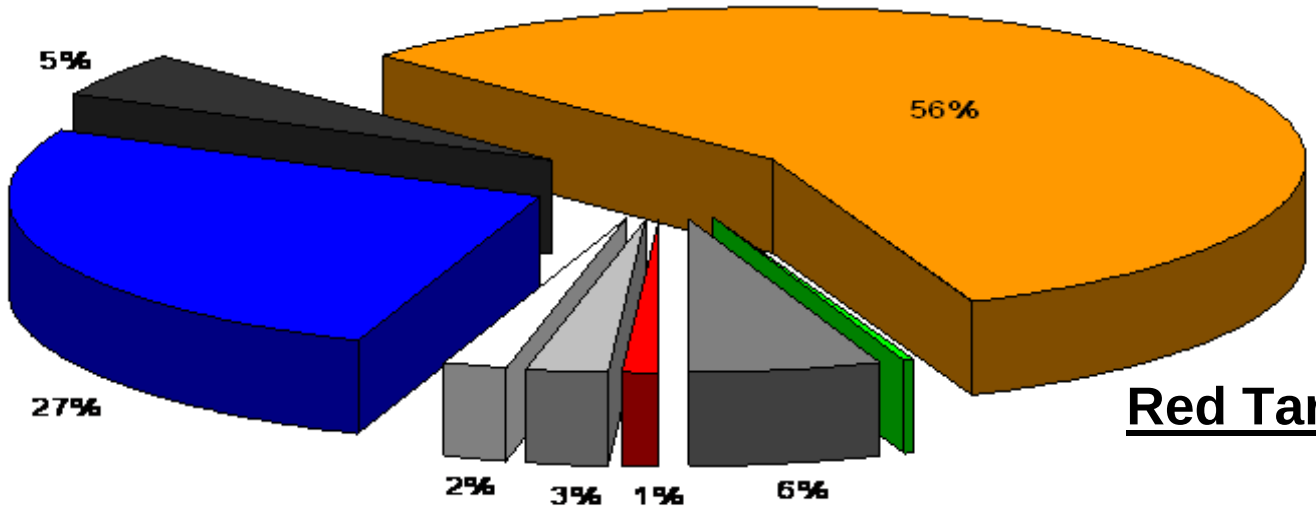
Total GMTI per sensor



MTI on ground targets only.
Does not include false alarms or MTI on airborne targets.

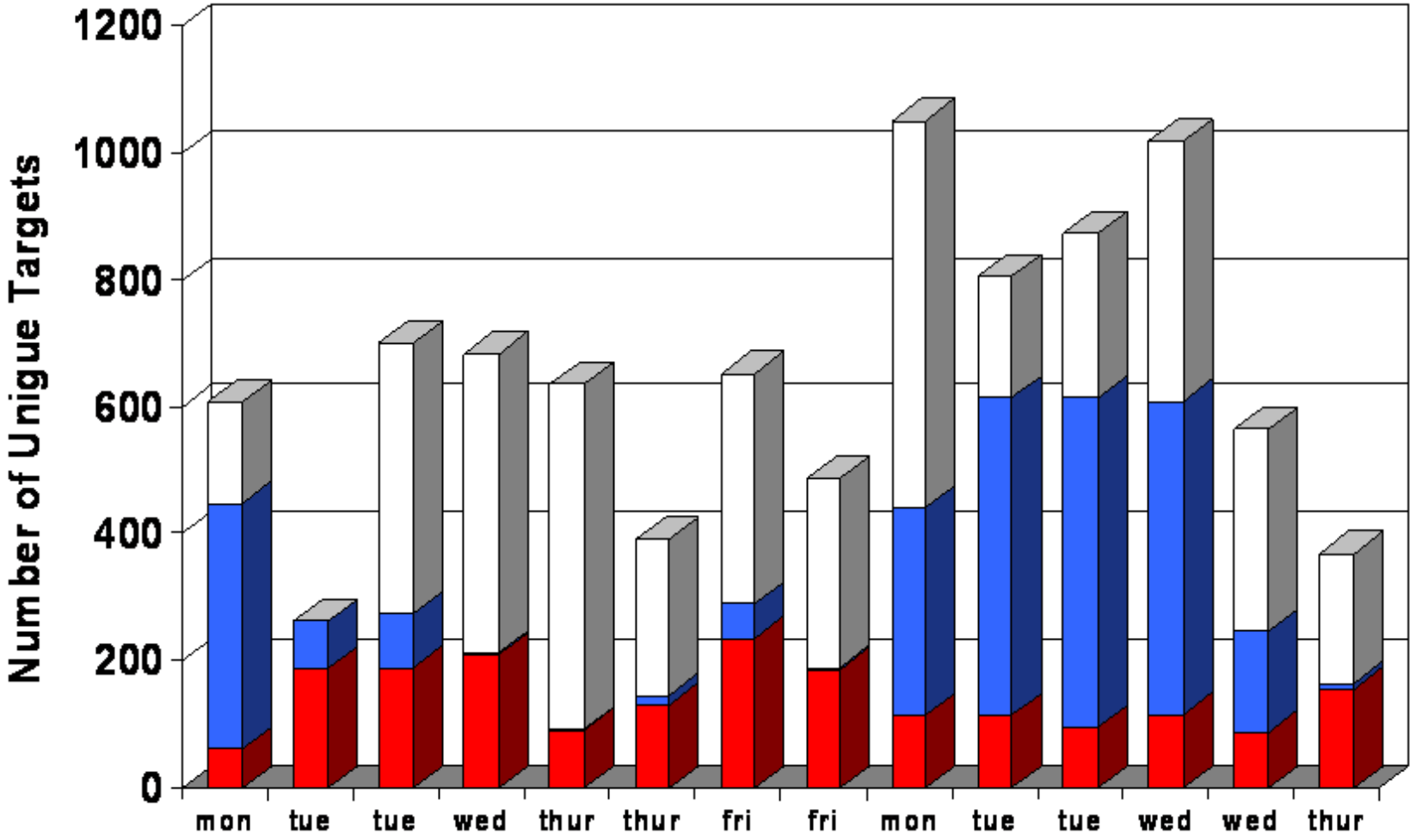
GMTI reports on red/hostile targets only





Red Targets Only

Targets Detected by GMTI Radar

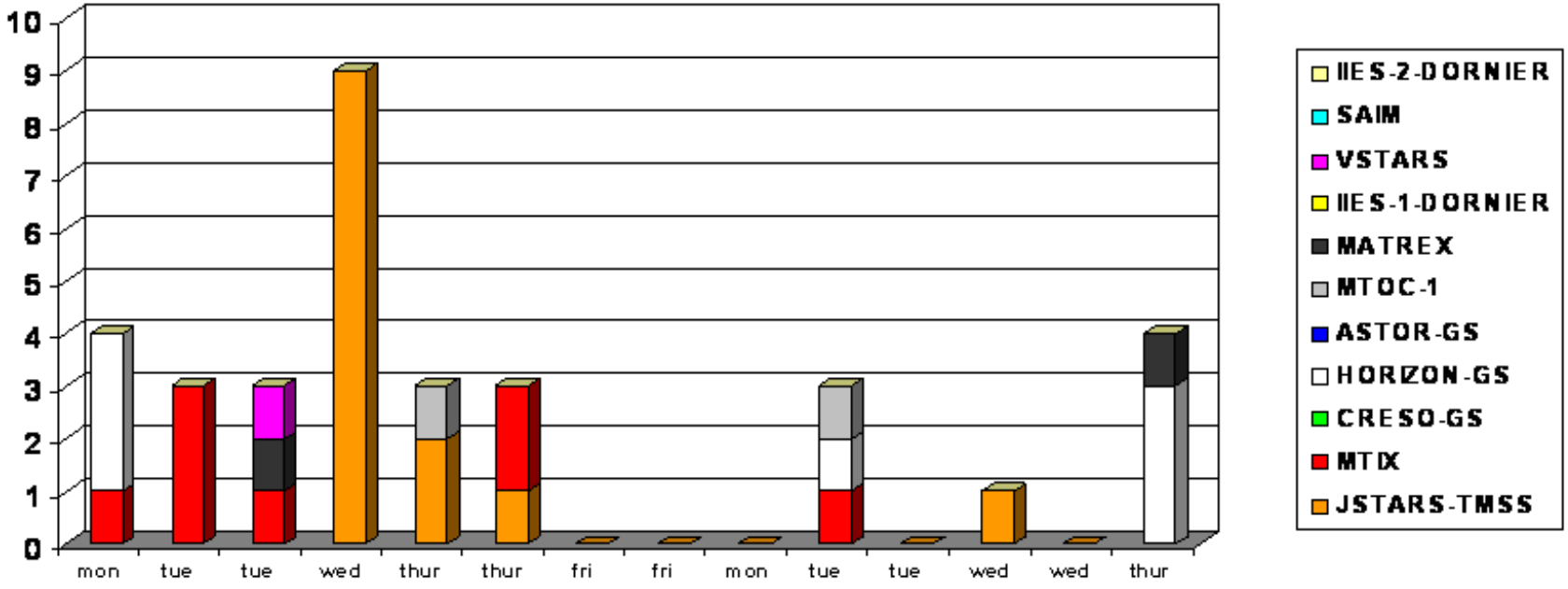


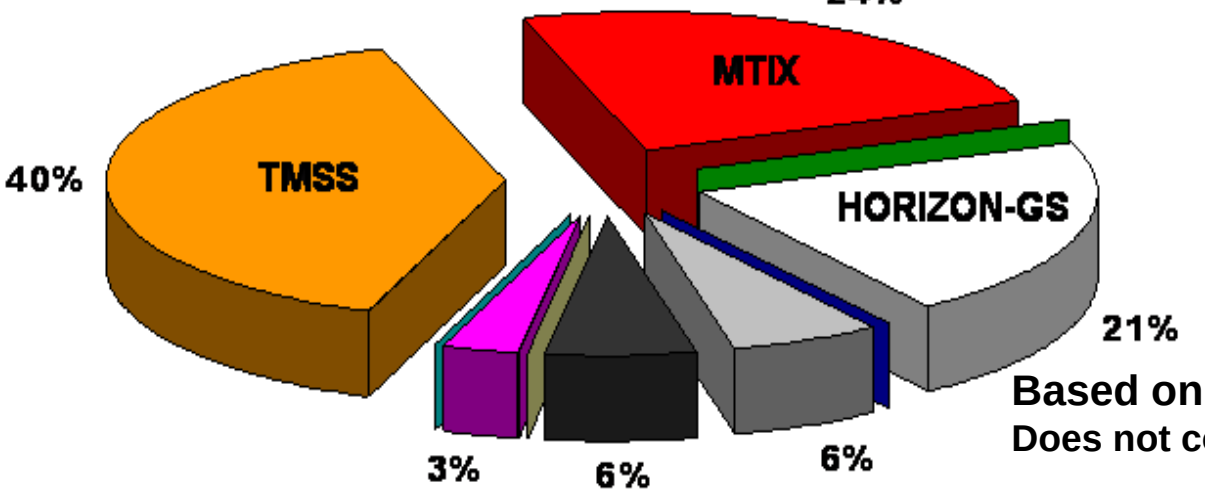
Based on all sensors combined.

Ground targets only.

Some runs are divided into AM/PM segments.

Unique Tracks per System – Red/Hostile Targets Only



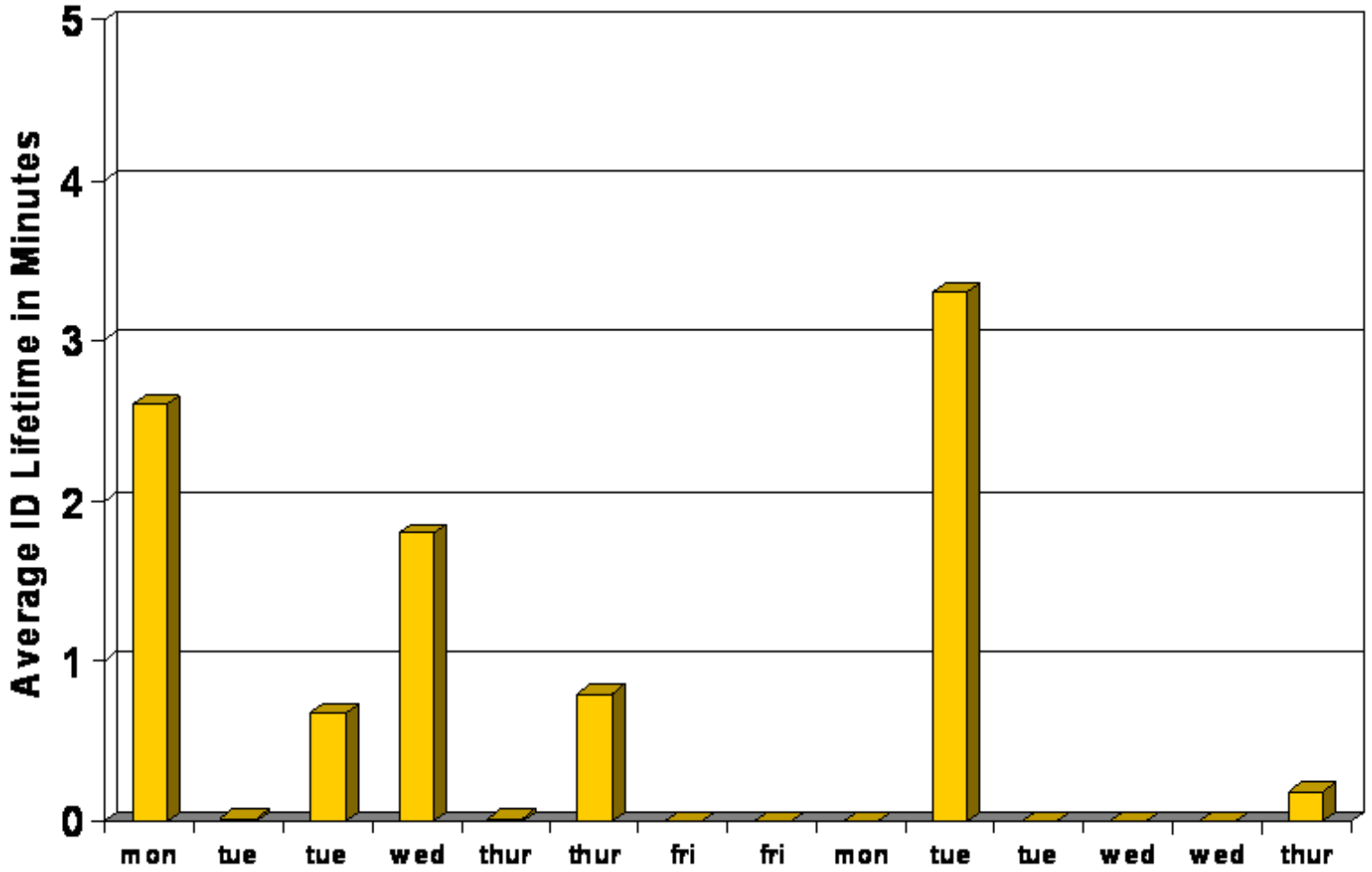


Tracks on Red Targets Only

Based on J3.5 on red targets only

Does not consider re-use of track ids per run/day

Track ID Lifetime – Hostile Targets



1.08 Minutes average across all J3.5 Tracks on red targets

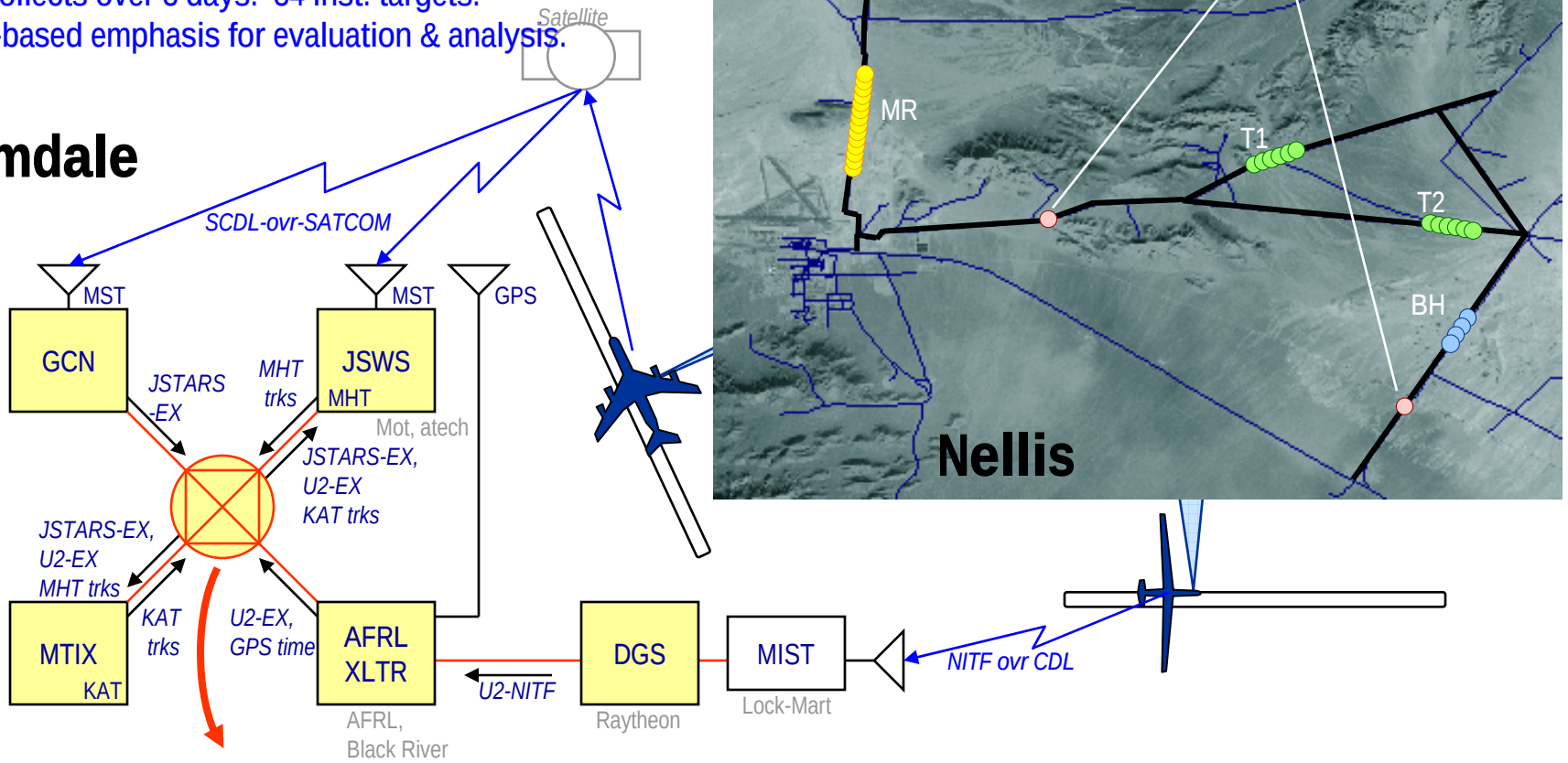
Track Updates are Today Performed through Voice Updates

Operator/Track Metrics Summary

- Current Army and Air Force Operators are use to Joint STARS
  - •There was an Operator Dependency on Joint STARS
- During the second week, operators tracked mostly friendly targets
  - -Difficulty with Intel given to operators or IPB ?
- Track ID lifetimes averaged slightly more than 1 minute
  - •Not Unexpected, current CONOPS and tools do not allow for Continuous Updates
- The majority of track update messages came from MTIX (67%)
  - -In one case 2000+ track messages were received for 4 tracks.
- The majority of targets tracked came from TMSS:
  - TMSS (28%), HORIZON (24%), and MTIX (17%)
- The majority of threat targets tracked came from TMSS :
  - TMSS (40%), MTIX (24%), and HORIZON (21%)
  - In one case 1 operator track switched between 19 red targets.

MPTE Experiment – Tracker Maturation

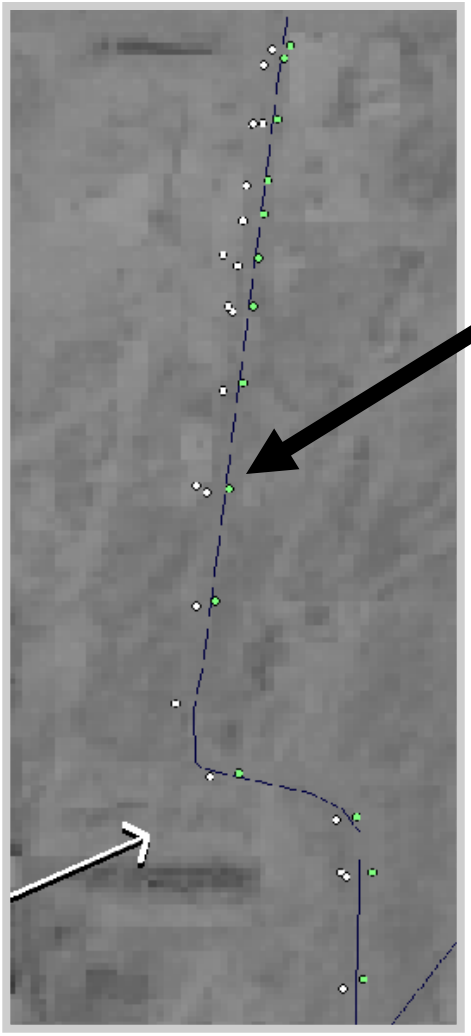
- Real-Time Fusion & Exploitation at Palmdale.
- Coordinated ISR collection.
- Dynamic re-tasking demonstrated.
- 3 Data collects over 3 days. 34 inst. targets.
- Ground-based emphasis for evaluation & analysis.



GMTI collected on GROUND network

MPTE program serves as tracking benchmark in 2001.

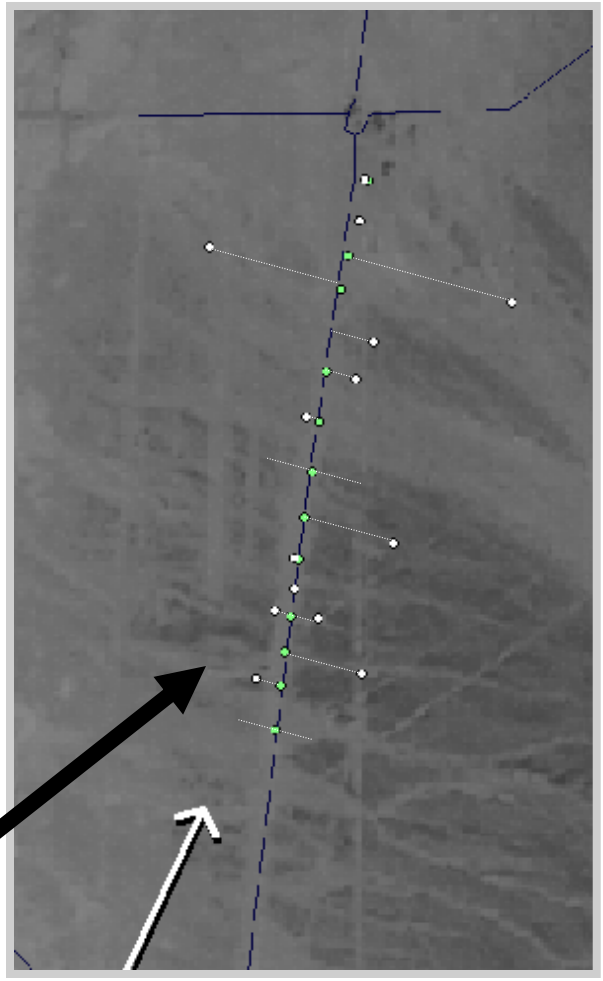
Sample Data



Platform 1

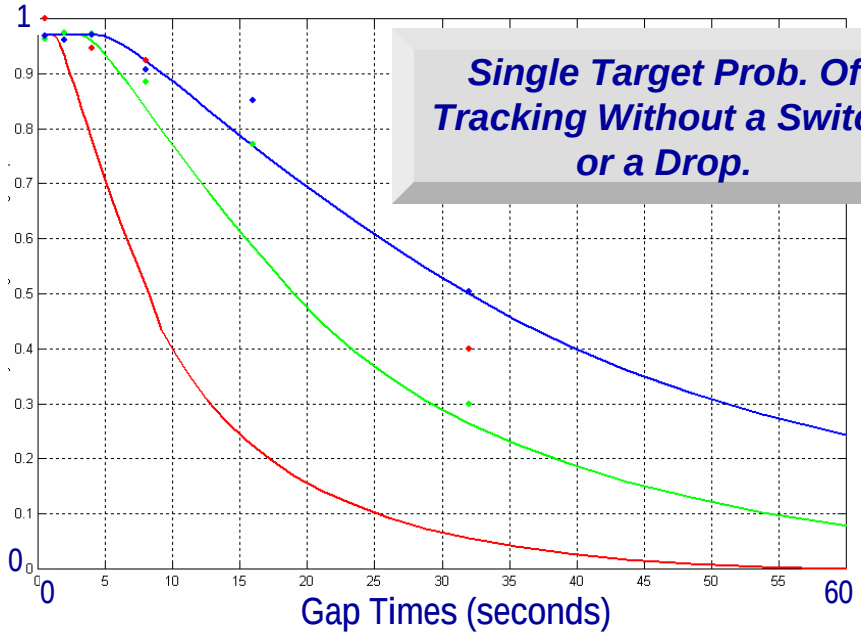
Measurements very accurate with quick revisits. Bias correction attempted during experiment. More systematic approach during track evaluation phase.

Range measurement very accurate with larger cross-range error expected (smaller antenna). No bias apparent.

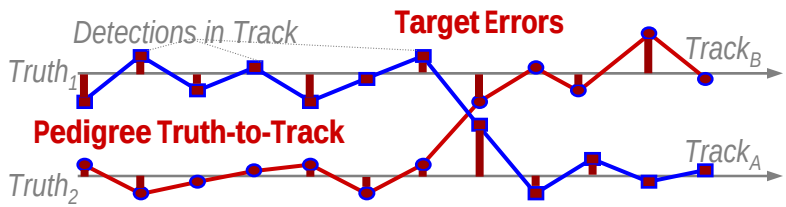


Platform 2

Single Target - Probability of Tracking

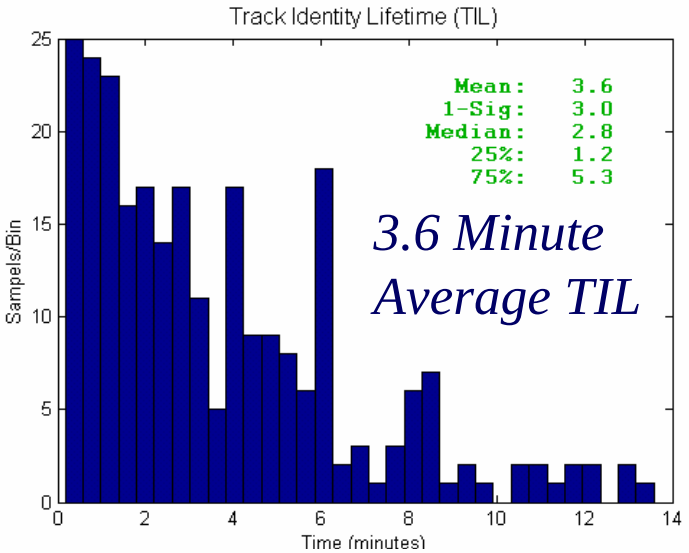


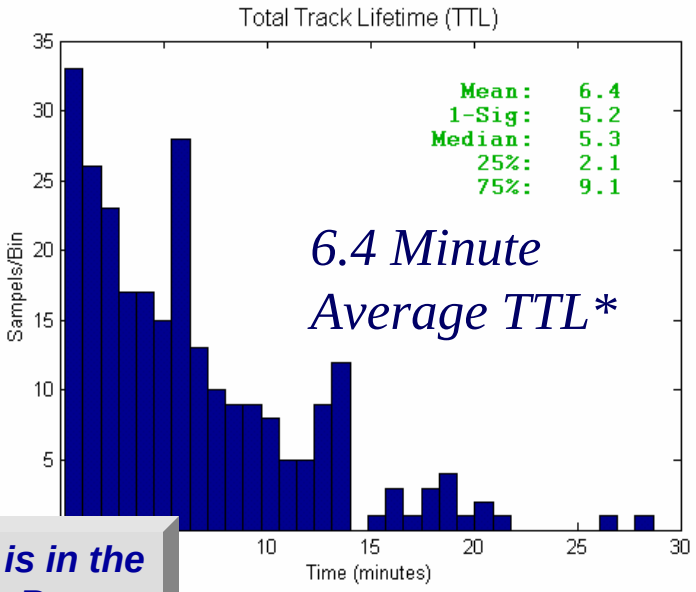
Single Target Prob. Of Tracking Without a Switch or a Drop.



Total Track Lifetime include track switching

Track Identity Lifetime excludes track switching

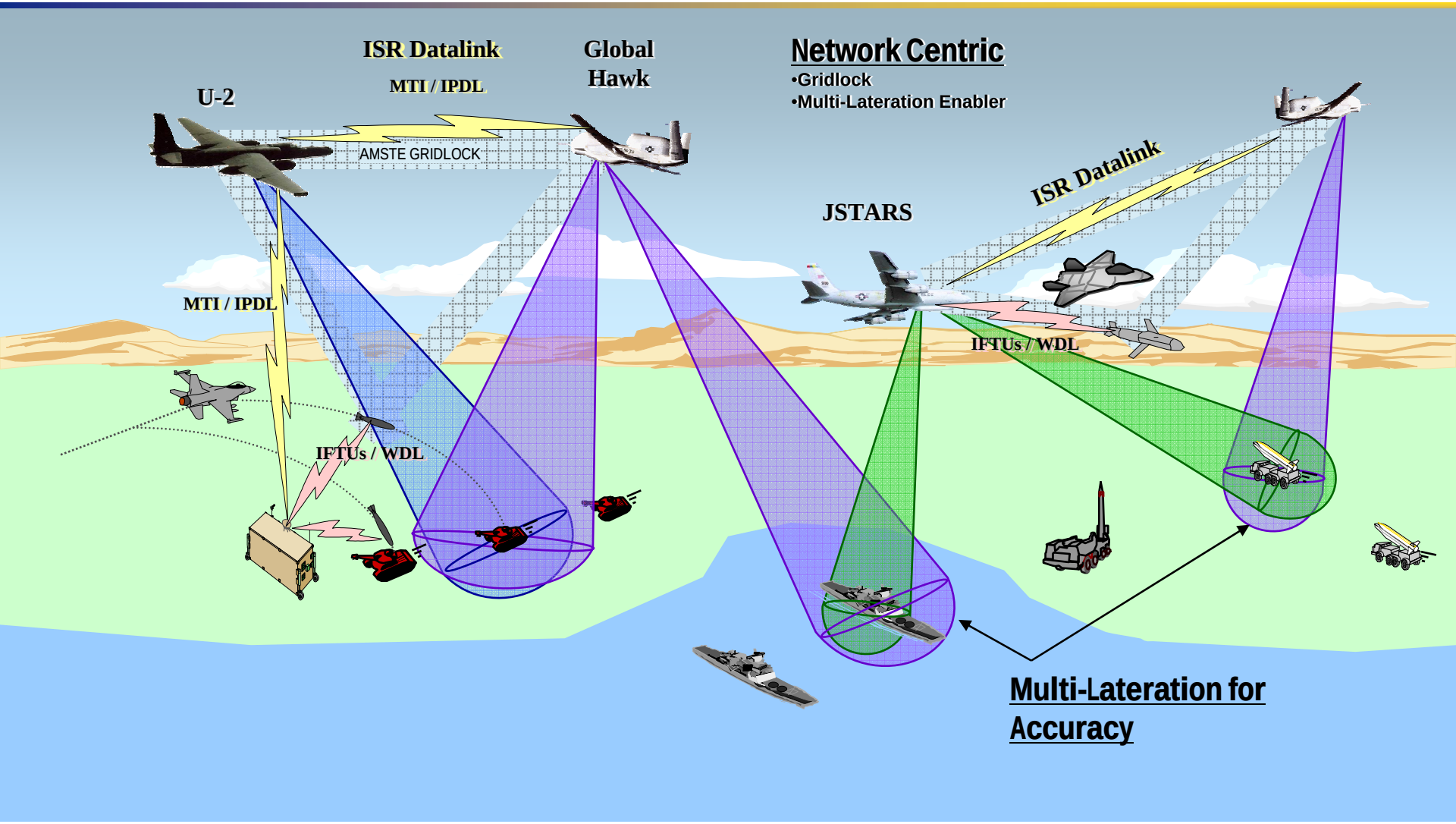




Results Show What is Now Called Tracklets

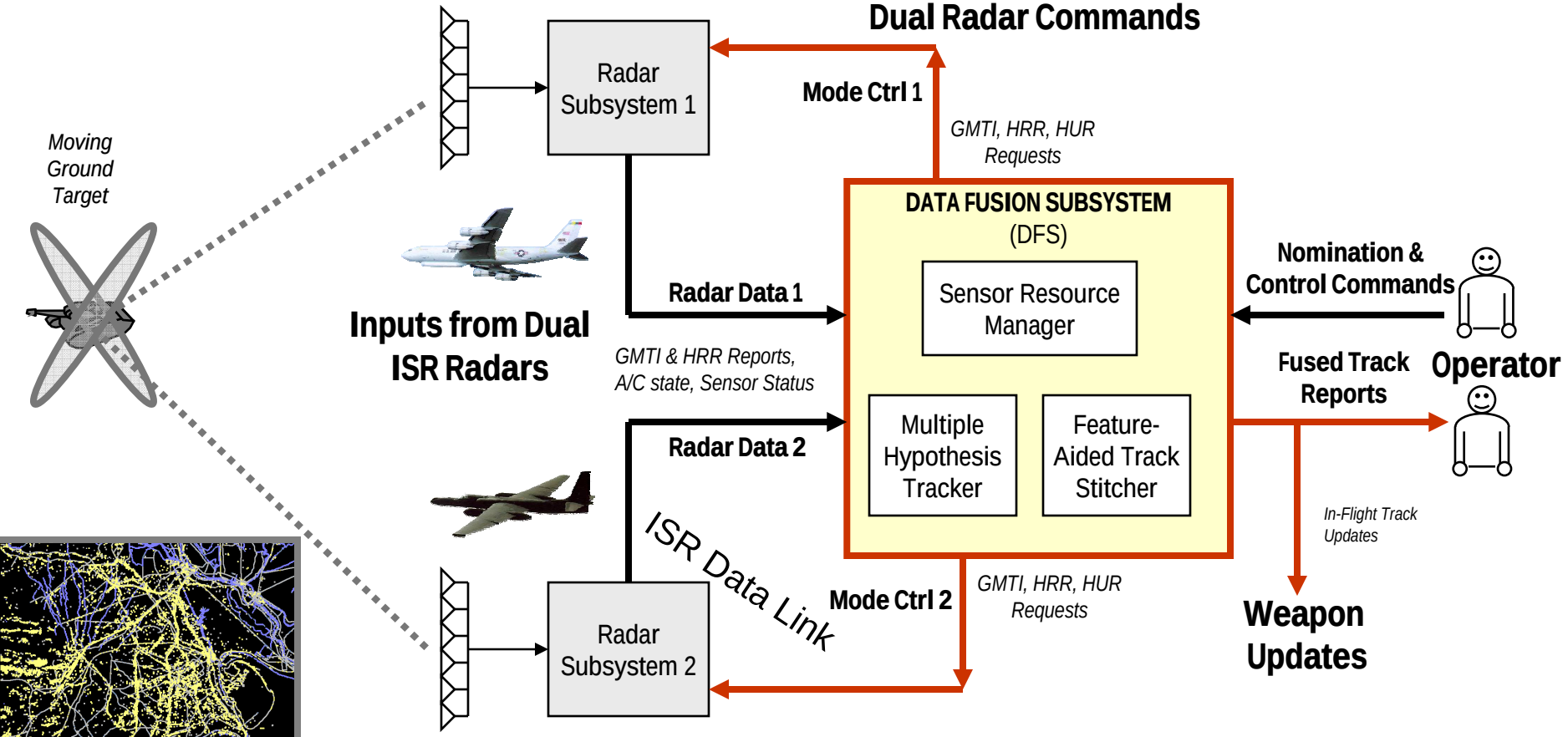
This is what is in the Track Data Base

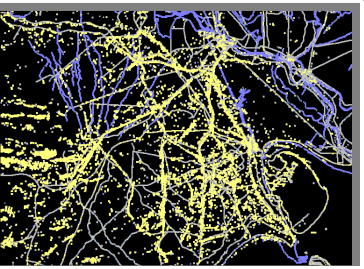
Affordable Moving Surface Target Engagement (AMSTE)



Network Centric Architecture

AMSTE Data Fusion System Architecture



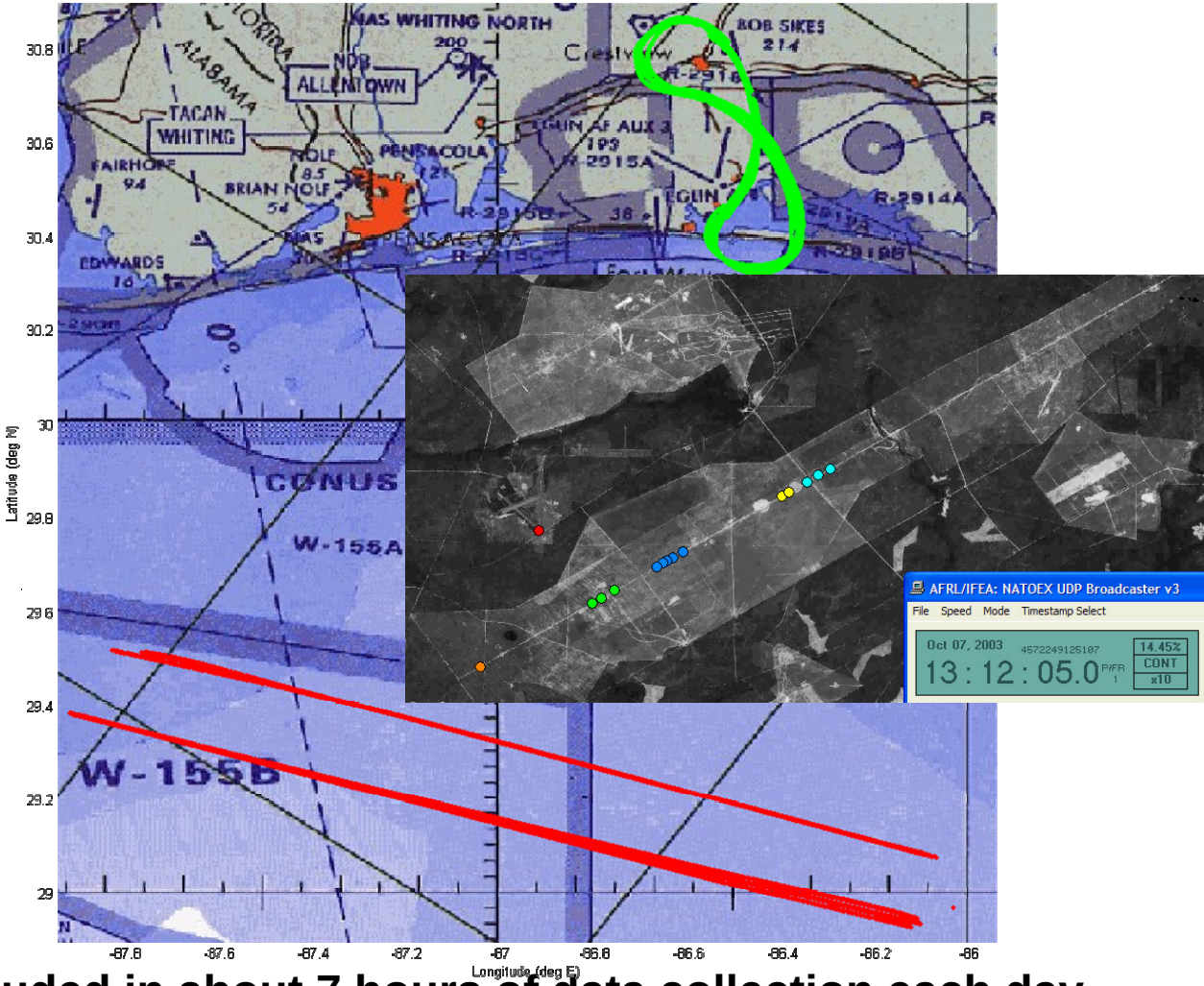


Given ISR GMTI detections, the challenge is Long Term Track Maintenance (>20 min.)

The DFS accepts ISR radar data and operator commands, and controls the weapon aimpoint and both radar systems.

AMSTE Oct 03 Exercise

- October 7th and 9th
- 6 Convoys
  - 2-6 Vehicles each
- Events
  - Passing
  - Intersection
  - Move-Stop-Move
  - On-Off Road
  - Terrain Blockage
- Features
  - HRR
  - RCS
  - TEA

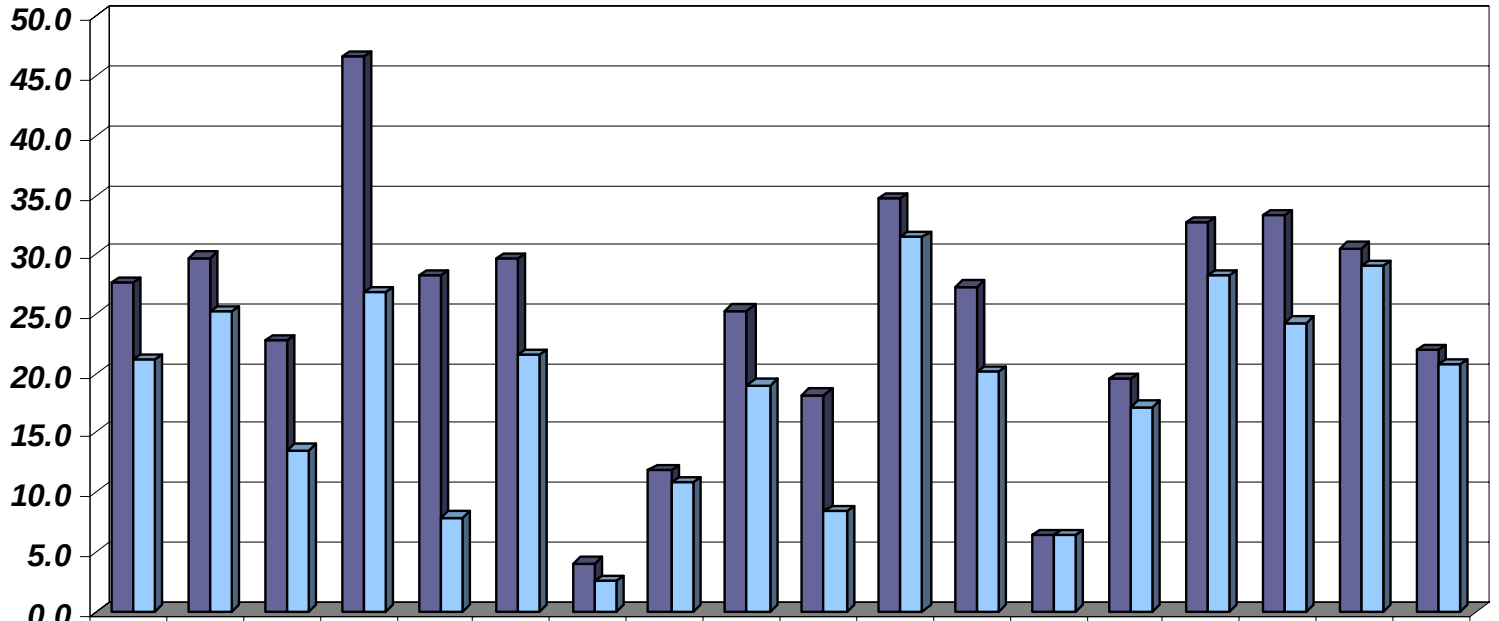


17 Scenarios included in about 7 hours of data collection each day

Each Confusion Event is Scored Based on Difficulty

LTTM Adjusted Lifetimes - 506

07-October, 2003 Flight 506 Nomination Duration & Track Lifetime (Adj.)

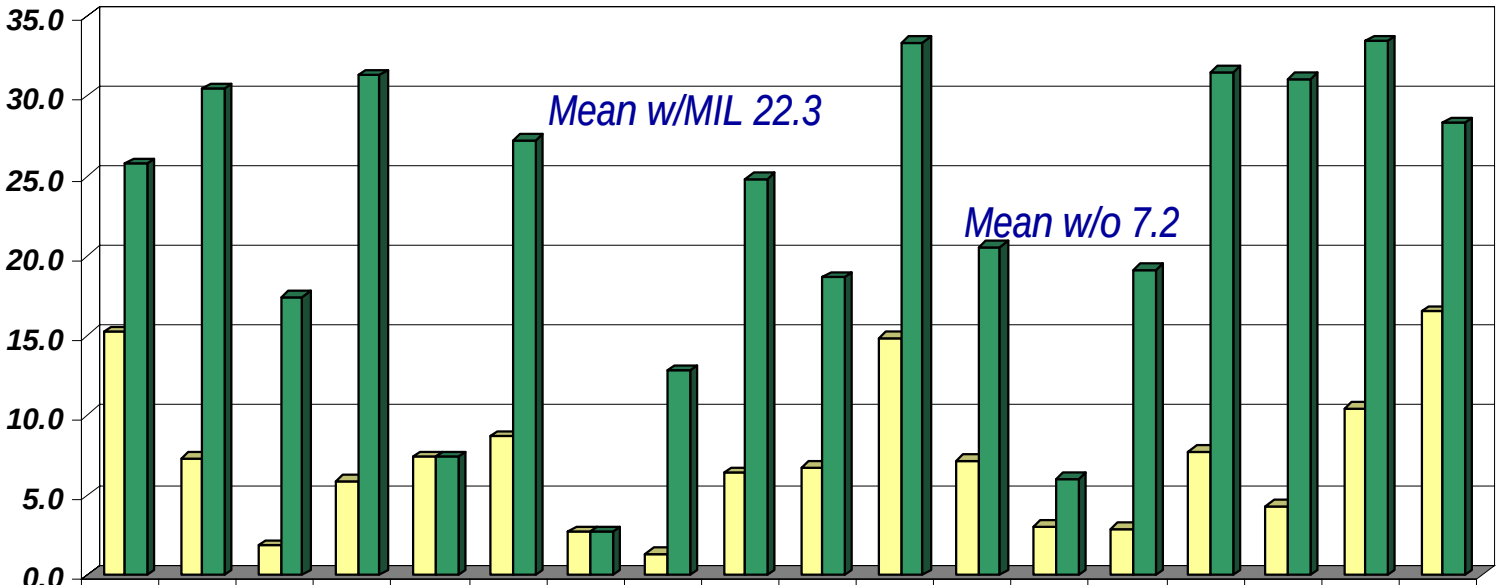


	1	2	3	4	5	6	7	18	8	9	10	11	12	13	14	15	16	17
Nomination Duration	27.6	29.8	22.7	46.6	28.3	29.6	4.0	11.8	25.3	18.2	34.7	27.4	6.4	19.6	32.7	33.3	30.5	21.9
Adjusted Lifetime	21.2	25.2	13.6	26.9	7.9	21.6	2.5	10.9	19.0	8.4	31.5	20.2	6.4	17.2	28.2	24.3	29.1	20.7

Track Identity Lifetimes (TIL) - 506

(with and without manual intervention)

07-October, 2003 Flight 506



	1	2	3	4	5	6	7	18	8	9	10	11	12	13	14	15	16	17
TIL - No Man. (min)	15.2	7.3	1.8	5.9	7.4	8.7	2.7	1.3	6.4	6.7	14.8	7.2	3.1	2.9	7.8	4.3	10.4	16.5
TIL - w/ Man. (min)	25.8	30.5	17.4	31.3	7.4	27.3	2.7	12.8	24.9	18.7	33.4	20.5	6.1	19.2	31.5	31.1	33.5	28.3

Weapon Drop

Weapon Drop

- F16 ~ 5 miles range
- Live JDAM, GPS Guided
- EPLRS Weapon Data Link
- EPLRS Inter Platform Comm.
- GMTI Coord. Passed to Weapon In Flight from JSTARS

Multi-Platform Fusion of GMTI Achieves Accuracy

Summary

- **GMTI Tactical Grade Tracking is "Hard"**
  - **Well Defines Measures of Performance**
  - **State of the Art is Improving**
  - **Requires Significant Resources**
- **State of the Art in Improving**
  - **MPTE achieved 3.6 minutes**
  - **AMSTE improved this to 7.2 Minutes**
- **Situation Awareness Metrics need Maturing**
  - **Operator in the Loop Measures Provide a Unique Result**
  - **Tracks are only performing "Book Keeping"**
  - **Detections Provide Some Unique "Pattern Analysis"**