Space-Based IR Sensors / Technical Support Group

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Introduction and Background

SBIR / TSG Requested by Dr. Deutch on 7 July '93

Tasking: Review and Recommend Options for Future U.S. Space-Based IR Surveillance Capability

- TW/AA, Theater Missile Defense, and Global Awareness
- Today Thru ≈ 2015
- Focus on DSP, FEWS, Brilliant Eyes (BE) Acquisition Options
- Consider Other Options as Appropriate
- Identify Cost-Effective Options for Consideration by DoD Executives

SBIR / TSG Members

Chairman:	**Mr. Robert R. Everett**	**MITRE**
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	Dr. Antonio F. Pensa	**MIT Lincoln Laboratory**
	Dr. John M. Ruddy	**MITRE**

SBIR / TSG Briefings Received / Deliberations

Requirements

- USCINCSPACE / CINCNORAD
- US Space Command
- Air Force Space Command
- Ballistic Missile Defense Office
- U.S. Army
- U.S. Navy
- Central MASINT Office
- Office of the Secretary of Defense

Systems / Contracts

- Architecture Integration Study (BDM)
- Brilliant Eyes (Hughes Team)
- Brilliant Eyes (Grumman Team)
- DSP Upgrades (Aerojet)
- FEWS (Lockheed Team)
- FEWS (TRW Team)
- GBR (Raytheon)
- TMD / GOES (ITT)

Threat

- Defense Intelligence Agency

Programs / Initiatives

- Brilliant Eyes (BMDO)
- COBRA BRASS (CMO)
- DSP (USAF)
- DSP / FEWS / BE (AF Space Div.)
- FEWS (USAF)
- JTAGS (USA)
- Patriot (PM)
- RADIANT IVORY (USN)
- Sea-Based Theater Missile Defense (BMDO / USN)
- System Cueing (POET)
- Talon Shield (USAF)
- TERPS (USAF)
- TMD C3 Architecture (BMDO)
- TPAR (USAF)

Executive Sessions

- 18 Meetings
- 17 Aug Thru 7 Oct

Key Findings (1 of 4)

Global SBIR for TW/AA is an Essential National Capability

Stereo DSP Provides Adequate Near-Term Capability for Deployed Missiles of >300 km Range

A Better Objective System Will be Needed ...

- To Lower Cost and Weight (For MLV-class Launchers)
- To Provide Growth Potential To Guard Against Future Missile Developments
- To Better Support Other Missions (e.g., "Mission E", Non-Missile Events)

Fundamental SBIR Needs can be Met with a Simpler, Less Costly System Than FEWS

- FEWS Design and Cost is Intertwined with Requirements Descended From SDI and Nuclear Warfighting
- Separating Sensor Support to Global Missile Warning and Other Missions Offers the Potential for Doing Both Better and at Lower Cost

There is a High Probability of a Gap in SBIR Coverage During System Transition without Block 23

Key Findings (2 of 4)

Polar BTH Coverage is Not Genuinely Needed for TW/AA and Drives System Design & Cost

A 5-Ball DSP Constellation Does Not Require Augmentation for Missile Warning Purposes

There are Other Important Needs such as Global Awareness (e.g., Slow Walkers, "Mission E", & Damage Assessment)

BE is of Marginal Value to TW/AA and Theater Missile Defense Against Shorter-Range Missiles

Key Findings (3 of 4)

SBIR Requirements Associated with Short-Range Missiles Drive Design & Cost - Radars Do the Job Better & Are There Anyway

< 300 km	Radars Warn and Assess; SBIR May Confirm
300 - 1000 km	Both Warn; Radars Assess
> 1000 km	SBIR Warn and Assess; Radars Assess & "Goal-Tend"

Launch Point Prediction is Greatly Improved Using Stereo Processing

- FEWS Provides Marginal Advantage Over Stereo DSP for Counterforce Operations

FEWS Provides Significantly Better Impact Point Prediction Than Stereo DSP, But ...

- Radars Provide More Accurate IPP for Missiles, Particularly < 1000 km Range
- IPP for Missiles using PBV's or Maneuvering Warheads Requires Either Radar or Midcourse IR Tracking - Depending on Range

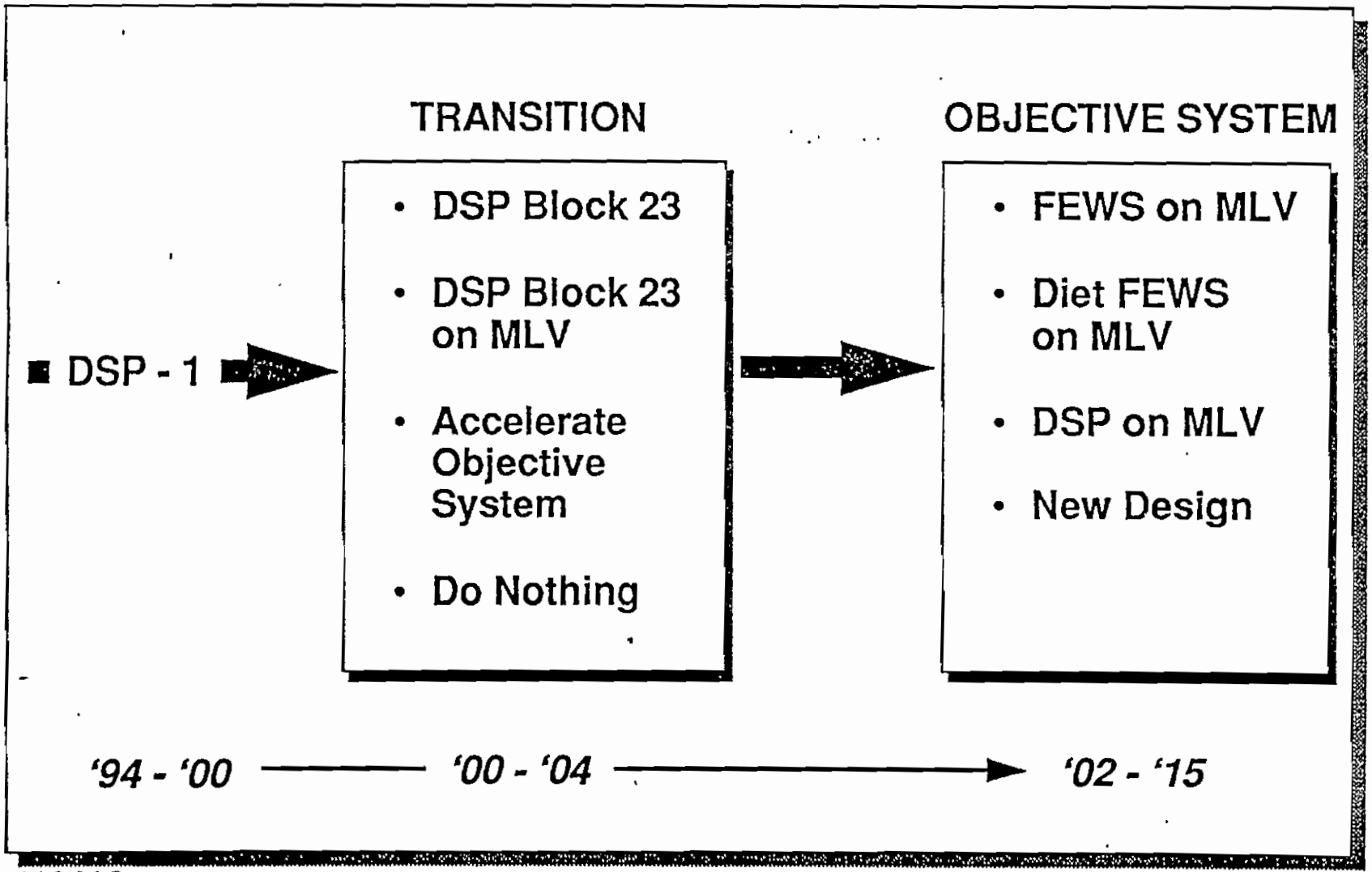
Key Findings (concluded)

C3 Supporting SBIR Has Significant Impact on Cost and Performance

- Cross-links and On-Board Processing are Not Needed Initially - if Ever.
- Direct-to-User Downlinks are also Not Worth Technical Risk and Cost. (Ground Processing with Integrated Comm's Solution is Sufficient.)

A Comparatively Small Investment in Environmental Data Collection Can Have Significant Payoff for Objective System Performance

Comparison of Options - Overview

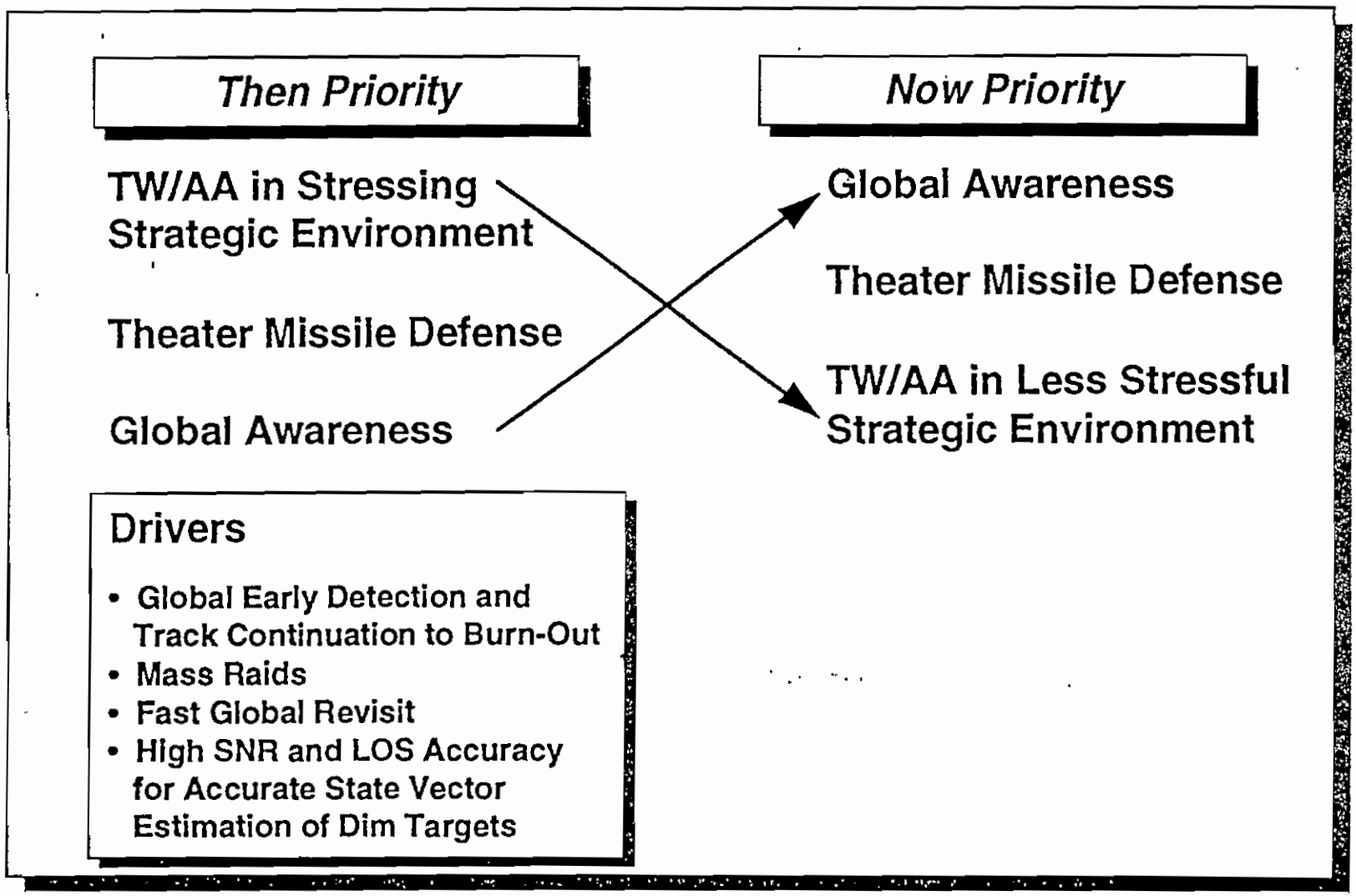


Transition

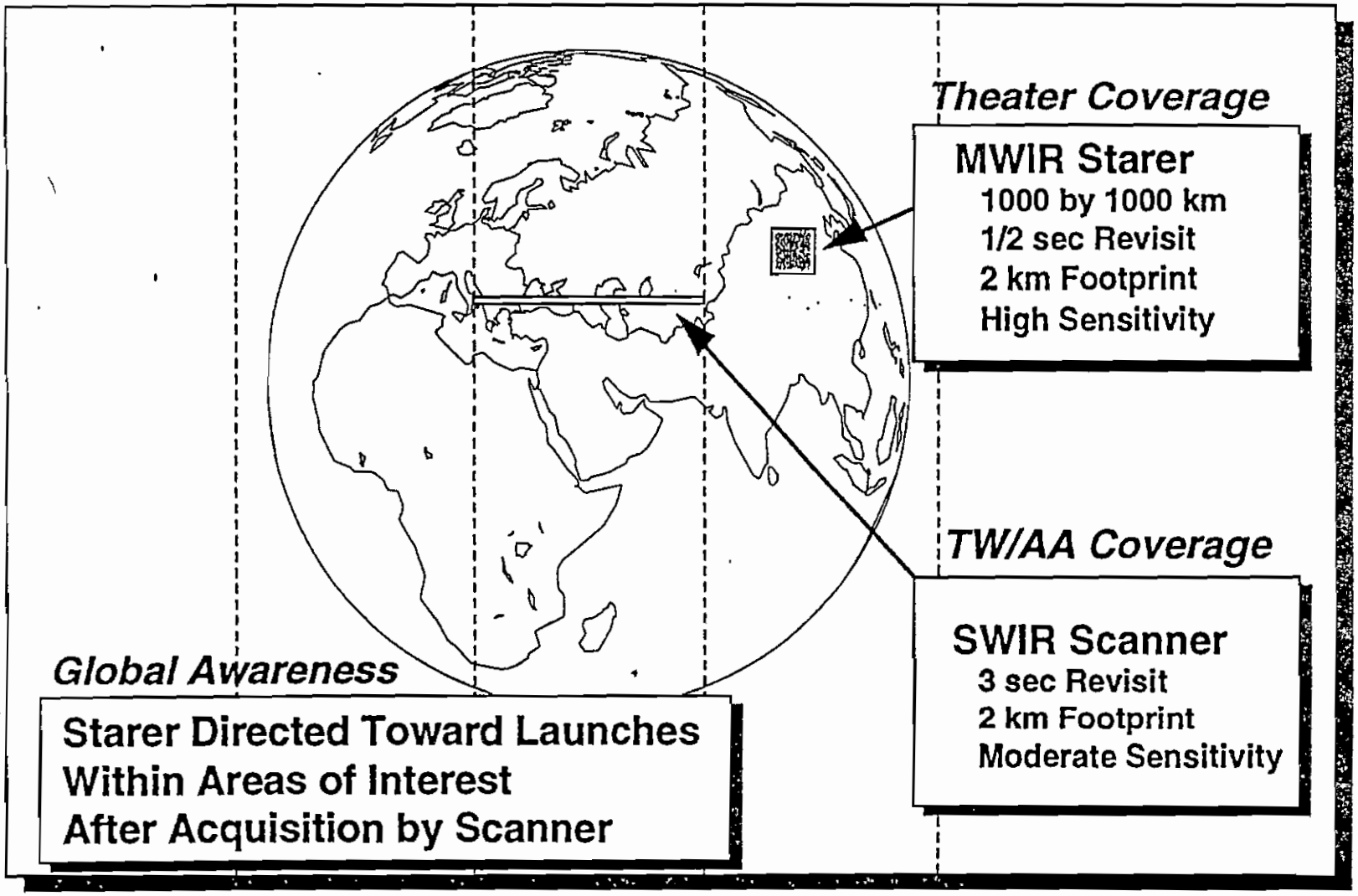
Evaluation of Options and Consideration of Coverage Gaps Suggests that ...

- DSP Block 23 be Acquired to Ensure Coverage
- Next 3 DSPs be Launched ASAP (on Shuttle if Necessary)
- Use of Flight 12 Configuration be Explored for MLV Launch

New Needs Allow Simpler Low Cost Design

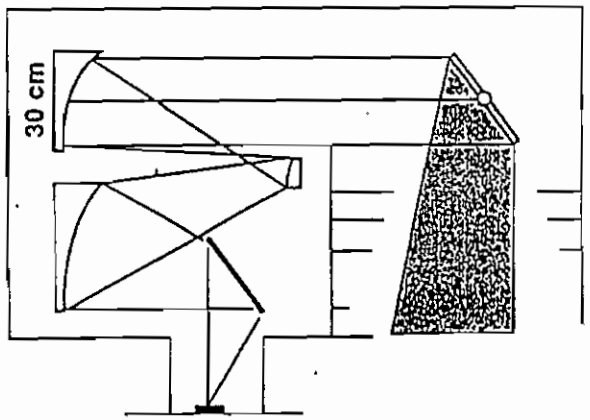


Example SBIR System-Concept of Operations

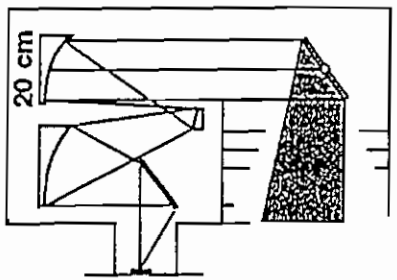


Example SBIR System-Satellite Concept

Sensor Configuration

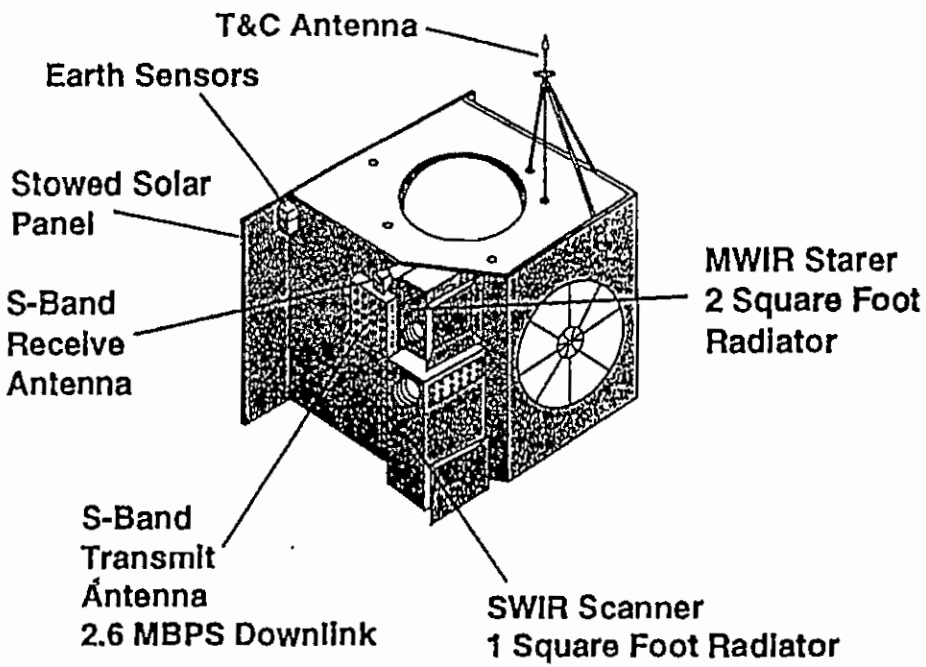


SWIR Scanner



MWIR Starer

GOES BUS



Example SBIR System-Data

Sensor Parameters

Parameter	SWIR Scanner	MWIR Starer
Aperture	30 cm	20 cm
FOV	18.7 deg	1.6 deg
Coverage	Global (to 600 km alt)	Theater (1000 x 1000 km)
Revisit Time	3 s	0.5 s
Detector IFOV	53 µrad	53 µrad
Footprint @ 40,000 km	2.1 km	2.1 km
Sample Time [1]	2.9 ms	500 ms
Focal Plane	16 by 2048	512 by 512
Detector Type	HCT	HCT
Temperature	130 K	100 K
Data Rate (Samples/s)[2]	57,000,000	520,000
Noise-Equivalent Target[3]	500 W/sr	100 W/sr

[1] Including 16-Stage TDI for Scanner
[2] After On-Chip TDI Processing
[3] Does Not Include Clutter

Weight and Power Estimates

	Weight (lb)	Power (W)
Payload[6]	680	350
Scanner	380	50
Starer	170	10
Electronics	40	40
Signal & Data Processor	90	250
Attitude/Orbit Control[4]	181	
Electrical Power[5]	220	
Telemetry, Command & Communications[4]	166	
Propulsion[4]	194	
Integration (Electrical & Mechanical)[4]	195	
Structure & Thermal Control[4]	511	
Total Satellite (Dry)	2147	

[4] Estimates Based on GOES-I Bus
[5] GOES-I Power System Capability = 1057 W
[6] GOES-I Payload = 682 lb

Objective System Options

Option	Description
FEWS / MLV	Existing design lightweighted for MLV.
Diet FEWS	Existing design for MLV launch ... minus on-board processing & cross-links.
DSP / MLV	Downsize to Mission 12 bus with updated power, FPA & electronics.
New Design	New 3-axis stabilized system based on new reqm'ts & "from scratch" design employing technology legacy from FEWS. Likely to include separate, but smaller, sensors for global awareness and "Mission E"support.

Objective System Cost

Space-Segment Costs (in Constant FY93 $M) Are ...

System	Non-Recur.	Recurring: Per Satellite	Recurring: Per Launch	Recurring: Total On-Orbit Per Satellite	Recurring: Cost / Yr. On-Orbit[2]	Total Constellation[3]
DSP-1[1]	200	350	300	650	540	8.7 B
DSP / MLV	800	250	120	370	220	5.2 B
FEWS / MLV	2500	550	140	690	400	11 B
Diet FEWS	2200	450	120	570	330	9.0 B
New Design	1300[4] 1800[5]	260	120	380	220	5.9 B[4] 6.4 B[5]

(1) Includes Replacement of Obsolete Focal Plane and Related Electronics
(2) Includes the Effect of Mean Mission Duration (MMD) - 6 Years for DSP-1; 8.5 Years for Other Satellites
(3) Projected for Deployed, 5-Ball Constellation From 2002 to 2015
(4) Using Existing Bus
(5) Developing New Bus

Ground Segments are Sufficiently Similar That Cost Differences Between Options are Second-Order

Conclusions (1 of 2)

DSP Will Be With Us For More Than 10 Years

Fortunately, Stereo DSP, Though Marginal, is Adequate for Most Purposes

There are Strong Reasons for Wanting a New, More Able Satellite in the Long Run

The Current Requirement and Associated FEWS Specification Originated in a Time of Complex Strategic Needs Including Nuclear War Fighting

Times Have Changed - Strategic is Less Important, Global Awareness and Theater Support are More Important

Conclusions (2 of 2)

Simple Modifications of Existing Plans will not Achieve the Lightest, Cheapest, Most Flexible, Least Risky Solution

There is Sufficient Time to Redo the Requirements and Compete for a Better, Simpler, Cheaper System within the Existing, Budget-Constrained Schedule

Readiness Calls for Filling the SBIR Coverage Gap with Block 23

Brilliant Eyes is Really a Part of a Very Long Range Missile Defense System (e.g., NMD) - For Which There is Currently Neither a Design Nor a Decision to Proceed

Block 23 has a Much Higher Priority Than Brilliant Eyes

Recommendations

Redo SBIR Requirements in Context of Expected Needs and Other Systems (e.g., GBR, AEGIS, ...)

Compete Objective System on Basis of Redone Requirements and Low Cost

Acquire DSP Block 23 to Ensure Coverage During Transition to Objective System

- Launch Next 3 DSPs ASAP to Fill Near-Term Gap (On Shuttle if Necessary)
- Explore Use of Flight 12 Configuration for MLV Launch

Reduce BE Technology Program and Reprogram Funds to Support Block 23 Acquisition

- CLASSIFIED -

Collect Environmental Data for SBIR Sensors

BACK-UP SLIDES

Performance of DSP

DSP is Adequate for TW/AA of Missiles Launched at the U.S.

- Must Fix the Ground Processing For Above The Horizon (ATH) Detection
- Must Keep Radars & NDS for Attack Assessment & Dual Phenomenology

Stereo DSP Provides Adequate Near-Term Capability for Deployed Missiles of >300 km Range

- Implies Triple Coverage Over Region(s) of Interest
- "Pushing the Performance Envelope" For the Existing Design

DSP's Value for "Mission E" is Marginal

JTAGS is Adequate For "Direct to User" Timeliness & Flexibility, if Desired

FOUO

The Coming Coverage Gap (1 of 2)

- CLASSIFIED -

The Coming Coverage Gap (concluded)

Far-Term (Transition) Gap Could be Avoided

- Faster Launches to Reduce Near-Term Gap will Raise Risk During System Transition in Early 2000's
- Further Transition Risk Due to ...
  - Potential Objective System Schedule Slippage
  - Transition to Inclined Orbits (May Require 2 for 1 Replacement)
  - Extended Initial On-Orbit Checkout of Objective System

Options

- *Plug Coverage Gap via Other Means (Radars, Acoustic, Local IR Sensors, ...)*
- *Buy DSP Block 23 and Either ...*
  Accelerate Titan Launches or ...
  Reach Agreement for Shuttle Launch or ...
  Shift Block 23 Birds to MLV Design
- *Accelerate Objective System*

SBIR Needs

TW/AA Mission Need Continues to be "High" for ...

- Rapid Warning of Launches From US Coastal Waters
- Less Rapid Launch Warning in Other Areas
- Attack Assessment (But Value Declines Rapidly After 10's of Events)

Theater Missile Defense is a New Need ...

- Must be Considered in Conjunction with Other Systems
- Requirements Depend on Importance Attached to Long-Range (> 1500 km) Threats

Global Awareness will Continue to Increase in Priority

- Monitor World-Wide Ballistic Missile Activity
- Observe Bright Non-Missile Signatures
- "Mission E"

Some Traditional Reqmt's are Now Lower in Priority

- Polar Launch Timeliness
- Heroic Survivability & Endurance Measures (But No "Cheap Shots" Allowed)
- Mass Raids

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TW / AA Availability Criteria

- CLASSIFIED -

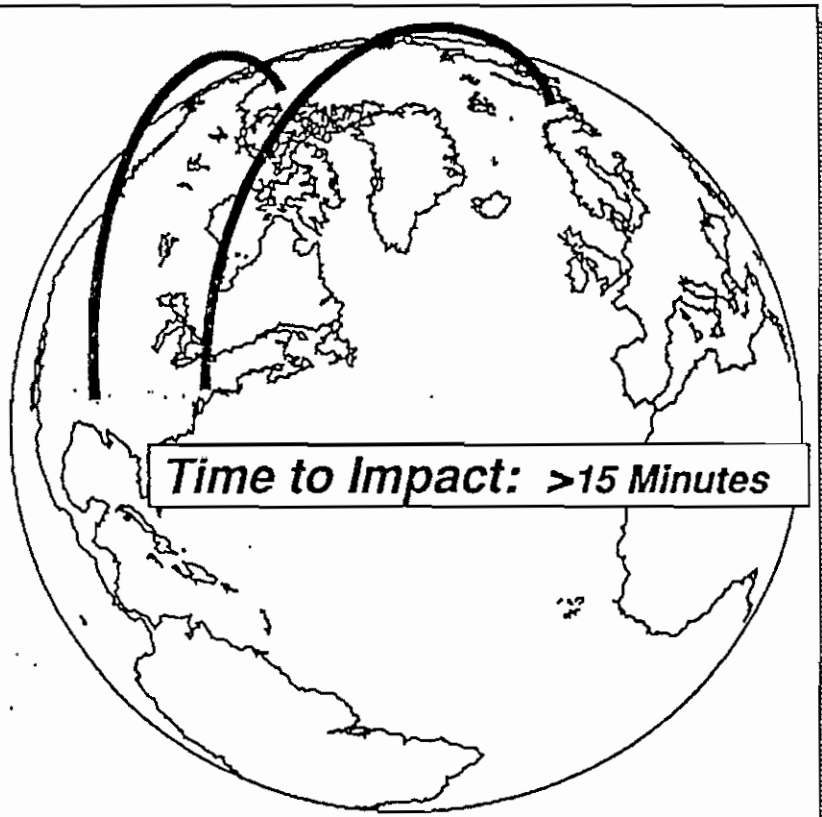
Polar Coverage

TW / AA Needs

- Timely Warning of SLBM Attack on CONUS (esp. Counter-Force / C3)
- Timelines for U.S. Force Execution and Non-Polar SLBM Launches Imply Acceptability of 2-3 Minutes Warning Time
- Requires Unambiguous Launch Azimuth (Toward US or Not)

TW / AA Implications

- BTH Coverage Meets Needs -- Must be Inclined Orbit.
- ATH Coverage Meets Needs --- May be Equatorial Orbit.



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TSG Assessment of TMD Needs

Missile Attack on Forces and Allies in Region of Conflict

- Warning
  - Within ≈2 min After Launch
- Assessment (within 2 - 3 min)
  - Number: Specific Count < 10 / 10's to 100 / 100s+
  - Missile Type (All Cases)
  - Predicted Impact: Identify Urban-sized Area Under Attack
    (One Quarter of Urban Area Desirable)
- Assist Active Defense
  - Location for Radar Cue: Few km's & +/- 3 deg. Azimuth
  - Location for Attack on TEL: 0.5 - 1 km CEP (Desirable) / 1 - 2 km (Required)
- Survivability: as above.
- Reliability
  - On the Order of 1 False Alarm Per Week
  - Probability of Detection ≈ 95%

Sensor Types vs. TBM Range

Efficacy vs. Range

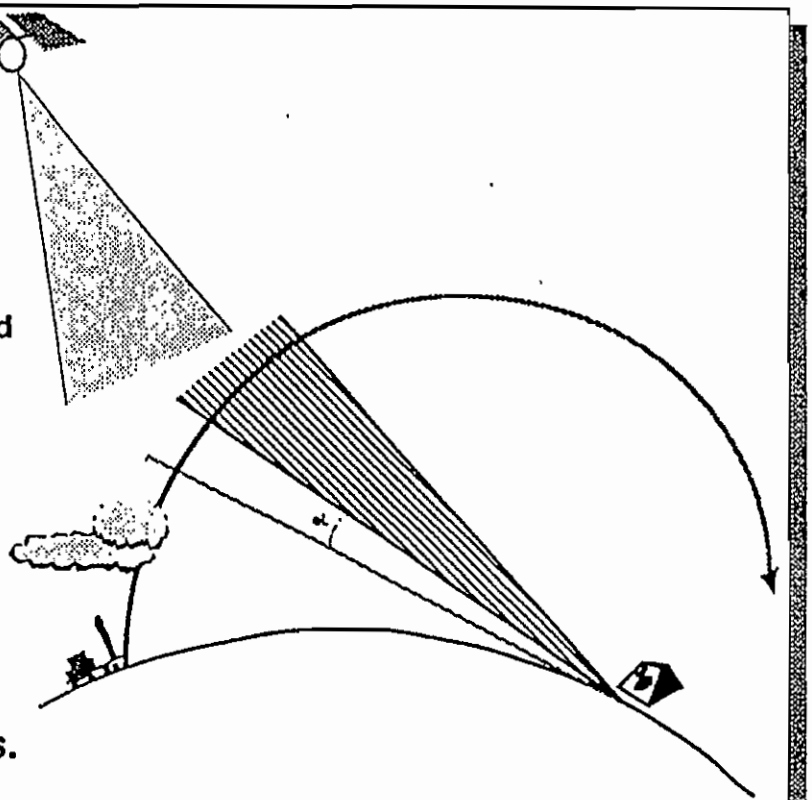
<300 km	300-1000 km	>1000 km
Radars Warn & Assess - SBIR Might confirm	Both Warn - Radars Assess	SBIR Warn and Assess Radars Assess & Goal-tend

Key Factors

Timeliness: Penetration of Search Fence vs.
Time of Cloud Break + Revisit Time

Availability: Air Deployable GBR or Shipborne vs.
Almost Always Present

Radar Energy Budget & Traffic Load Determines
Need for Cueing by SBIR Sensor
(Very Useful for Long Range Characterization Tasks)



Example Shown is Representative of
800 km Range From Launcher to Radar

TMD Performance Measures

Cueing Sensor	Performance Measure				
	Location Est. (km)		Cueing (km)		
	Launch	Impact	GBR ACQ Range	Direct To Int.	UOES THAAD Footprint
Autonom Radar	~ 0.5	~ 0.5	500	Yes	250
	~ 3				175
	~ 10				100
Boost Low Data Rate	1-2	~ 25	1000	No	400
		~ 50	1000		350
		~ 100	500		100
Boost High Data Rate	0.5-1	~ 5	1000	No	400
		~ 10			350
		~ 20			300
Midcourse	0.2-0.4	~ 1	1000	Large Divert Int. Only	400/400*
					350/450*
					300/675*

* Valid for Objective THAAD with Commit on BE

TBM Range
300 km
1000 km
3000 km

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FEWS Improvement in LPP Has Marginal Effect on TBM Counterforce

Launch Point Accuracy (km, CEP): FEWS: (classified)
Stereo DSP: (classified)

Method of Finding & Attacking TEL	Assessment
F-15E Autonomously	If F-15E > 70 km from TEL, TEL departs before aircraft arrival.
	If F-15E < 70 km from TEL ...
– Drops Bombs on GPS Coord.	Neither FEWS nor DSP Adequate
– Find TEL with APG-70 SAR	
Hi-Res SAR Pattern:	FEWS Marginal; DSP Inadequate
Lo-Res SAR Patterns:	Both Adequate (Target ID Uncertain)
JSTARS	
Finds TEL with SAR Mode, Tracks with MTI after departure, passes coord. to F-15E equipped with LANTIRN	Both Adequate - (Slightly quicker detection and lower false contact rates with FEWS data.)

FEWS and DSP Support for TBM Counterforce

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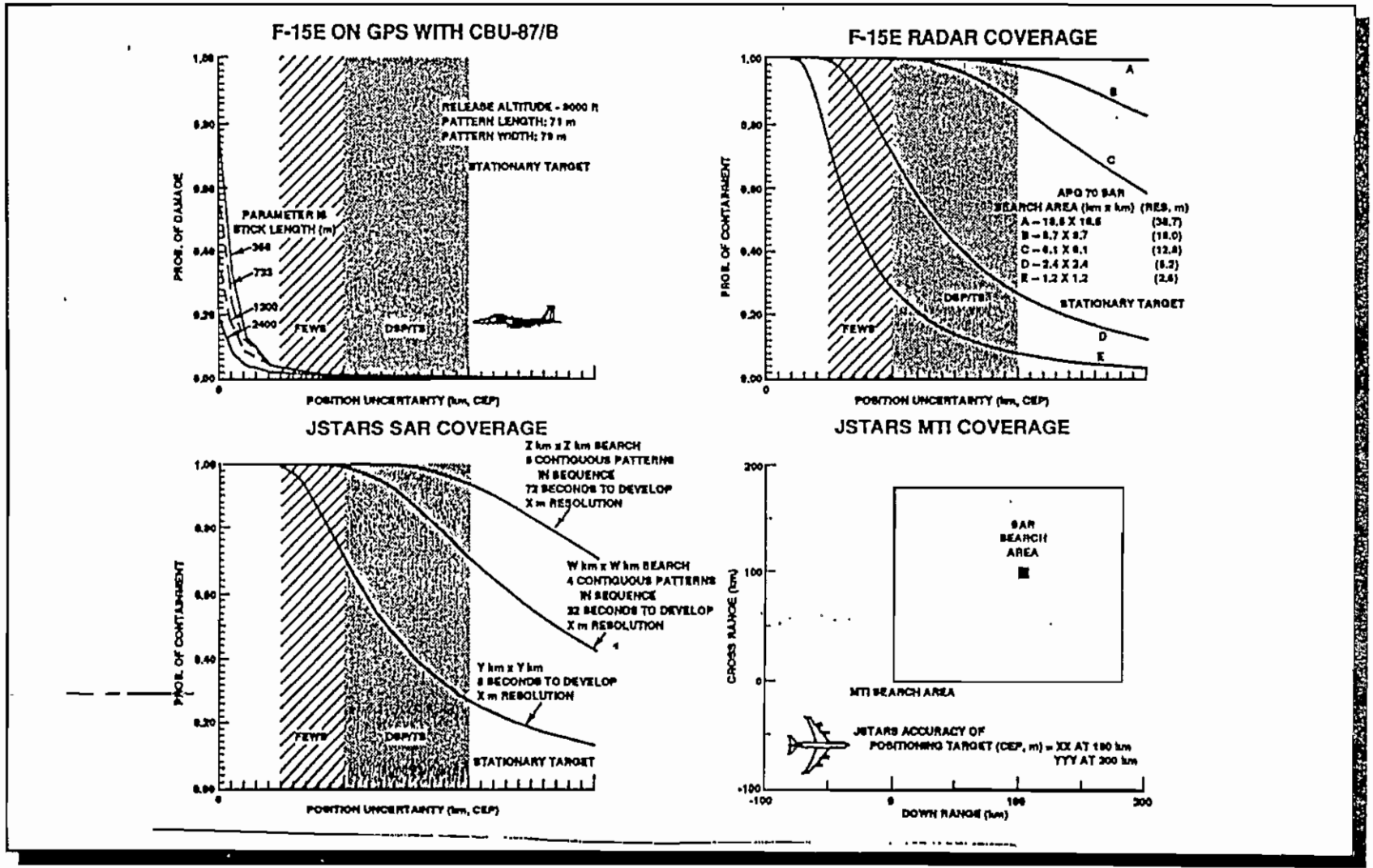

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New Design

Basic Concept: New 3-axis stabilized system based on new reqm'ts & "from scratch" design employing technology legacy from FEWS. May include separate, but smaller, sensors for global surveillance and regional / "Mission E" support.

PRO's	CON'S
• Meets Missile Warning Needs	• Programmatic Risk
• Meets Many Mission E Needs	• Ground-based Processing Required
• Allows Growth to Support Military Operations (i.e., Non-missile Events)	• No Direct-to-User Operations (But Direct-to-Theater with JTAGS)
• Operational Flexibility	
• Second Lowest Cost	
• Allows Funding of Low Risk Transition	

Cost -

New Design

Cost Per Sat. on Orbit:	$ 380 M
Non-Recurring:	$ 1.3 B
To 2015:	$ 5.9 B

Est. Total to 2015:

Block 23 Transition =	$ 2.1 B
Grand Total =	$ 8.0 B

Total in '94 - '99:

Block 23 Transition =	$ 2.1 B
New Design =	$ 1.9 B

Preamble

What We Tried to Accomplish ...

- Provide for Military Needs as we Understand Them
- Without Dangerous Gaps in Coverage
- At an Acceptably Low Cost

We Believe we have Succeeded

Military Needs

TW / AA of Ballistic Missile Attack on the U.S.

Global Awareness of Ballistic Missile Activities (and Such Other Activities as may be Possible) - Continuous, World-wide

Support Theater Operations ...

- Warning of Theater Missile Attack
- Launch Point Prediction to Aid Counter-Force Attack
- Impact Point Prediction to Cue Active Defenses and Alert Forces for Passive Measures
- Regional IR Coverage for Intelligence Support to Conventional Operations

SBIR Information Delivered to Users with Minimum Delay

Technical Intelligence

What Did We Find?

New SBIR System with Improved Accuracy, Sensitivity & Revisit Rate is Highly Desirable

There is Sufficient Time to Get an Objective System That will Meet Military Needs at Much Lower Cost Than the Proposed FEWS

Stereo DSP Provides Adequate Near-Term Capability for Deployed Missiles of >300 km Range

There is a High Probability of a Gap in SBIR Coverage During System Transition without Block 23

Role of Augmentation

- CLASSIFIED -

What About Brilliant Eyes?

BE Could be a Valuable Part of a National Missile Defense System

BE Will be of Only Marginal Value in Theater Missile Defense

- Regional Missiles (i.e., < 1500 km Range) Adequately Addressed by Patriot PAC-3 and THAAD Supported by (Cued) Radars
- Need to Acquire a High-Energy Interceptor (e.g., Navy Upper Tier) + Defense Policy to Prioritize Dollars for BMD of Allies vs. Other Needs ... Before BE is Really Valuable for TMD

BE (As Planned) Will be of Marginal Value to Global TW/AA

- Accurate Mid-Course Attack Assessment for Long-Range & Strategic Missiles
- Alternate Source to Support Dual Phenomenology

Credible Options

- *If You Commit to Acquiring NMD, Do a Detailed BMD Evaluation, Buy BE + Examine Potential to Relieve Objective TW/AA System From Some Regional Requirements*
- *If Not, Do At Most One BE Demonstration and Reprogram Funds*

C3, Processing, and Dissemination

Processing

- Autonomous Processing in the Satellite Derived From Nuclear Warfighting - Expensive, Entails Risk, and is Less Flexible Than on Ground
- Ground Processing is Needed in Any Event
- Talon Shield is Suitable for DSP and Objective System
- JTAGS Available When Processing is Needed in Theater
- Simple Proliferated Ground Relays are Needed

Dissemination to the User

- Many Types of Information are Important to User Besides SBIR (e.g., Radar)
- Building a "Stovepipe" System for SBIR is Neither Justified nor Recommended
- An Overall Architecture for Theater C3 is Needed, within which SBIR Must Fit

FOUO

Environmental Data Needs

Every BTH SBIR Sensor for TW/AA has been Clutter-Limited

"Modelled" Clutter Characteristics Drive All Proposed Designs
- Keys are Spatial and Spectral Structure vs. Viewing Geometry (Probabilistic)
- Key for Band Selection, & Processing Algorithms and Design

Models are Not Backed by Adequate Data
- MWIR Clutter is Assumed at Relevant Spatial Resolutions & Sensitivities
- Long-term, Synoptic SWIR Data of Relevant Resolution & Sensitivity Absent
- AND Models are Unvalidated and Lack Context

Measurements are Essential - Can be Done Once, if Done Well
- Need Data in Multiple Bands, Synoptic, Long-Term
- Small-Sat, Long-Duration Experiment with Good Sensors will do the Job

Investment is Second-Order Compared to Any Proposed Objective System - Benefit in Performance & Risk Reduction is First-Order

FEWS / MLV

Basic Concept: Existing design lightweighted for MLV.

PRO's

- Minimal Programmatic Impact
- Meets Missiles Warning Needs
- Meets Many Mission E Needs
- Hedge Against Russian Revanche and Renewed Policy of Nuclear Warfighting

CON'S

- Most Costly Option
- No Weight Margin for Growth
- Uncertain On-orbit Reliability
- Inclined Orbit Constrains Operational Flexibility
- Implies Acceptance of Transition Coverage Gap Due to FYDP Cost

Cost -

FEWS/MLV

~~Cost Per Sat. on Orbit:~~	~~$ 690 M~~
Non-Recurring:	$ 2.5 B
To 2015:	$ 11 B

Est. Total to 2015:

Block 23 Transition =	$2.1 B
Grand Total =	$ 13 B

Total in '94 - '99:

Block 23 Transition =	$2.1 B
FEWS / MLV =	$3.6 B

Diet FEWS

Basic Concept: Existing design for MLV launch ... minus on-board processing & cross-links.

PRO's

- Minimal Programmatic Impact
- Meets Missiles Warning Needs
- Meets Many Mission E Needs

CON'S

- Second Most Costly Option
- Little Weight Margin for Growth
- Inclined Orbit Constrains Operational Flexibility
- Implies Acceptance of Transition Coverage Gap Due to FYDP Cost
- Requires Ground-based Processing
- No Direct-to-User Operations (But Direct-to-Theater with JTAGS)

Cost -

Diet FEWS

Cost Per Sat. on Orbit:	$ 570 M
Non-Recurring:	$ 2.2 B
To 2015:	$ 9.0 B

Est. Total to 2015:

Block 23 Transition =	$ 2.1 B
Grand Total =	$ 11 B

Total in '94 - '99:

Block 23 Transition =	$ 2.1 B
Diet FEWS =	$ 3.1 B

DSP / MLV

Basic Concept: Downsize to Mission 12 bus with updated power, FPA & electronics.

PRO's

- Lowest Cost Option
- Meets Strategic Missile Warning Needs
- Meets Current Regional Missile Warning Needs
- Lowest Transition Risk

CON'S

- Does Not Meet "Mission E" Needs
- Support to Regional Warning / Assessment Missions May be Fragile In Future
- Very Limited Growth Avenues
- Ground-based Processing Required
- No Direct-to-User Operations (But Direct-to-Theater with JTAGS)

Cost -

DSP / MLV

Cost Per Sat. on Orbit:	$ 370 M
Non-Recurring:	$ 800 M
To 2015:	$ 5.2 B

Est. Total to 2015:

Block 23 Transition =	$ 2.1 B
Grand Total =	$ 7.3 B

Total in '94 - '99:

Block 23 Transition =	$ 2.1 B
DSP / MLV =	$ 1.5 B