MIT
Security Studies Program

Science and Technology Shortfalls in the National Missile Defense Program

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Washington, DC
Thursday 1 March 2001

Essential Points

- The EKV Must Be Able to Discriminate on its Own for the System to Work
- The Physics and Phenomenology of the Infrared Signals from the Objects Observed in the IFT-1A are Not Understood
- This Means that They Cannot Accurately Predict What the EKV Will See Even When the Details of the Objects and Their Dynamics Are Known
- The Baseline Algorithm Cannot Work Unless there is Accurate Prior Knowledge of the Properties of the Signals -- Even Then, the Means and Variances of the IR Signal Intensities from the Different Targets Must Not Substantially Overlap
- The Kalman Filter Will Only Work If the Properties of the Fitting Function Properly Match Those of the Signal Being Analyzed – Even Then, the Oscillating Behavior of the Signal Must Somehow Be Connected to an Unalterable Identifying Physical Characteristic of the Warhead
- The IR Signals Have Oscillatory Behavior that is not Properly Captured by the Fitting Function – This is Why the POET Could Not Initialize the Kalman Filter
- All the Above Having Been Said – The Features of the Signals Needed to Determine Which Objects are Warheads and Which are Decoys Must Be Connected to Unalterable Physical Properties of Warheads Relative to Decoys.
- If This is Not the Case, Both Logic and Physics Dictate that Discrimination Can Never Be Achieved.

Why the Kill Vehicle Must Identify the Lethal Object Without Help From the Radar

POET Study 1998-5

Independent Review of TRW Discrimination Techniques Final Report

(Title UNCLASSIFIED)

M-J. Tsai, MIT Lincoln Laboratory

Larry Ng, Lawrence Livermore National Laboratory

Glenn Light, Aerospace Corporation

Frank Handler, POET/Lawrence Livermore National Laboratory

Charles Meins, MIT Lincoln Laboratory

Unclassified Draft

EXECUTIVE SUMMARY

[U] The exoatmospheric kill vehicle (EKV) is the most technically challenging aspect of National Missile Defense (NMD) development. The EKV must acquire and track the target complex, discriminate and select the reentry vehicle (RV), maneuver to the RV, and kill it by kinetic impact. Target discrimination and selection must be done with or without handover information [illegible]out the target from the rest of the NMD system.

[U] TR[illegible] an onboard autonomous discrimination [illegible] a set of algorithms for the Boeing [illegible] against threats described in the *Technical Requirements Document* (T[illegible]) using simulated data, as well as against the target suite flown on integrated flight test IFT-[illegible] using data collected by the Boeing EKV. During the past two years, various technical concern[illegible]ave been raised regarding the concept, implementation, and performance of TRW's discriminati[illegible] baseline algorithms (BLA).

[U] Recently a POET team was tas[illegible]d by *BMDO JN/I to conduct an independent review of* TRW's baseline discrimination techn[illegible]ues. With cooperation from the Ground-Based Interceptor Program Office (GBI PO), TRW, N[illegible]C, and DCIS, the POET team has completed three major tasks: (1) a review of the scientific, [illegible]athematical, and engineering principles of TRW's BLA; (2) a review of the BLA's perform[illegible]ce against the IFT-1A data as reported by TRW to the Government; and (3) a determin[illegible]on of the projected performance of the BLA against possible IFT-3 scenarios.

[U] In fulfillment of the first t[illegible]k, the POET team reviewed the concept, design, implementation, and operational performance [illegible]alyses of the BLA, primarily by studying technical documents provided by TRW, JN/I, th[illegible]GBI PO, and DCIS. The POET team's major findings may be summarized as follows:

[U] 1. Overall, the B[illegible]A are well designed and work properly, with only some refinement or redesign requi[illegible]d to increase the robustness of the overall discrimination function. (Specific com[illegible]ents on redesign are listed in items 2 and 3 below; items 4 and 5 pertain to ro[illegible]stness).

[U] 2. The gap-f[illegible]ng algorithm (GFA), *which was designed to fill data gaps induced by low* signal-to-n[illegible]se ratio (SNR) signals early in the engagement timeline, has not yet been demonstr[illegible]d to be effective. Its use may actually hurt rather than help with baseline discrimi[illegible]ion, as demonstrated in the IFT-1A postmission data analyses.

[U] 3. Amo[illegible] the eight features included in the BLA, only a few can be used in combi[illegible]ion for the discrimination function. Because they are derived *from only two* indep[illegible]dent radiant-intensity sequences as measured by the EKV sensor, the eight

III

EXECUTIVE SUMMARY

[U] The exoatmospheric kill vehicle (EKV) is the most technically challenging aspect of National Missile Defense (NMD) development. The EKV must acquire and track the target complex, discriminate and select the reentry vehicle (RV), maneuver to the RV, and kill it by kinetic impact. Target discrimination and selection must be done with or without handover information about the target from the rest of the NMD system.

Rigging of the Test Program to Avoid the Simplest of the Baseline Threats

The Highest Priority National Missile Defense Threats All *Properly* Included Tumbling Warheads, Including Tumbling Warheads Accompanied by Decoys – Yet the Missile Defense Test Program Was Carefully Designed to Reach Deployment While Avoiding Tests Against Tumbling Warheads with Decoys

DEPARTMENT OF THE ARMY
PROGRAM EXECUTIVE OFFICE, MISSILE DEFENSE
P.O. BOX 1500
HUNTSVILLE, ALABAMA 35807-3801

REPLY TO ATTENTION OF

October 3, 1994

National Missile Defense
Program Office

Mr. Ernest Demarchi
Rockwell International Corporation
P.O. Box 3089
Seal Beach, California 90740-2089

Dear Mr. Demarchi:

The following information is provided for your consideration in program planning and reporting element design refinement activities. The Technical Requirements Document (TRD), September 28, 1993, remains the source of the functional, performance, and interface requirements and guidelines for the Exoatmospheric Kill Vehicle (EKV) Program. The information below complements the TRD by providing threat requirements prioritization and nuclear environments guidance consistent with SW-K08-90 and the TRD. This prioritization is not intended to redirect your efforts, but to establish clearer guidelines for refining design requirements allocations and reporting compliance to meet the TRD.

The enclosed Table 1 provides the threat priorities to achieve compliance with the TRD near-term threat. The highest priority threat weapon types and scenarios for the Ground Based Interceptor (GBI) Element concept refinement are categories 1, 2, and 3 in Table 1. Category 1 is either the long range, single Reentry Vehicle (RV) threats with normal debris, fragments, or tumbling RVs. Category 2 expands category 1 to include the long range, single RV threat with Reentry Vehicle Associated Objects (RVAOs), simple penaids, or tumbling RVs. Category 3 adds the long range, multiple RV with RVAOs, Electronic Countermeasure (ECM), or simple penaids threats to the category 2. The TRD scenario number is included as a cross reference to the TRD requirements. This prioritization remains consistent with the TRD and aligns to current general guidance on threat priorities.

Category 4, the long range, multiple booster threats, is the next priority threat for the GBI Element concept. The Kill Vehicle (KV) capability to successfully engage these weapon system types is basically covered by categories 1, 2, and 3 requirements. As noted in the TRD, these higher threat traffic levels should not be considered in reporting single site, treaty compliant capabilities.

Appendix F

-2-

Category 5, the out-of-bastion Submarine Launched Ballistic Missile (SLBM) threat, and category 6, the TRD mature threat, are the lowest priority threats for the GBI Element concept. Existing documentation for performance against category 5 is adequate; no further effort is required on these threats. Documentation of performance capabilities and cost/complexity balancing in the preliminary and test KV designs should be completed in accordance with the contract for category 6. Summaries of capabilities against the mature threat beyond those required for the near term threat should only be documented and reported in accordance with SW-K08-90, paragraph 3.1.1. This is expected to be a summary of the robustness of the GBI Element and preliminary/flight test KV designs to threat evolution. Completion of documentation and submission of results for category 6 will be sufficient for this scope of work requirement.

Your preliminary KV design must comply with Level 1 nuclear requirements in accordance with SW-K08-90 and the TRD. You should identify deviations from the Level 1 requirements that could support near term contingency deployment options. You should use these options as the basis for identifying a traceable path from the flight test KV to the preliminary KV design meeting Level 1 requirements. The growth path to Level 2 required by SW-K08-90 should show a relationship to these options and the priorities for technology growth. You should provide risk assessments that form the basis for technology development recommendations supporting low risk achievement of Level 1 and growth to Level 2.

Point of contact is Mr. Charlie Dobson, (205) 895-3880.

Sincerely,

Jerry W. Cavender
Program Manager, National
Missile Defense

Enclosure

Table 1. Threat Prioritization

Category	Description	Scenario #	Comment
1	Long-Range, Single-RV Threats with Normal Separation Debris and/or Fragments and/or Tumbling RVs	5a, 8a, 10	
		9c	Excursion Scenario (N. Korea to Los Angeles)
		10b	Excursion Scenario (Iran to WDC)
2	Long-Range, Single-RV Threats with RVAOs and/or Simple Penaids and/or Tumbling RVs	4, 9a, 15	
3	Long-Range, Multiple-RV/Single Booster Threats – May have RVAOs and/or ECM and/or Simple Penaids	1c, 2c, 3c	Stressing Single-Booster Cases from Scenarios 1a, 2a, 3a
		6, 7a, 11, 12, 13	
4	Long-Range Multiple-Booster Threats	1a, 1b, 2a, 3a	
5	Out-of-Bastion SLBM Attacks	14, 16	Reduced Priority Due to Recent OSD Guidance
6	Mature Threats	2b, 3b, 5b, 7b, 8b, 9b, 16b, 17	Limited Design Refinement Beyond Near-Term Threat

POET Acknowledgement of the Significance of Overlapping Expected Values and One-Sigma Ellipses

IFT-3 Discrimination Performance
POET Team's Prediction

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- Chance of success is excellent for nominal deployment conditions
  - IFT-1A represents the most stressing target suite
  - Utilize IFT-1A data collection for the MDL classifier database construction
  - Better seeker for IFT-3
- Chance of success is good even when penaids are misdeployed
  - Observed in previous tests (IFT-1, IFT-1A, IFT-2, etc)
  - Include anomalous target models in the MDL classifier database
- Risk is high when MRV tumbles
  - Heavy overlapping in feature space with MRLR (tumbling or spin-stabilized)

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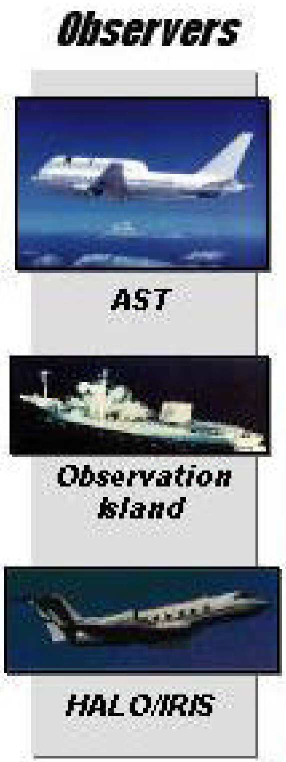
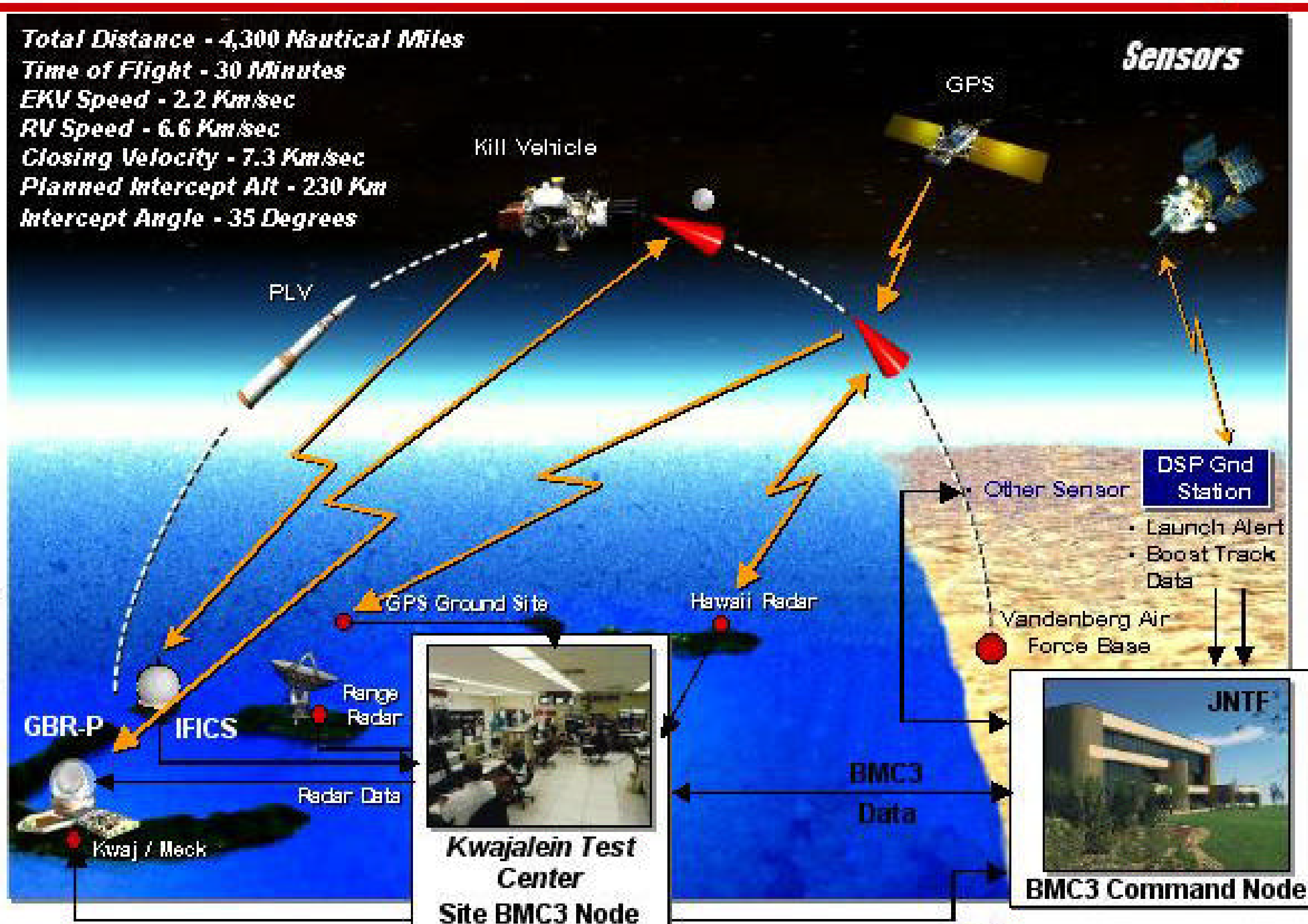
MRV means
Medium Reentry Vehicle

MRLR is the
Medium Rigid Light
Replica Decoy
(Cone-Shaped Decoy)

The Experimental Conditions for the Integrated Flight Tests 1A, 2, 3, 4 and 5 (IFT-1A, IFT-2, IFT-3, IFT-4, and IFT-5)

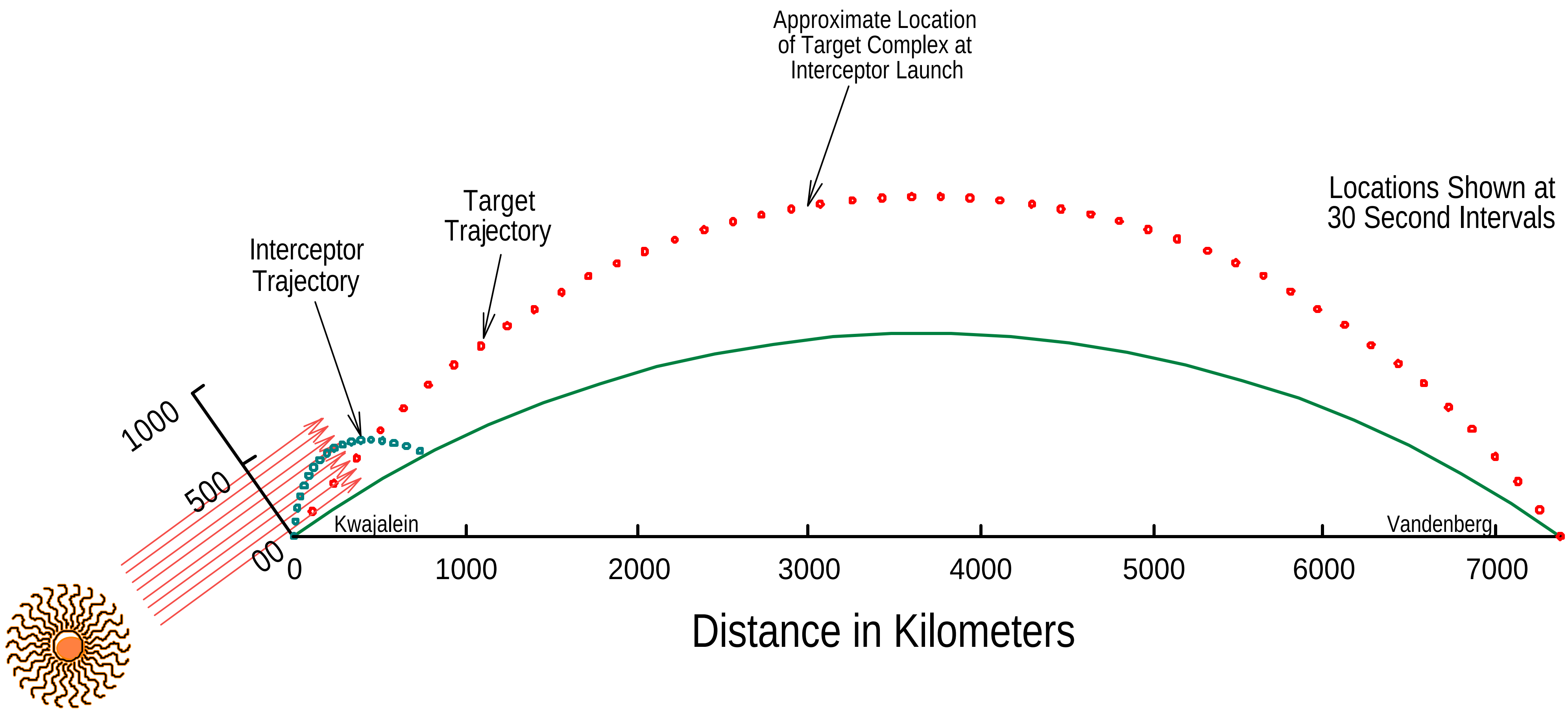
IFT-5 CONFIGURATION





Actual Geometry of the IFT-1A Through IFT-5 Experiments

Intercept Conditions
Altitude ≈ 230 km
Location ≈ 680 km from Kwajalein
Speeds at Intercept ≈ 2.1 km/sec and 6.5 – 6.6 km/sec



The Baseline Algorithm

Requires Prior Knowledge
of the Signal Intensities
and the Fluctuations in Intensities
from the Warheads and Decoys

Fails Because

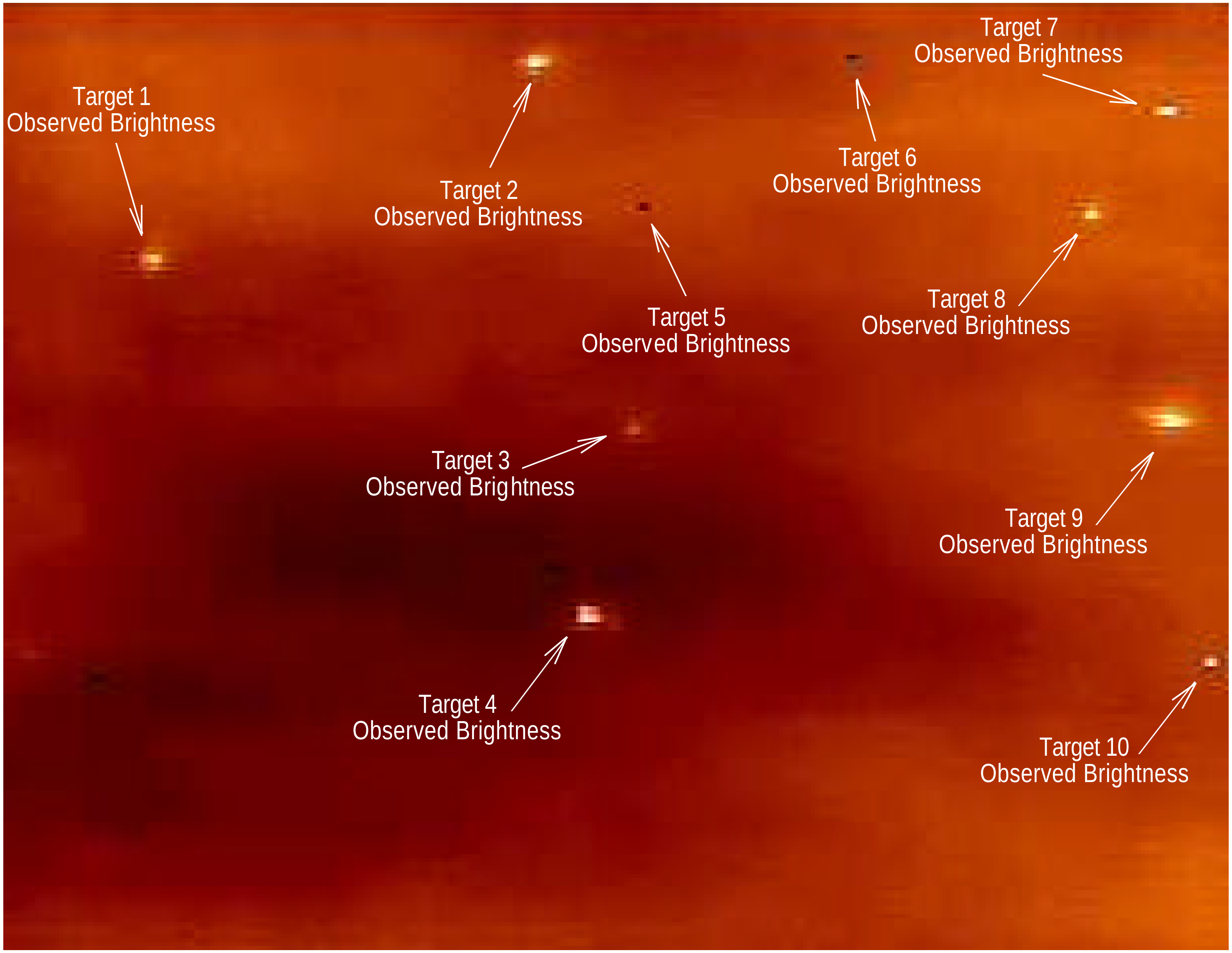
Measured Target Intensities Did Not Match the *Predicted* Intensities

and

Observed Average Target Intensities Were *Unstable* in Time
(Signals were Non-Stationary)

Targets are Identified by Their Brightness in Two Infrared Wavelength Bands

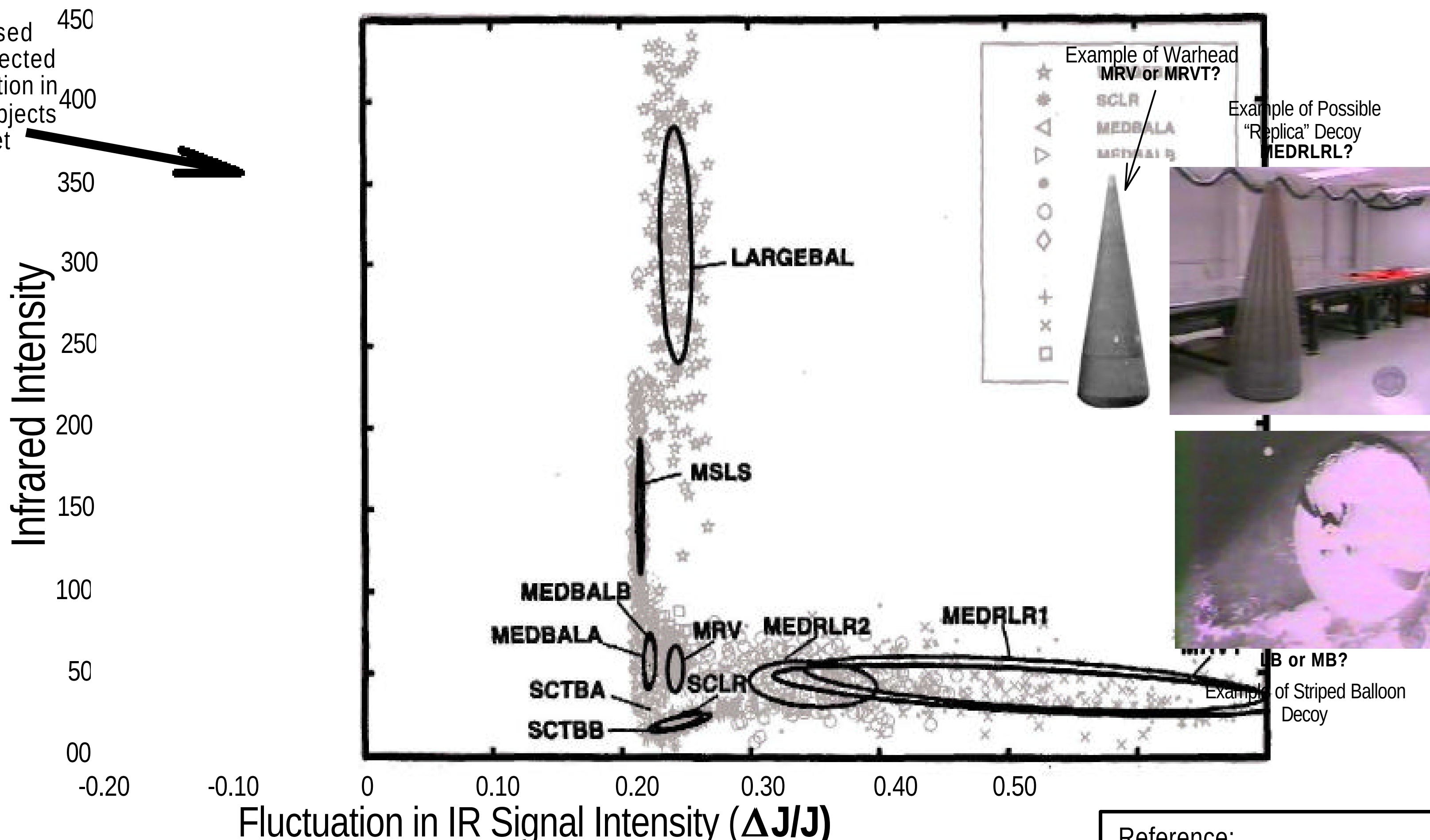
Targets As They Might Be Seen at 200 kilometers range
~20 seconds to impact, lateral separation ~ 3.5 – 7 km?, total divert ~1 km/sec



Expected Brightness and Fluctuation in the Brightness of the Objects in the IFT-1A and IFT-2 NMD Tests

Note: The Expected Brightness and Fluctuations in the Brightness of Targets Actually Observed in the IFT-1A Experiment Did *NOT* Match the Pre/Post-Flight Physics-Based Predictions of Brightness

Published Physics-Based Predictions of the Expected Brightness and Fluctuation in the Brightness of the Objects in the IFT-1A Target Set



Reference:

Transparent Overlay of Figures 4 and 5 from the POET Report 1998-5

[U] Figure 5. One-σ ellipses computed from the feature vectors shown in Figure 4.

How the Ellipses Used in the Baseline Algorithm Were Generated

Requires Prior Knowledge of the Target Structure, Shape, Environment, and Dynamics

Fails Because

Unexpected Deviations in Target Dynamics, Structure, and possibly the Space-Environment are Not Captured in the Calculations

Solution to Problem

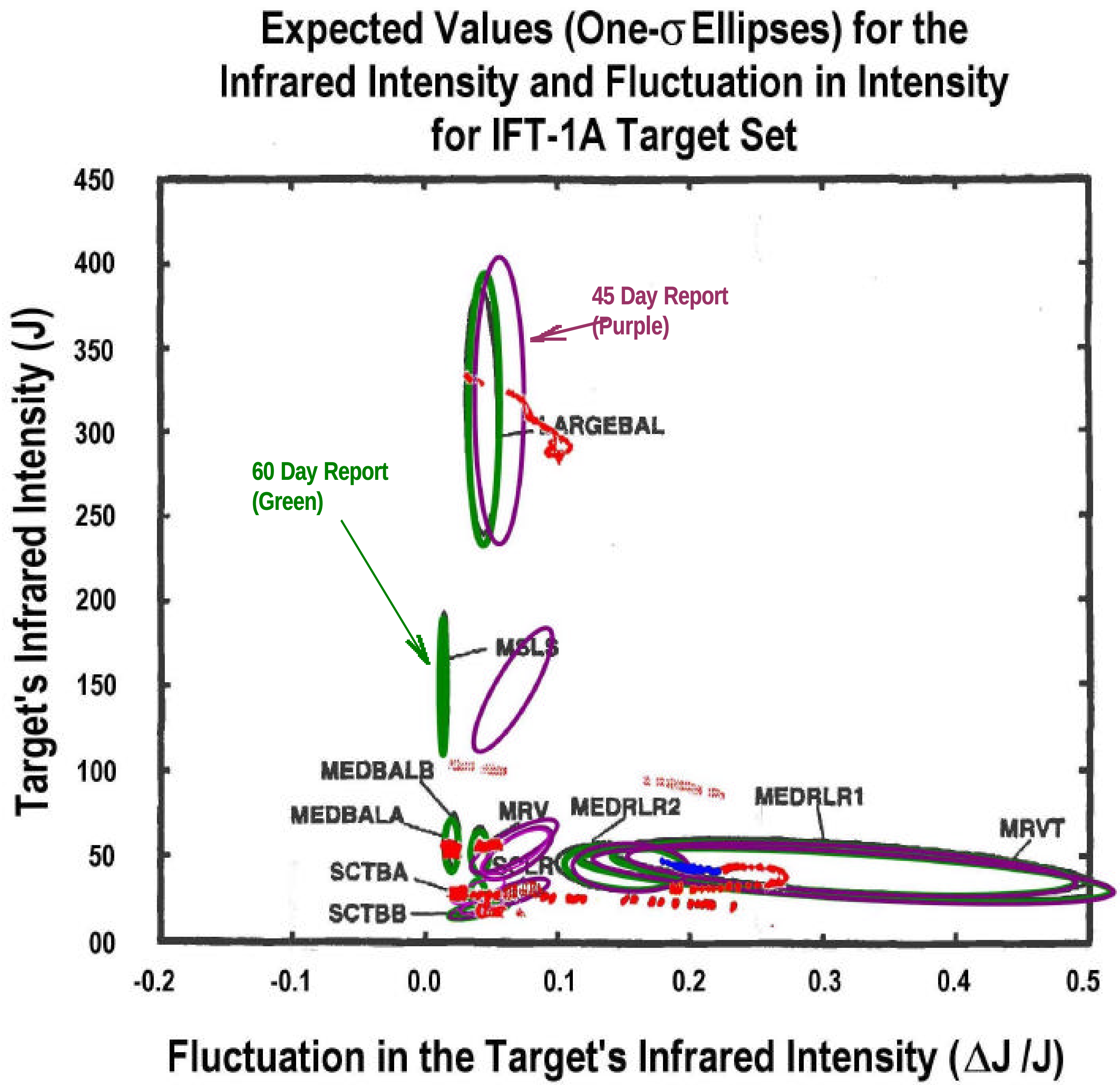
Construct the Ellipses Used in the Baseline Algorithm by Matching Them to the Observed Data
(That is, Move the "Bulls Eye" to Where Hits Occurred)

Statement Indicating that Top Management of the Ballistic Missile Defense Organization Knew About Discrimination Problems Identified in the IFT-1A Experiment

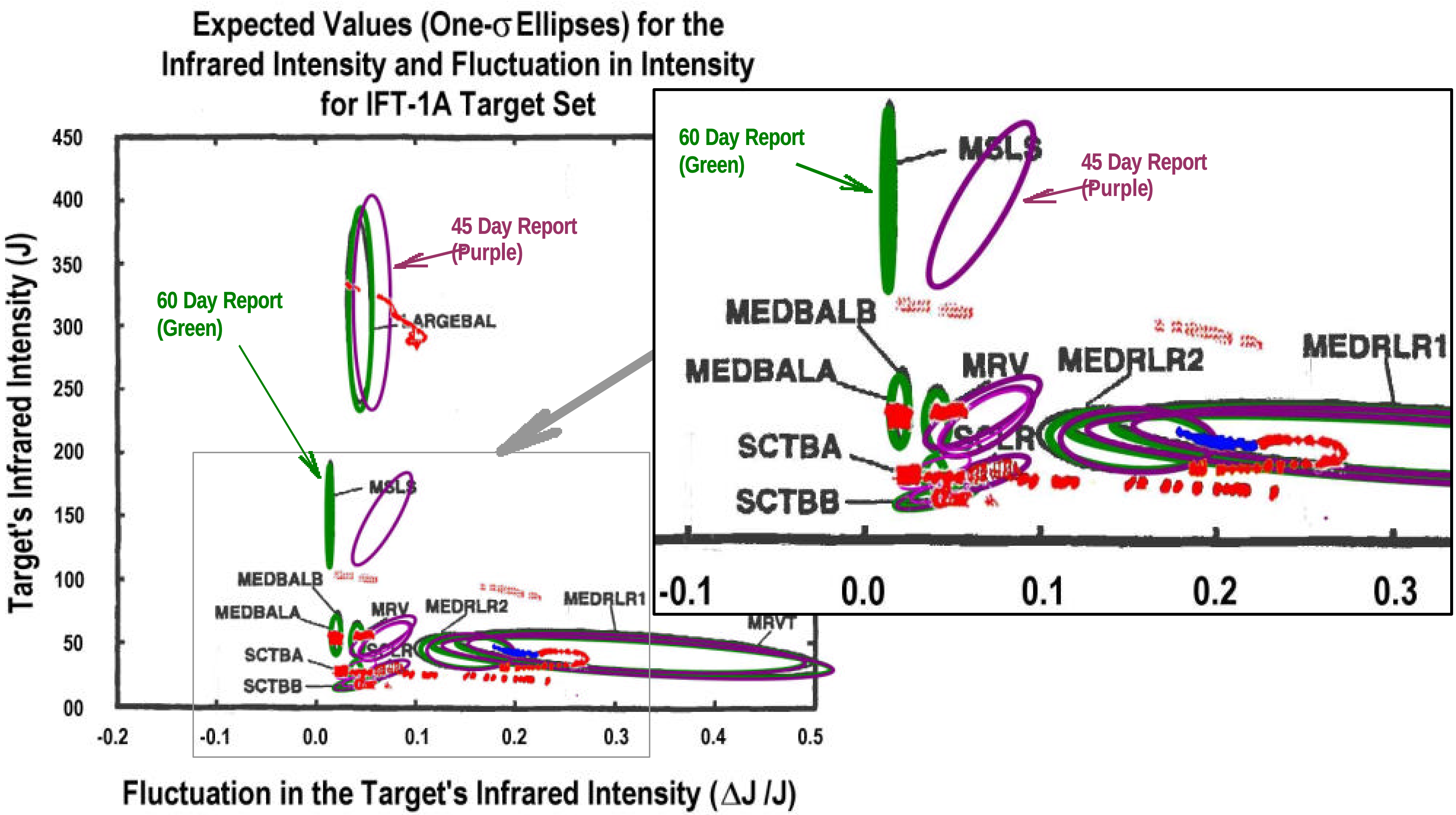
"So the decoy is not going to look exactly like what we expected. It presents a problem for the system that we didn't expect,"

Statement of
Lieutenant General Ronald Kadish,
Director of the Ballistic Missile Defense Organization,
while being filmed by 60 Minutes II after learning that
the 2.2 meter balloon misdeployed (did not inflate properly)
during the IFT-5 experiment

Discrepancies in One-σ Ellipses in the 45 Day Report with the Ellipses in the 60 Day Report

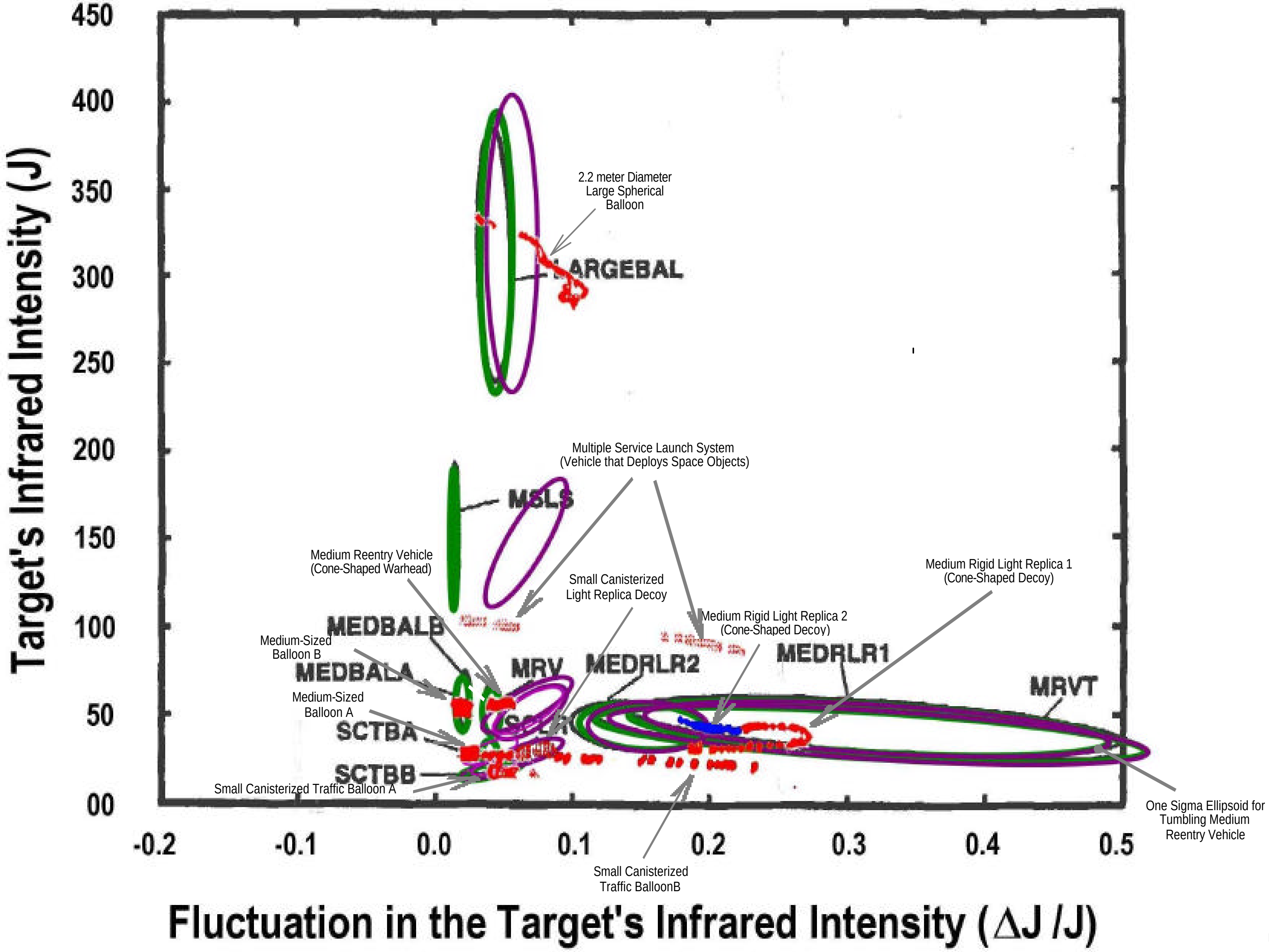


Discrepancies in One-σ Ellipses in the 45 Day Report with the Ellipses in the 60 Day Report

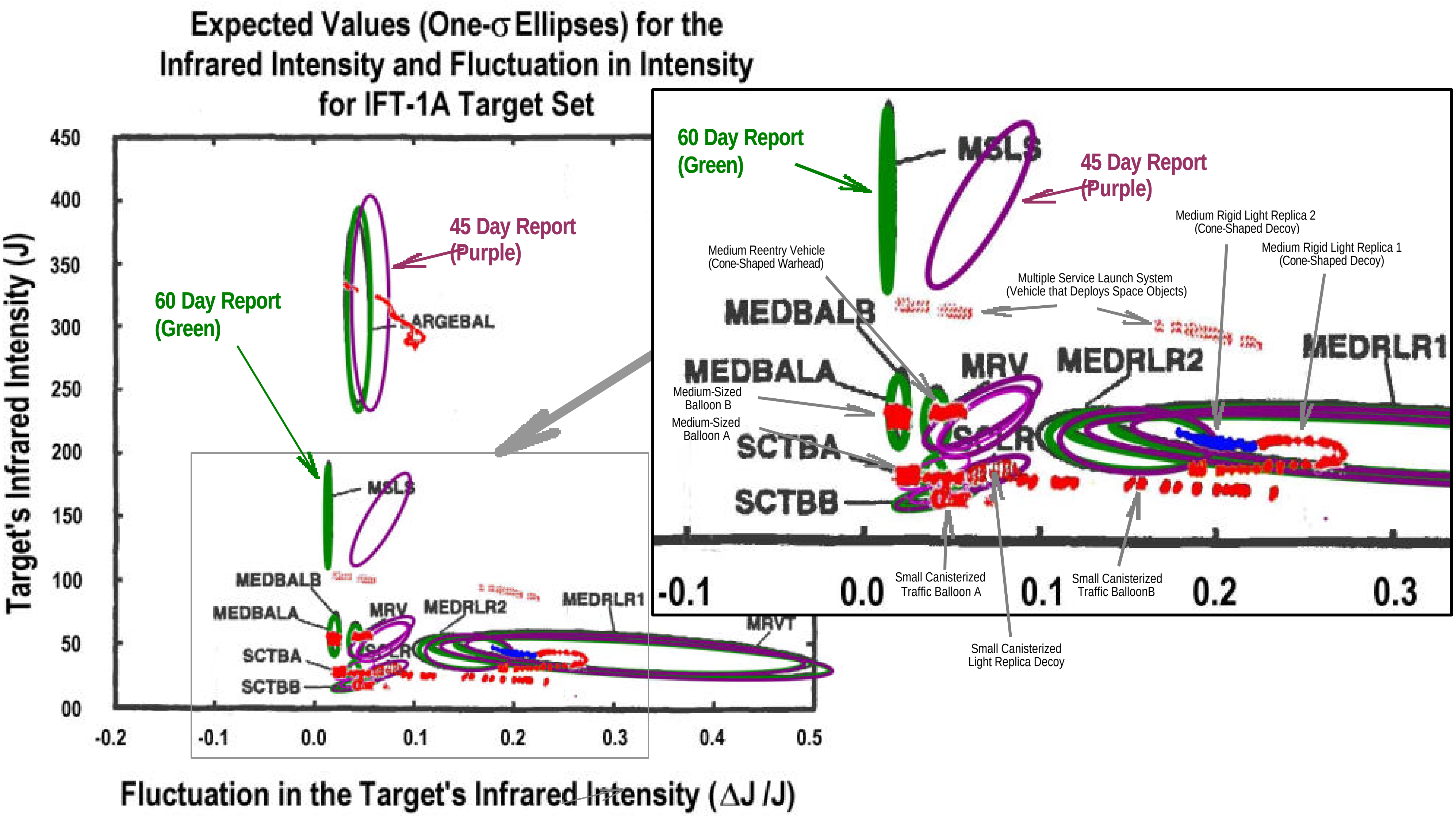


[U] Figure 5. One-σ ellipses computed from the feature vectors shown in Figure 4.

Estimated Identities of Targets Based on Observed Data, Expected Values, and One-Sigma Ellipses

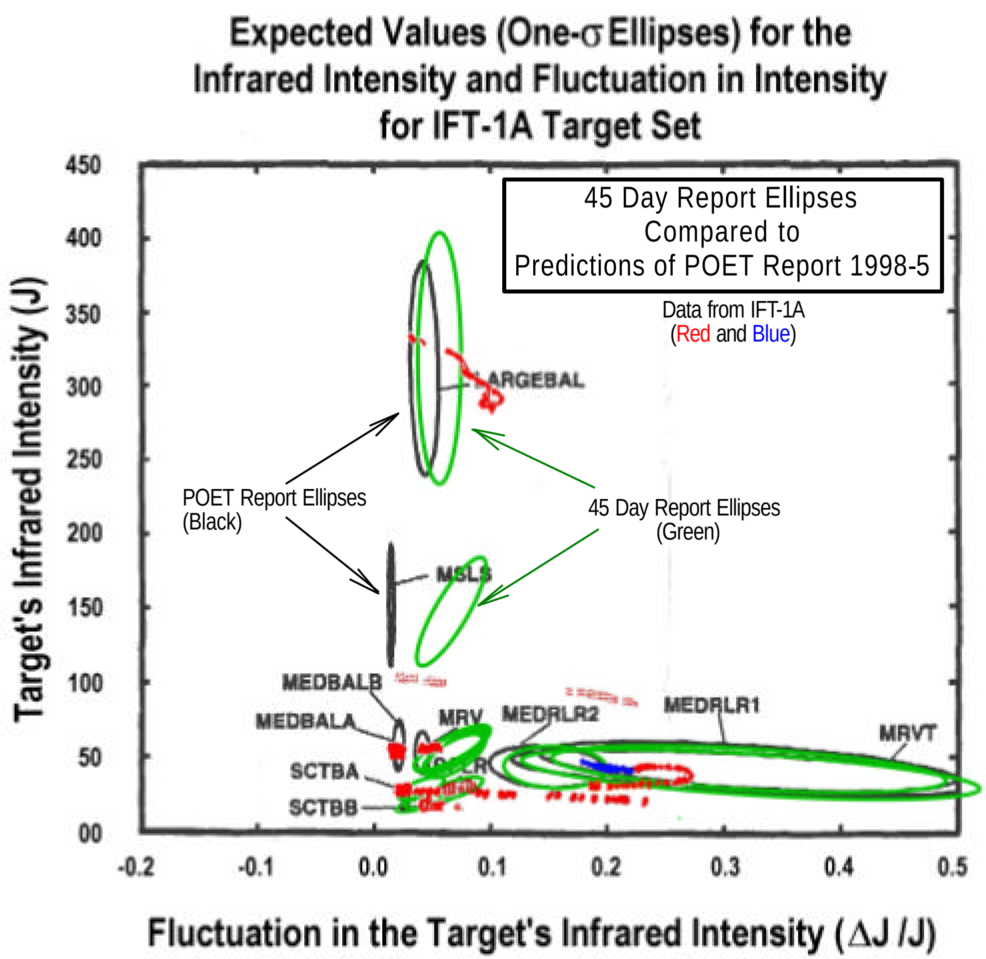


Discrepancies in One-σ Ellipses in the 45 Day Report with the Ellipses in the 60 Day Report

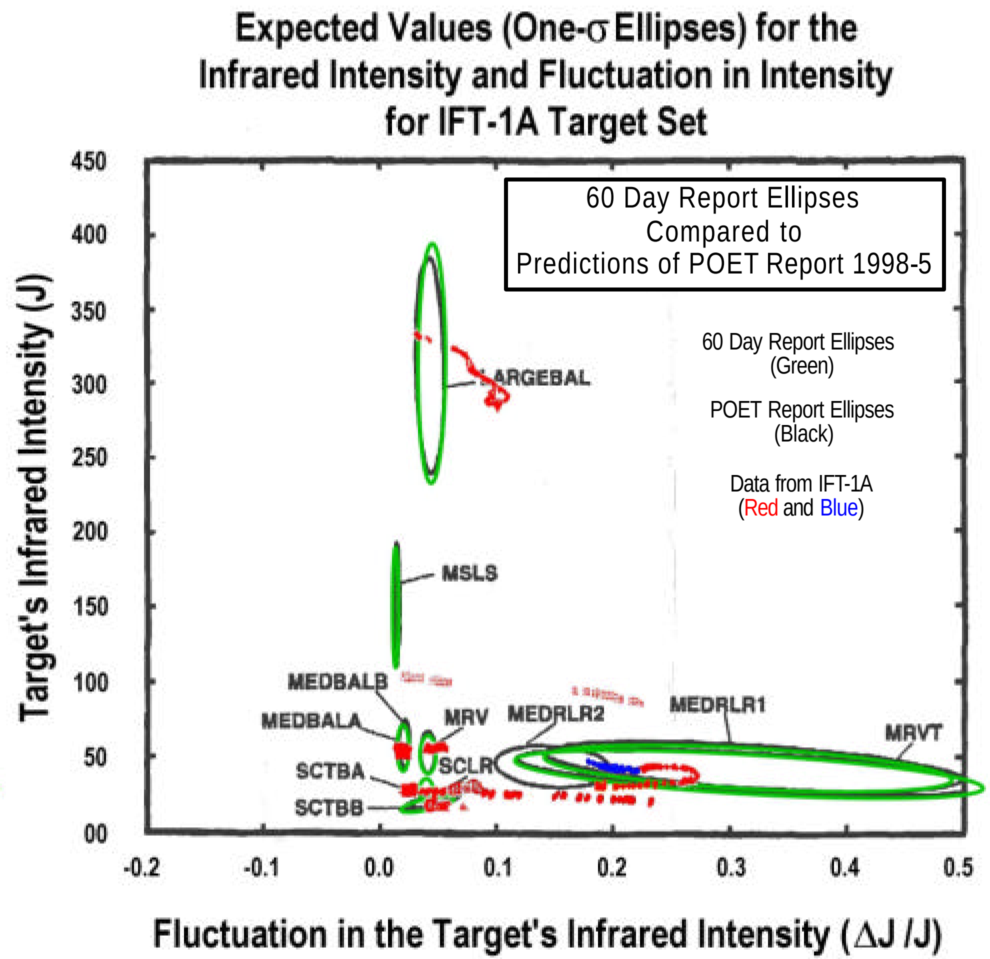


[U] Figure 5. One-σ ellipses computed from the feature vectors shown in Figure 4.

Distribution of Intensities and Variances Assumed in the 45 Day and 60 Day Reports Compared to Theoretical Predictions in the POET Report 1998-5



[U] Figure 5. One-σ ellipses computed from the feature vectors shown in Figure 4.

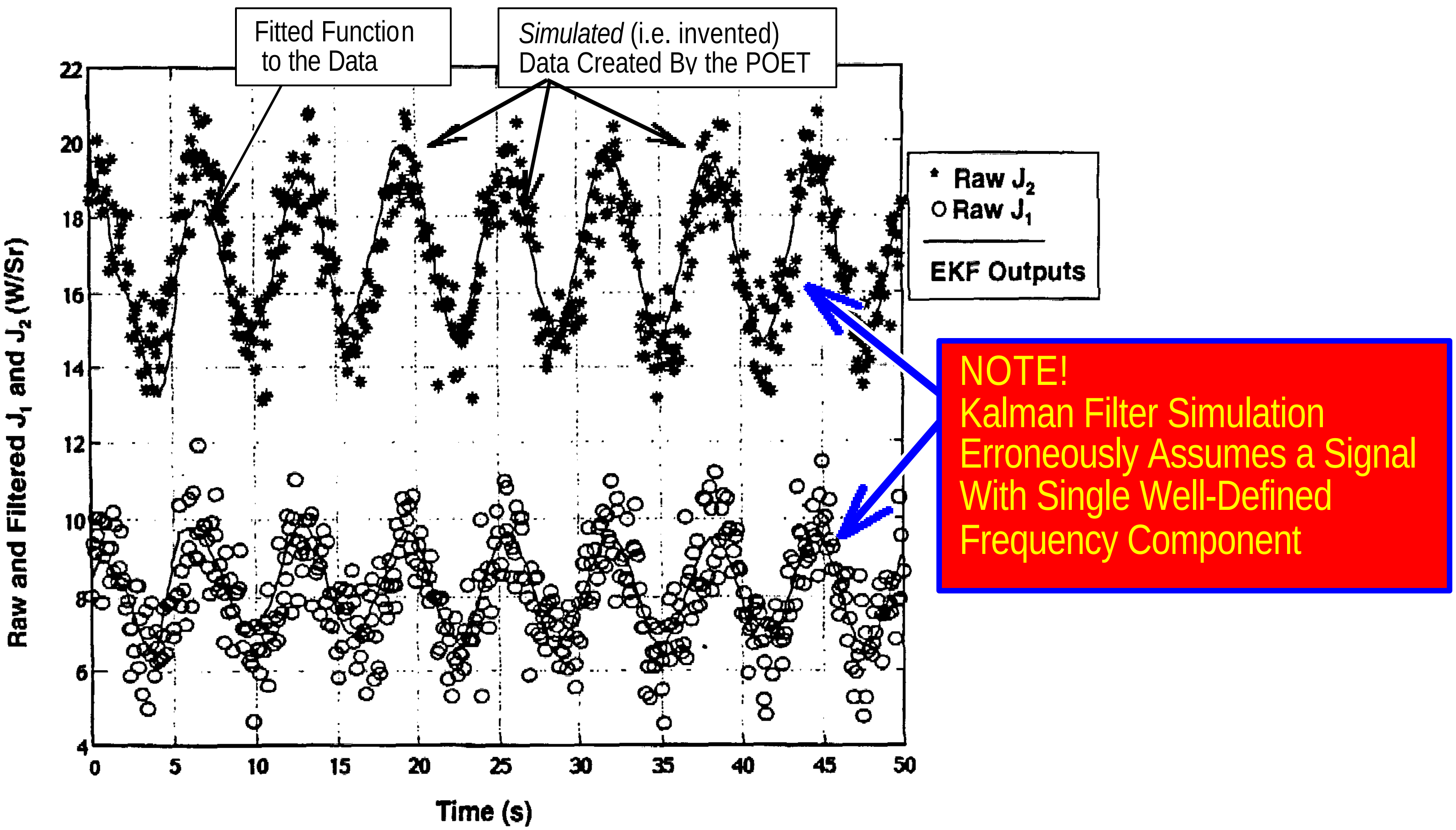


[U] Figure 5. One-σ ellipses computed from the feature vectors shown in Figure 4.

The Kalman Filter

Fails to Extract Features Because
the Filter Assumes that the Target Signals Contain Only *One* Frequency
When They Instead Contain Multiple Frequencies

Why the Specific Characteristics of the Signal from the Space-Targets is the Probable Source of the Kalman Filter Initialization Problems

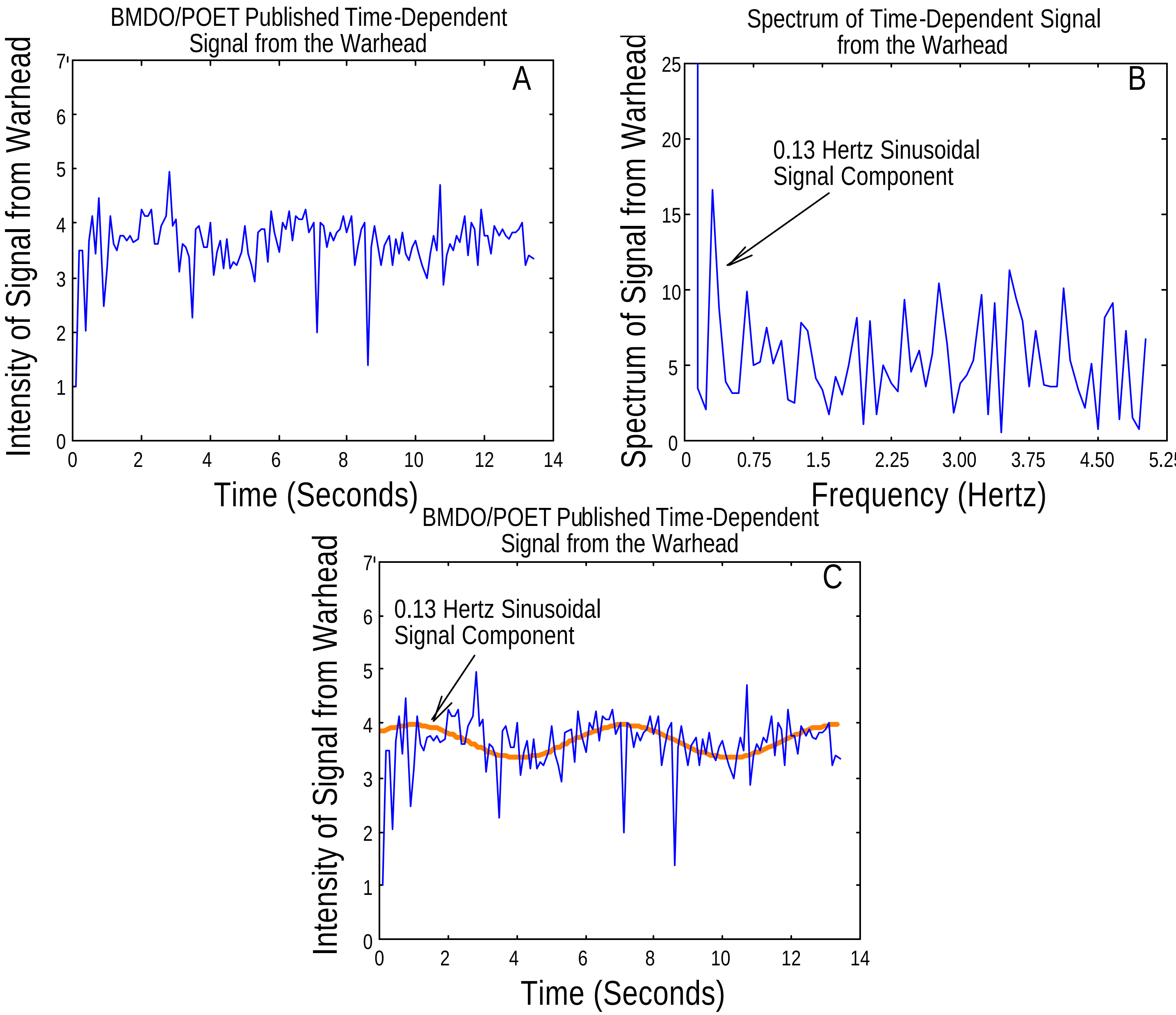


POET Fitting Function for Time Dependent Intensity of the J_1 Signal $= A_1 + B_1 \cos(w t + j_1)$

POET Fitting Function for Time Dependent Intensity of the J_2 Signal $= A_2 + B_2 \cos(w t + j_2)$

Simulated Noisy Two Band Intensity Signals—Used by the POET team to demonstrate the "Convergence" of the Kalman Filter.
Above graph from *"POET Study 1998-5, Independent Review of TRW Discrimination Techniques, Final Report,"* Figure 15, Page 33.

Spectral Content of the Signal from the Warhead
In the Time Interval Between 1751 and 1768 Seconds



Power Spectral Densities from Targets Inconsistent and Show No Single Well-Defined Frequency

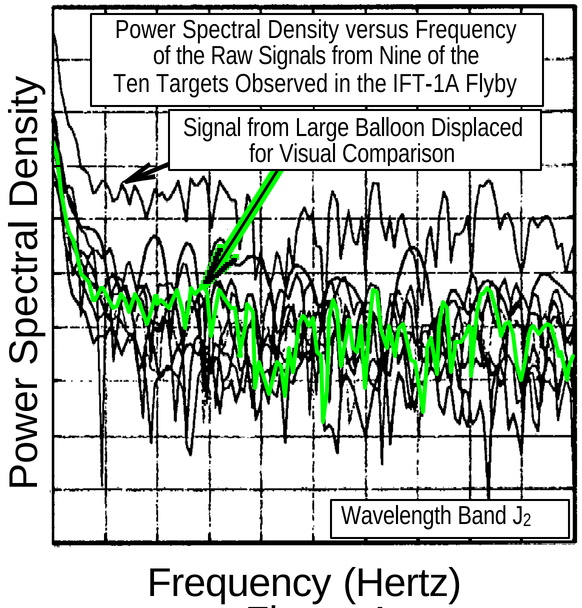


Figure A

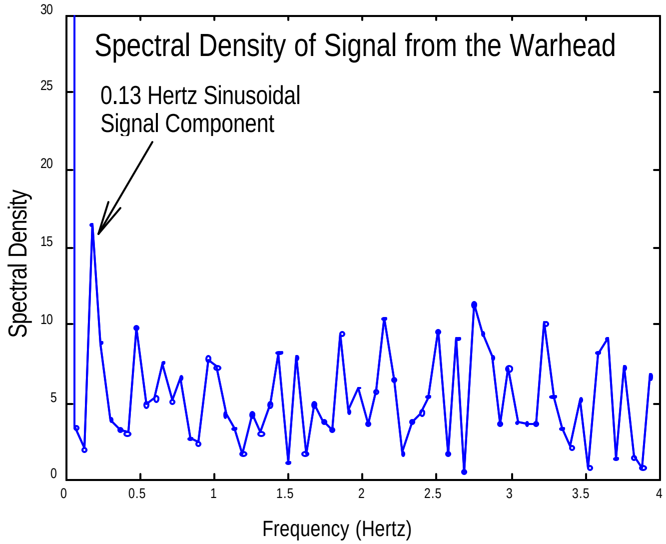


Figure B

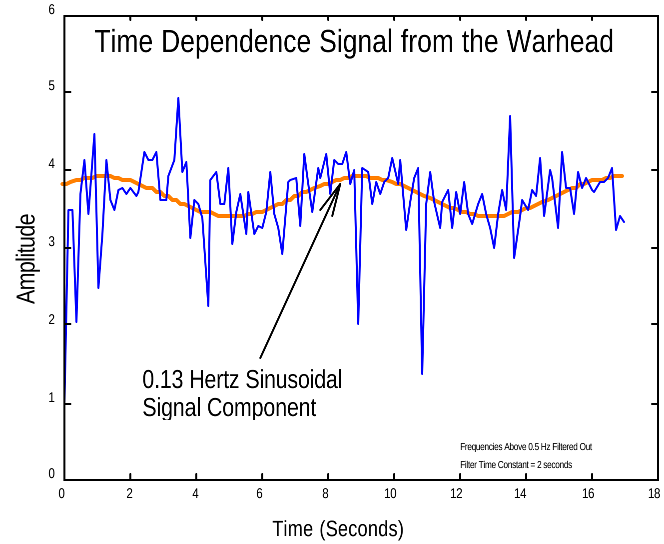
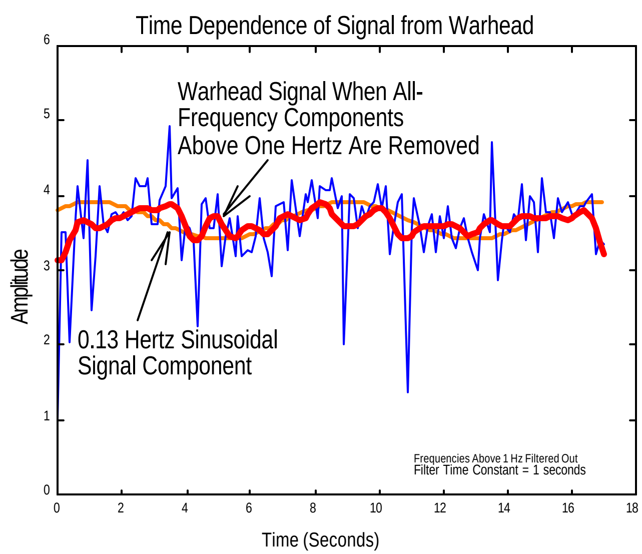


Figure C



Evolution of the Mix of Decoys and Warheads Following the IFT-1A and IFT 2 Experiment

Original Plans to Fly Ten or More Objects in IFT-3 and IFT-4 Experiments

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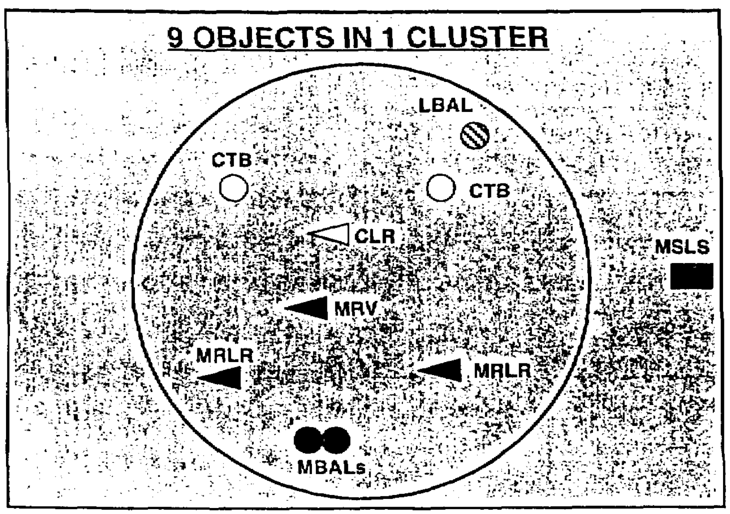
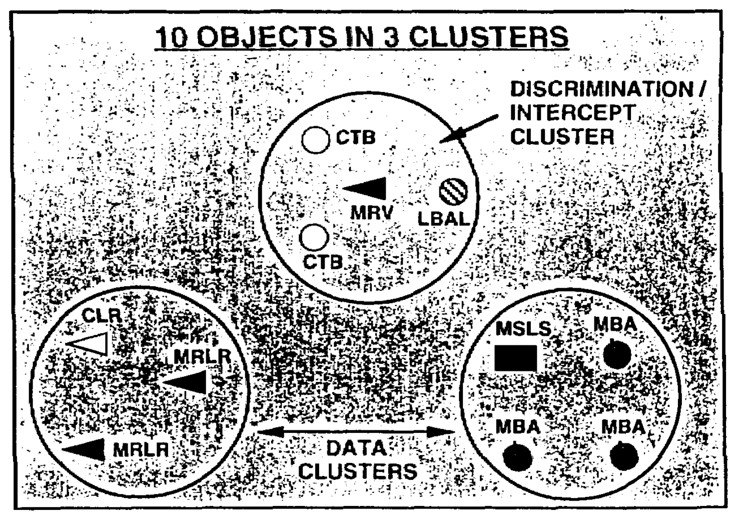
Nichols Research

TSRD TARGET REQUIREMENTS SUMMARY (IFT-1 – 1FT-4) (U)

NRC

IFT 1&2 SENSOR FLIGHT TESTS AUG 96 / NOV 96	IFT 3&4 EKV FLIGHT TESTS OCT 97 / JAN 98
1 MED RV (I)	1 MED RV (I)
2 MED RIGID LIGHT REPLICAS (MRLR) (I)	2 MED RIGID LIGHT REPLICAS (MRLR) (I)
2 MED BALLOONS (MB) (U)	3 MED BALLOONS (MB) (U)
1 CANISTERIZED LIGHT REPLICA (CLR) (I)	1 CANISTERIZED LIGHT REPLICA (CLR) (I)
2 CANISTERIZED TRAFFIC BALLOONS (CTB) (I)	2 CANISTERIZED TRAFFIC BALLOONS (CTB) (I)
1 LG BALLOON (LB) (U)	1 LG BALLOON (LB) (U)



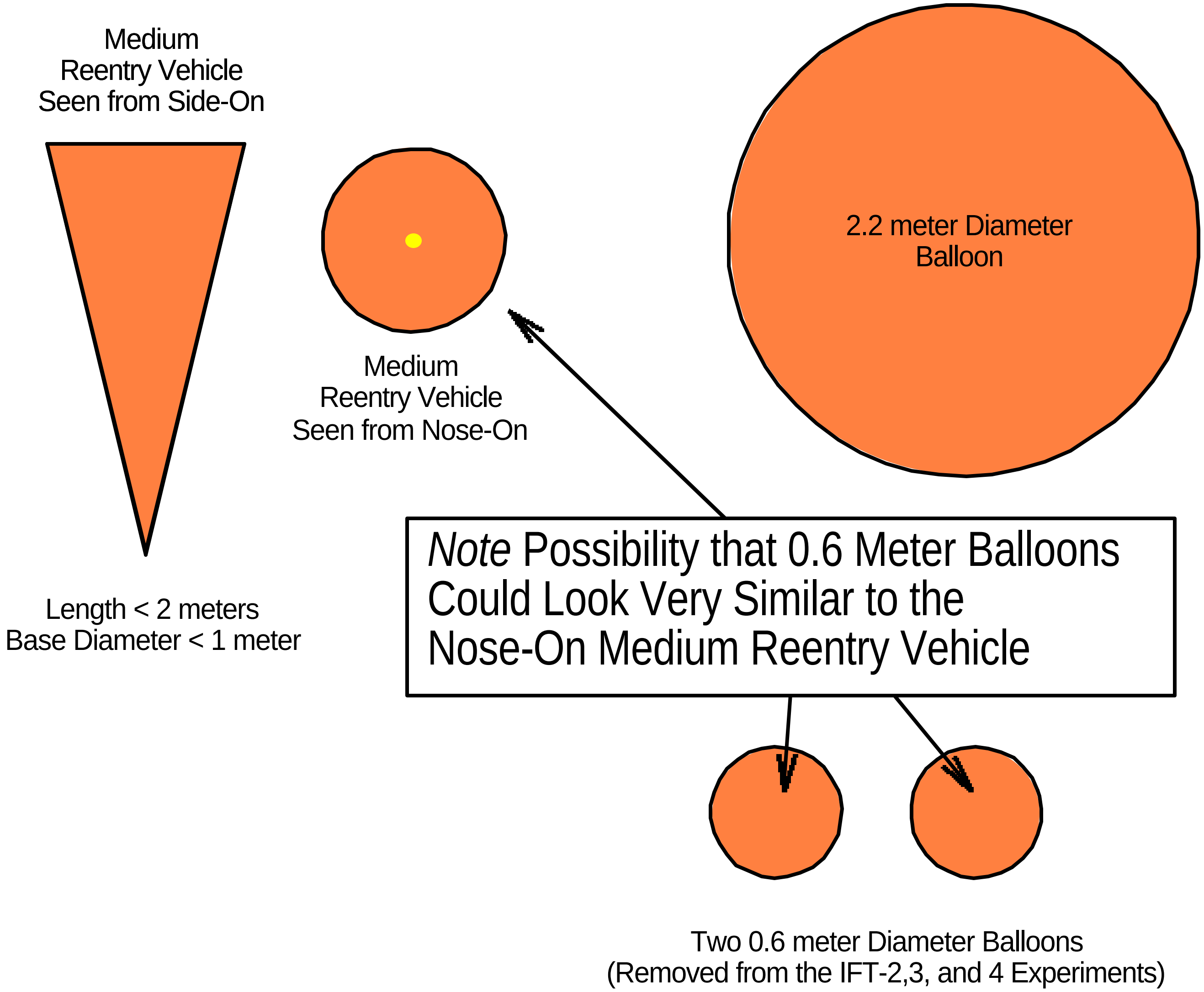


I - INSTRUMENTED
U - UNINSTRUMENTED

LARGE CL
MED. CLA
SMALL CL

Modifications of IFT-3 and IFT-4 to Hide the Fact that the Kill Vehicle Cannot Discriminate Between Targets and Decoys

Target Set for First Three NMD Intercept Attempts



NMD Flight Test Program Viewed with Respect to the Results of the IFT-1A Experiment

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IFT TARGETS SELECTIONS AS OF 05/05/00 (U)

For Planning Purposes

Objects Not to Scale

Date mm/yy	IFT #	MRV	LB	CSB-1	CSB-2	MB	MRLR	SCLR	LSB	SSB-A	SSB-B	MTRV	IRB-1	IRB-2	IRB-3	IRB-4	IRB-5	RB-1	RB-2	GROW	MLRV
		EXISTING TARGETS							NEW TARGETS												
06/97	1A	1	1	1	1	2	2	1													
01/98	2	1	1	1	1	2	2	1													
10/99	3	1	1																		
01/00	4	1	1																		
06/00	5	1	1																		
09/00	6	1	1	1	1																
01/01	7	1							1	1	1										
05/01	8								1	1	1	1									
08/01	9							System 5				1						6			
11/01	10											1		4				2			
03/02	11																			1	
06/02	12		Prod. Rep. KV					System 2 (Dynamics A)												1	
11/02	13							System 5				1		4				2			
03/03	14		Weapon LRIP Decision					Lethality System 5													1
06/03	15							System 2 (Dynamics B)						1	1	1	1		2	1	
11/03	16							Lethality System 5													1
02/04	17							Lethality System 5													1
06/04	18							System 2 (Dynamics B, CSOs)						1	1	1	1		2	1	
11/04	19																				
03/05	20														OTA TESTS						
05/05	21																				

Configuration controlled by NMD JPO – Do not alter this document.

▭ = Nighttime Engagement

NMD Forging America's Shield

5/5/00 NMD Flight Test Targets and Scenarios Task Update

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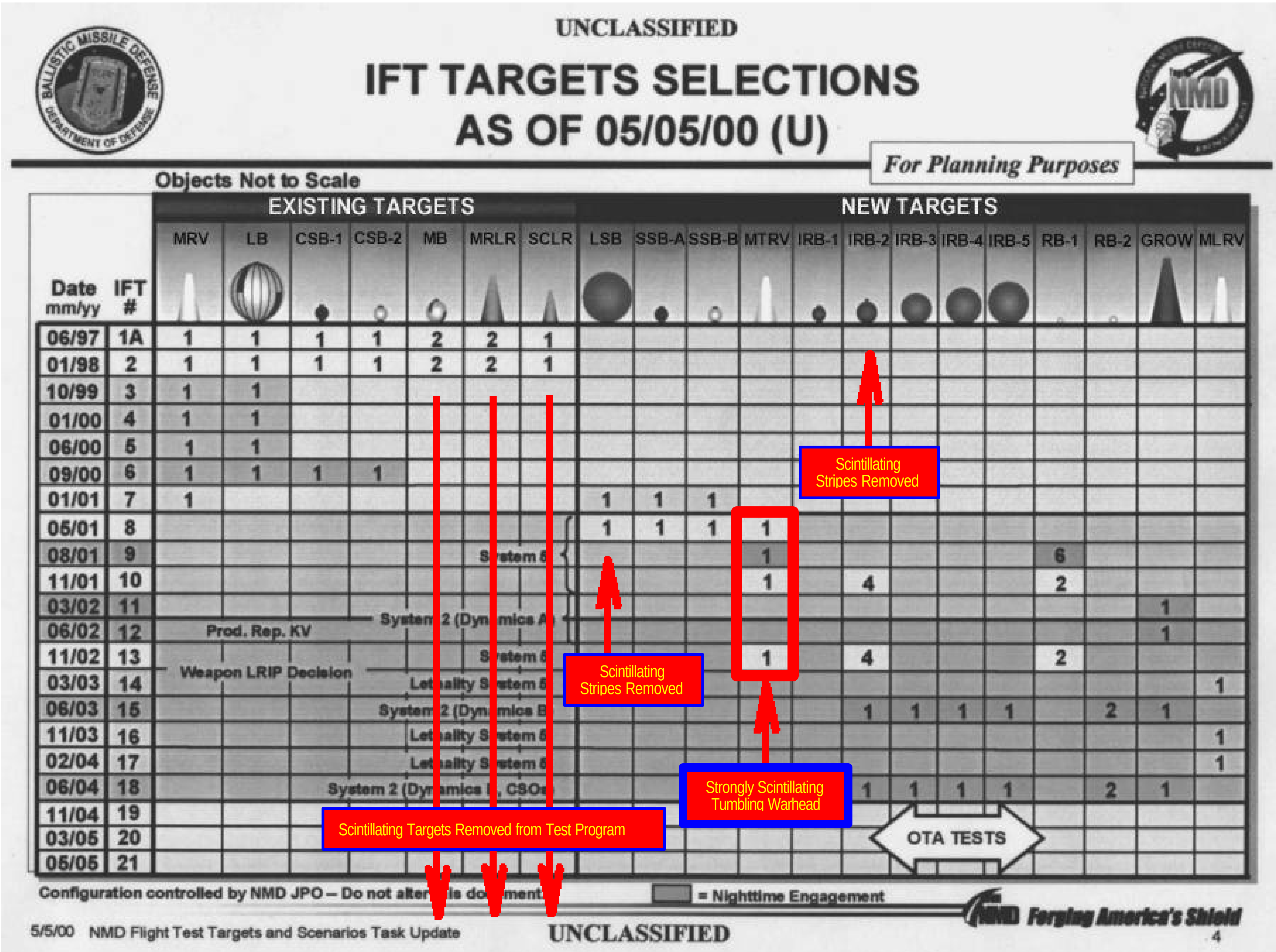
Rigging of the Test Program to Avoid the Simplest of the Baseline Threats



Date mm/yy	IFT #	MRV	LB	CSB-1	CSB-2	MB	MRLR	SCLR	LSB	SSB-A	SSB-B	MTRV	IRB-1	IRB-2	IRB-3	IRB-4	IRB-5	RB-1	RB-2	GROW	MLRV
06/97	1A	1	1	1	1	2	2	1													
01/98	2	1	1	1	1	2	2	1													
10/99	3	1	1																		
01/00	4	1	1																		
06/00	5	1	1																		
09/00	6	1	1	1	1																
01/01	7	1							1	1	1										
05/01	8								1	1	1	1									
08/01	9											1						6			
11/01	10											1		4				2			
03/02	11																			1	
06/02	12																			1	
11/02	13											1		4				2			
03/03	14																				1
06/03	15													1	1	1	1		2	1	
11/03	16																				1
02/04	17																				1
06/04	18													1	1	1	1		2	1	
11/04	19																				
03/05	20																				
05/05	21																				

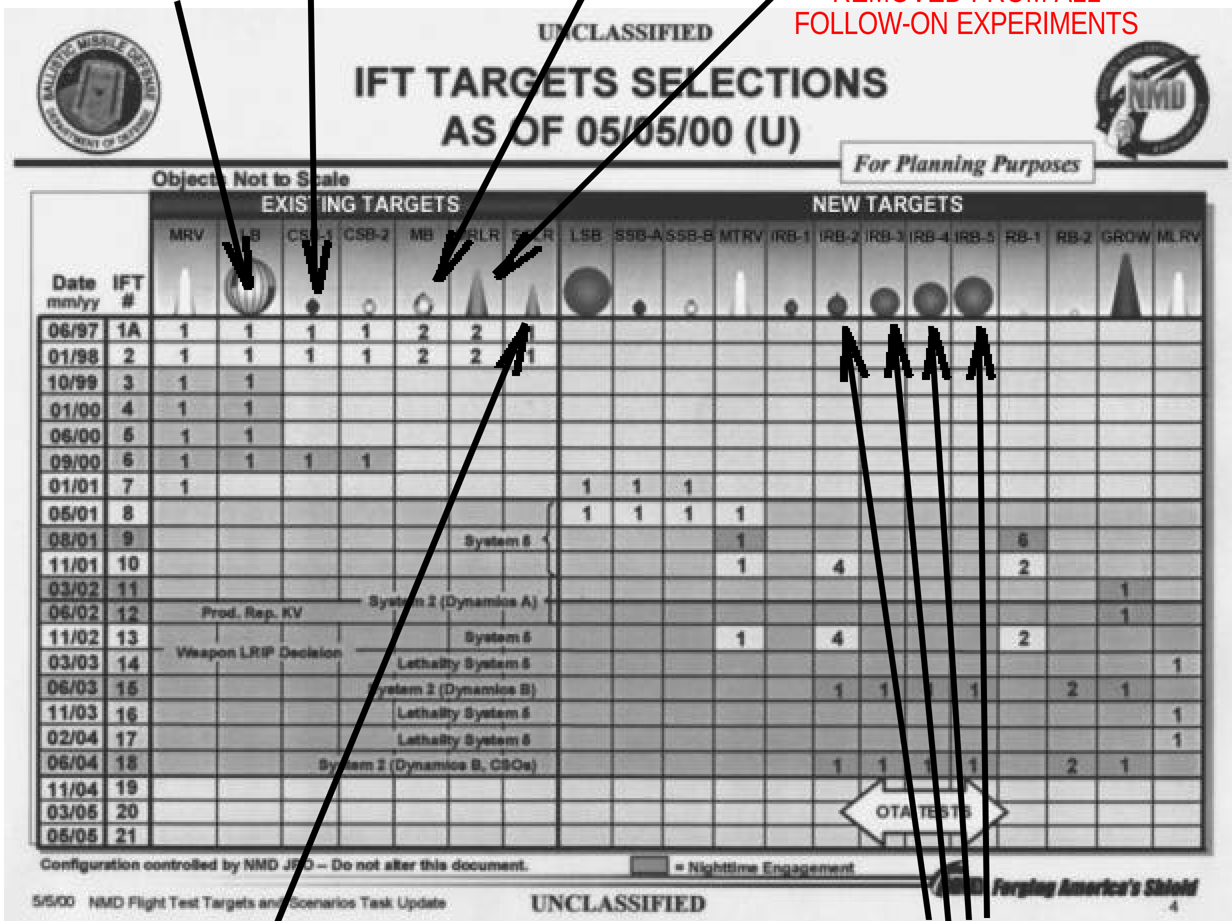
NMD Flight Test Program Viewed with Respect to the Results of the IFT-1A Experiment

Small Canisterized Traffic Balloons – One Half to One Third as Bright as the warhead

Medium Striped Balloon Decoy
Indistinguishable from Stabilized Spinning Warhead
REMOVED FROM ALL FOLLOW-ON EXPERIMENTS

2.2 meter Balloon
Six to seven times brighter than the warhead

Medium Rigid Light Replica Decoy
Indistinguishable from Tumbling Warhead
REMOVED FROM ALL FOLLOW-ON EXPERIMENTS



Date mm/yy	IFT #	MRV	LB	CSB-1	CSB-2	MB	MRLR	SRLR	LSB	SSB-A	SSB-B	MTRV	IRB-1	IRB-2	IRB-3	IRB-4	IRB-5	RB-1	RB-2	GROW	MLRV
		EXISTING TARGETS							NEW TARGETS												
06/97	1A	1	1	1	1	2	2	1													
01/98	2	1	1	1	1	2	2	1													
10/99	3	1	1																		
01/00	4	1	1																		
06/00	5	1	1																		
09/00	6	1	1	1	1																
01/01	7	1							1	1	1										
05/01	8								1	1	1	1									
08/01	9					System 8						1						6			
11/01	10											1		4				2			
03/02	11					System 2 (Dynamics A)														1	
06/02	12		Prod. Rep. KV																	1	
11/02	13					System 8						1		4				2			
03/03	14		Weapon LRIP Decision			Lethality System 8															1
06/03	15					System 2 (Dynamics B)								1	1	1	1		2	1	
11/03	16					Lethality System 8															1
02/04	17					Lethality System 8															1
06/04	18					System 2 (Dynamics B, CSOs)								1	1	1	1		2	1	
11/04	19																				
03/05	20													OTA TESTS							
05/05	21																				

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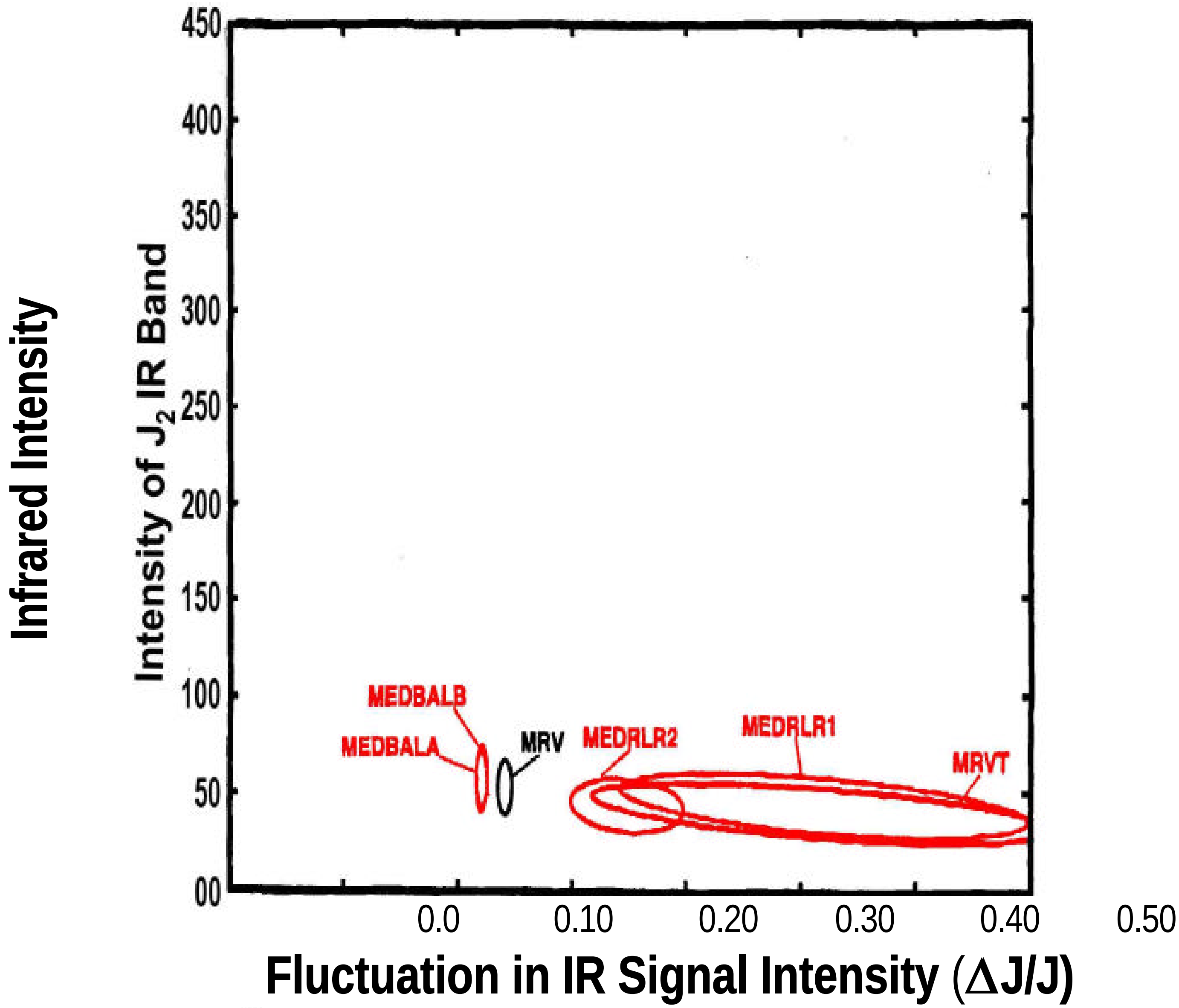
5/5/00 NMD Flight Test Targets and Scenarios Task Update UNCLASSIFIED NMD Forging America's Shield 4

Small Canisterized Light Replica Decoy
Very Similar to Tumbling Warhead
REMOVED FROM ALL FOLLOW-ON EXPERIMENTS

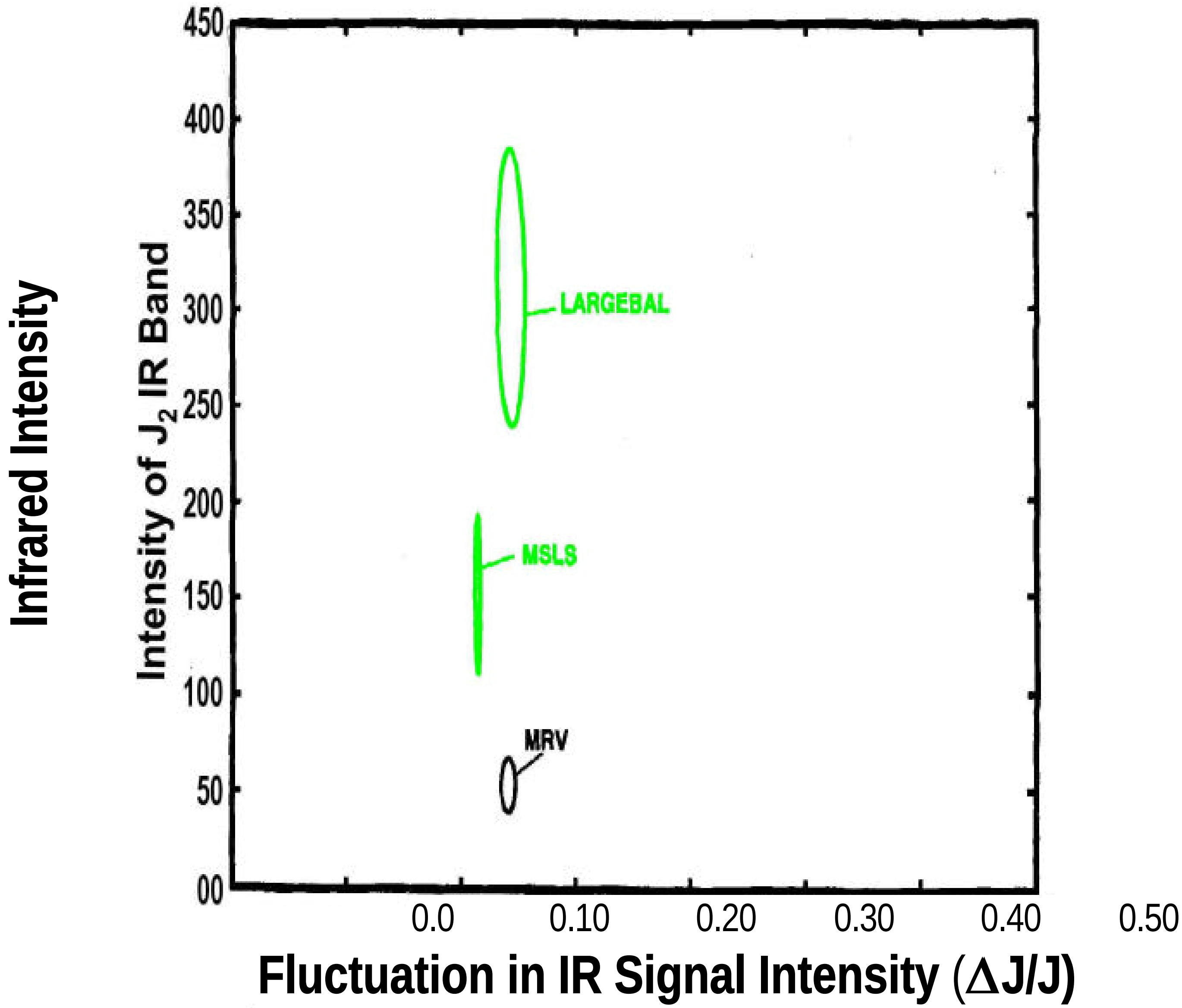
ALL NEW INFRARED DECOYS MODIFIED TO BE FEATURELESS SPHERES SO THEY HAVE *NO* TIME-VARYING SIGNALS LIKE THOSE OF THE NON-SPHERICAL SPINNING AND TUMBLING WARHEADS

Ellipses of the Highly *Effective* Decoys that Were Removed from All NMD Flight Tests Following the Revelations From the IFT-1A and 2 Flight Tests



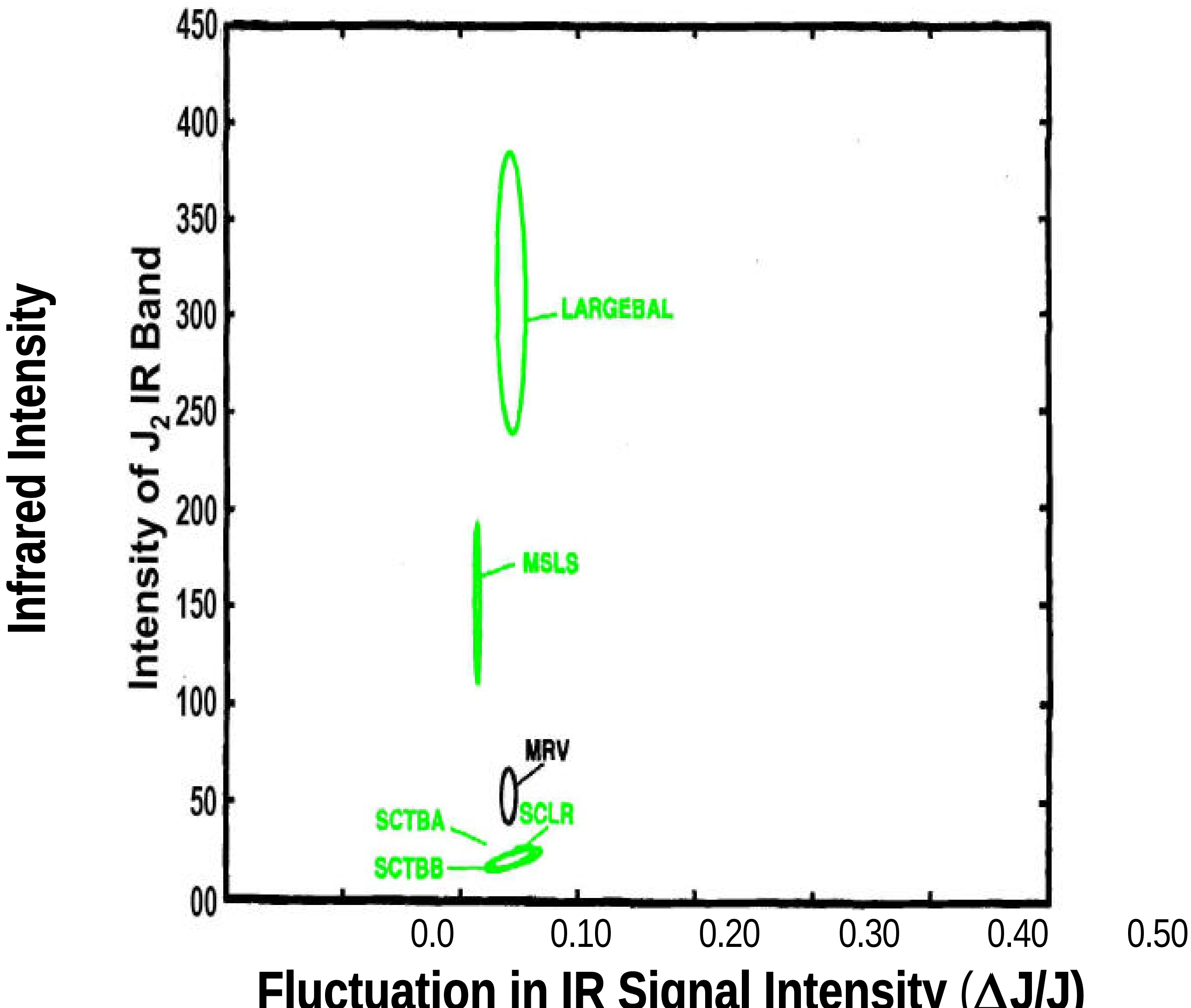
[U] Figure 5. One-σ ellipses computed from the feature vectors shown in Figure 4.

Ellipses of the Carefully Selected *Ineffective* Decoys that Were Used in the IFT-3, 4, and 5 Flight Tests that Were to be Used By the President to Support a Decision to Proceed



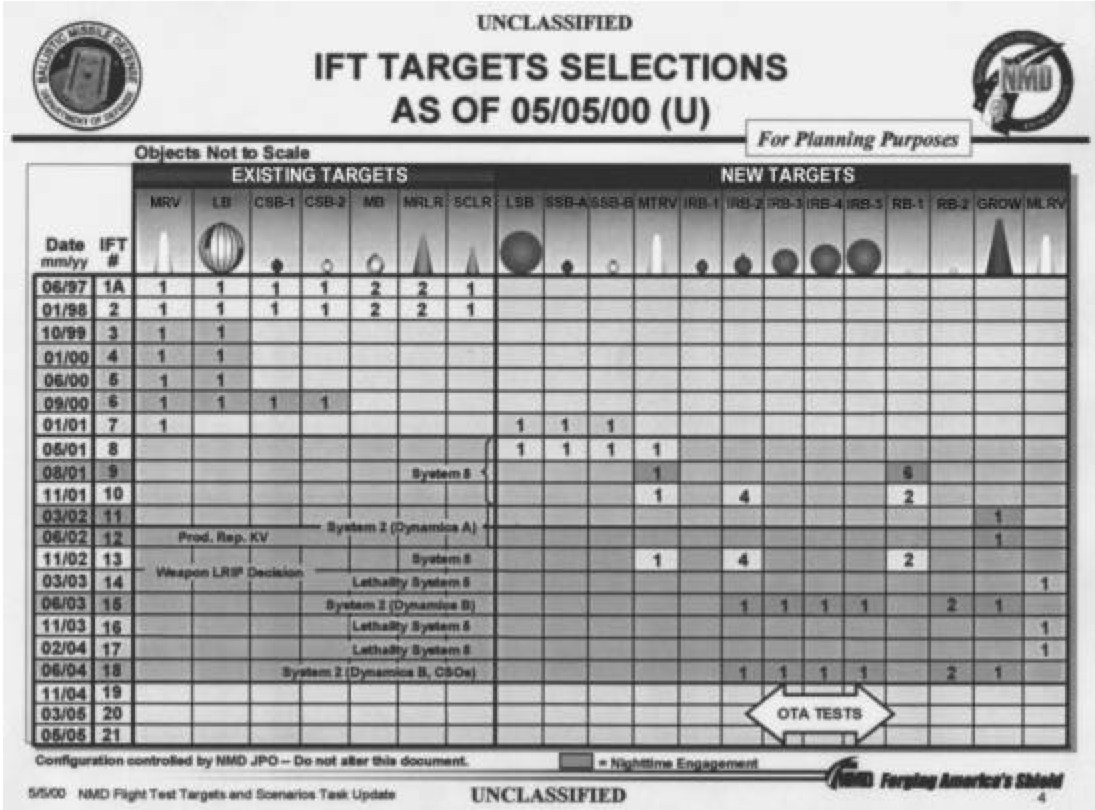
[U] Figure 5. One-σ ellipses computed from the feature vectors shown in Figure 4.

Ellipses of the Carefully Selected *Ineffective* Decoys that Were Planned for IFT-6 Prior to Substitution of Even Simpler Decoys in All Subsequent NMD Flight Tests



[U] Figure 5. One-σ ellipses computed from the feature vectors shown in Figure 4.

NMD Flight Test Program Viewed with Respect to the Results of the IFT-1A Experiment



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IFT TARGETS SELECTIONS
AS OF 05/05/00 (U)

For Planning Purposes

Objects Not to Scale

Date mm/yy	IFT #	EXISTING TARGETS: MRV	LB	CSB-1	CSB-2	MB	MRLR	SCLR	NEW TARGETS: LSB	SSB-A	SSB-B	MTRV	IRB-1	IRB-2	IRB-3	IRB-4	IRB-5	RB-1	RB-2	GROW	MLRV
06/97	1A	1	1	1	1	2	2	1													
01/98	2	1	1	1	1	2	2	1													
10/99	3	1	1																		
01/00	4	1	1																		
06/00	5	1	1																		
09/00	6	1	1	1	1																
01/01	7	1							1	1	1										
05/01	8								1	1	1	1									
08/01	9							System 5				1						6			
11/01	10											1		4				2			
03/02	11							System 2 (Dynamics A)												1	
06/02	12	Prod. Rep. KV																		1	
11/02	13	Weapon LRIP Decision						System 5				1		4				2			
03/03	14							Lethality System 5													1
06/03	15							System 2 (Dynamics B)						1	1	1	1		2	1	
11/03	16							Lethality System 5													1
02/04	17							Lethality System 5													1
06/04	18							System 2 (Dynamics B, CSOs)						1	1	1	1		2	1	
11/04	19																				
03/05	20													OTA TESTS							
06/05	21																				

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NMD Forging America's Shield

5/5/00 NMD Flight Test Targets and Scenarios Task Update

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4

Description of Target	Comments
MRV – Medium Reentry Vehicle (Spin Stabilized Warhead)	**WARHEAD TARGET**
LB – Large (Striped) Balloon (Decoy)	**REMOVED**
CSB – Canisterized Small (Traffic) Balloon (Decoy)	**REMOVED CREDIBLE DECOY**
MB – Medium (Striped) Balloon (Decoy)	**REMOVED CREDIBLE DECOY**
MRLR – Medium Rigid Light Replica (Warhead -Shaped Decoy)	**REMOVED CREDIBLE DECOY**
SCLR – Small Canisterized Light Replica (Warhead -Shaped Decoy)	**REMOVED CREDIBLE DECOY**
LSB – Large (Featureless) Spherical Balloon (Decoy?)	**NEW LESS CREDIBLE DECOY**
SSB – Small (Traffic) Balloon (Decoy?)	**NEW LESS CREDIBLE DECOY**
MTRV – Medium Tumbling Reentry Vehicle (Tumbling Warhead)	**WARHEAD TARGET**
IRB – Infrared (Featureless) Spherical Balloon (Decoy?)	**NEW LESS CREDIBLE DECOY**
RB – Radar Decoy (Decoy? – Radar Tracking Aid?)	**RADAR TARGET**
GROW – Generic Rest-of-the-World Reentry Vehicle (Warhead)	**WARHEAD TARGET**
MLRV – Medium Lethality Reentry Vehicle (Warhead)	**WARHEAD TARGET**

This figure from page 4 of *"NMD Test Targets VV&A Working Group (TTVWG) Kickoff Meeting: Flight Test Targets Selections,"* Rosslyn, Virginia, 28 April 2000, Dr. Richard Foster, NMD Sysytem Engineering Team (UNCLASSIFIED)

Conclusions and Summary of the Facts

Summary of Findings About the Ballistic Missile Defense Organization's "Independent Review of TRW's Discrimination Techniques" (POET 1998-5)

- The physics-based predictions by TRW and the POET of the infrared mean intensities and variances for the space-targets observed in the IFT-1A experiment do not agree with those measured in the experiment.
- The ability to select threatening targets with high probability by matching intensities requires that the means and variances of the signals from all targets be known accurately and in advance.
- In addition, even if intensities can be accurately predicted, if there is significant overlapping of signal intensities from different objects it will not be possible to accurately match each signal to the right target.
- Stated differently, when signal intensities from different targets overlap, it means that the signals look roughly the same, and it is not possible to select the threatening object with high probability.
- Thus the POET has not shown to *any* accepted scientific standard that the Baseline Algorithm works, they have not shown to *any* accepted scientific standard that the signals from the IFT-1A experiment can be predicted using physics-based methods, and they have not shown to *any* accepted scientific standard that the variances and intensities in the target infrared signals could reliably be expected to be sufficiently distinct to make it possible to select the warhead, or the tumbling warhead, with high probability.
- If these points are disputed by the POET, or the BMDO, then it is mandatory that the POET and BMDO's counterclaims be examined by scientific peer review.
- Such a peer review would be very simple to do.
- No special knowledge of missile defense or access to classified material is needed to verify the accuracy of the claim that the POET presented no evidence to support any of its conclusions.
- All that is needed for such a review is a group of independent disinterested scientists who have an elementary knowledge of experimental statistical techniques and measurement theory.
- Such knowledge is ubiquitous in the scientific community.

What the POET Needed to Do to Resolve the Serious Discrepancies Between Theory and Experiment and to Demonstrate that the Warhead Could be Selected from the Measured Data

- The POET's own calculated intensities for the targets in the IFT-1A experiment shows that the high degree of intensity overlapping in the IR intensities makes it mandatory that the IR intensity fluctuations be used in addition to the intensities to achieve a higher probability of correctly selecting the lethal target.
- However, to obtain a better probability of correctly selecting the warhead, the POET needed to, but did not, demonstrate that their physical calculations were accurate, repeatable, and explainable, so that they could be used to predict the fluctuations in the intensities of the target signals.
- Even if the POET could have produced such calculations, they would have also needed to show that the mean and variance of the fluctuations in the infrared intensities of the different targets made it possible to use this feature to select the warhead with high probability.
- In fact the POET's own estimates of the infrared intensities of the different targets shows that the warhead could not be selected with high probability even if the POET's own calculations of the means and variances for the fluctuations in the intensities had proved to be correct.
- Most fundamental of *all*, is that the fluctuations in the intensities of the different targets is controlled by the deployment dynamics and accidents of the deployment dynamics.
- Hence, feature 5 (the fluctuation in the signal intensity) can never be relied upon for discrimination of targets.

Evidence of Overt Tampering by the POET with the Results of its Statistical Calculations

- It appears that the discrepancies discussed above between the POET's own physical data and the "Confusion Matrix" are not a result of error, but instead the result of tampering with the results of the statistical calculations.
- An inspection of the confusion matrix shows the following:
- All rows in the matrix add up, as they should, to 200 – with the exception of row 7, the MB-A, which adds up to 201.
- All entries for the Tumbling Medium Reentry Vehicle (MRVT) in the last column are zero, except for the last row-entry for the MRVT.
- This result, if it were correct, would indicate that the MRVT would be correctly selected with a probability of one.
- In fact, the probability of correct selection of the MRVT is much closer to 0.37!
- A Tumbling Warhead and a Tumbling Cone-Shaped Rigid Decoy are almost certainly the simplest of all threat combinations for a primitive adversary to deploy. Spin-stabilizing a warhead is not difficult, but requires an additional engineering step relative to simply deploying a warhead without spin. Deploying ice-cream cone shaped decoys that can be stacked one upon the other is also certainly no more difficult than inflating a balloon in space.
- Yet the BMDO has downplayed, or worse yet, ignored, this very serious and credible threat to their baseline system.

Failure to Scientifically Establish the Capability of the Kalman Filter

- The Kalman Filter simply attempts to add the use of observables resulting from target dynamics and geometry as a means of increasing the chance of correct selection of the warhead.
- This was supposed to be achieved by finding the frequency of a slowly oscillating piece of the infrared signal from each target and then using that frequency to aid in the identification of the warhead.
- The POET was unable to use the Kalman Filter to find a single unique frequency associated with the signal from each target because the signals from the targets contained multiple frequencies.
- Furthermore, even if they could have extracted frequencies for each target, there is no general physical reason why such measured frequencies would indicate that a target was a warhead or a decoy.
- Thus, the POET did not show that the Kalman Filter could be used to extract frequencies from the signals from real targets, and the POET also did not show that they could identify targets with high probability even if they had extracted frequencies for the targets.

Final Comments

- The POET's own calculations showed that the observed and predicted mean intensities and variances of the signals from all targets were NOT in agreement.
- The POET never asked the most basic question:
  How could it be possible to select targets by matching their intensities and scintillation frequencies when the intensities and scintillation frequencies were unknown.
- In order to predict the means, variances, and scintillation frequencies of the infrared signals from all targets, there must be a detailed model of all the targets to be engaged, and a detailed physical understanding of how reflected infrared sun and earth signal from each target alter the appearance of the target during real engagements in space.
- The POET simply treated all the serious discrepancy between measured data and the predictions as if it were simply a minor issue of no special concern.
- These facts alone show that the POET's analysis has absolutely no basis in science,
  and no merit as science.