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TITLE: The Future of Ballistic Missile Defense Technology

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The following component part numbers comprise the compilation report:
ADP011183 thru ADP011193  ADP204784 thru ADP204818

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The Future of Ballistic Missile Defense Technology

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BMDO Chief Scientist

10th Annual AIAA/BMDO Technology Conference
Williamsburg, Virginia

23–26 July 2001
## BALLISTIC MISSILE DEFENSE MISSION AND TECHNICAL CHANGES 1984 - 2001

### Technology Segment

<table>
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<tr>
<th>Research</th>
<th>Phase I</th>
<th>GPALS</th>
<th>TMD</th>
<th>NMD</th>
<th>BMDS</th>
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<tr>
<td><strong>Mission</strong></td>
<td>Protect Against Massive Soviet Attack</td>
<td>Deterrence</td>
<td>Protect Against Limited Attack</td>
<td>Tactical Requirements</td>
<td>Protect Against Limited Attack</td>
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<td><strong>Element Focus</strong></td>
<td>DEW</td>
<td>Space (SpaceBased Interceptors (SBI))</td>
<td>Brilliant Pebbles</td>
<td>Terminal Interceptors (THAAD)</td>
<td>EKV</td>
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<tr>
<td><strong>Key Challenges</strong></td>
<td>Feasibility</td>
<td>Survivability</td>
<td>Midcourse Discrimination</td>
<td>Family of Systems Integration</td>
<td>Midcourse Discrimination (One Tier Architecture)</td>
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<td></td>
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<td>Midcourse Discrimination</td>
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</tbody>
</table>
BMD EVOLUTIONARY DEVELOPMENT

- Add New Capability Based On Technical Maturity
- Upgrade Existing Capability – Insert Technology
- Procure Additional Force – Enhance Capability
- Extend To Allies And Friends When Appropriate

Evolutionary Spiral Development

- Technology Development
- Architecture Re-balancing
- Counter-countermeasure Development
  - Red, White, And Blue Teams
- Requirement Evolution
GOALS OF BMDS PROGRAM

Technology Segment

- Single BMD Acquisition Program With Goal Of Deploying Incremental Capabilities As Soon As Practical
- Start With What WE Know – Build On The Technical Progress Made To Date Without Losing Focus
- Get Capability In the 2004-2008 Time Frame
- Move To A Layered Defense Soonest
TECHNOLOGY MATURATION

Technology Segment

- TRL 1 Paper studies
- TRL 2 Invention
- TRL 3 Component Development
- TRL 4 Breadboard Integration
- TRL 5 High Fidelity Integration
- TRL 6 Test Prototype in Relevant Environment
- TRL 7 Test System Prototype in Operational Environment

- TECHNOLOGY SEGMENT FOCUSES ON EARLY DEVELOPMENT OF HIGH-RISK, HIGH-PAYOFF, BREAK-THROUGH CAPABILITIES

- OTHER SEGMENTS’ RISK REDUCTION PROGRAMS CONTINUE MATURATION

CAPABILITY SPECIFICATIONS

- DT&E TRL 8
- OT&E TRL 9
• **Extended Footprint for Upper Tier Systems**
  - Demonstrate Capability to Increase Defended Area of THAAD Through the Development of Strapdown IR Seeker, Solid DACS, Batteries and Composite Structures.

• **Long Range Atmospheric Defense**
  - Investigate an Innovative Concept to Increase Defended Area with a High Speed, Long-Range Interceptor Operating in the Atmosphere
LONG-RANGE ATMOSPHERIC INTERCEPTORS

Technology Segment

The UAV "Positioner" Carries Sensors For Discrimination And Fire Control, Multiple Interceptors For Kill

Lightweight Objects Slowed By Atmosphere

Rocket Boost To Altitude

The "Positioner" Pulls Up To Battle Position In The Path / Plane Of The Reentering Cluster

2.4 Mach Cruise, 470 km Range
MIDCOURSE SEGMENT PROGRAM PLAN

Technology Segment

- Implement Complementary, Capability-based, Block Upgrade Midcourse Development

- Ground-based:
  - Include Robust Counter-countermeasure Program
  - Implement Test Infrastructure Improvements Netted Into An Operational Test Bed
  - Could Make Available A Rudimentary Ground-based ICBM Defense Contingency Capability By 2004
  - Achieve Ground-based Capability By 2006

- Sea-based: Begin Concept Development For Expanded Midcourse Capability Including Sea-based Ascent Phase Intercepts
  - Continue AEGIS LEAP Intercept (ALI) Flight Testing
  - Provide Rudimentary Sea-based MRBM Defense Capability
  - Leverage Boost Phase Propulsion And Kill Vehicle Risk Reduction Activities
  - Leverage Midcourse Ground-based Propulsion, Kill Vehicle, BM/C² And Test Infrastructure
  - Achieve Navy Theater Wide IRBM Or ICBM Capability By 2008 / 2010
MIDCOURSE COUNTER-COUNTERMEASURES (CCM)

**Technology Segment**

- **Discriminating Seeker**
  - Demonstrate Capability To Discriminate RVs From Advanced Countermeasures Based on Temperature, Shape and Dynamics
  - Integrate Multi-Spectral IR FPAs, Ultra Compact Laser Radar and a High-Speed Miniature Fusion Processor

- **Interactive Discrimination**
  - Explore Novel Methods of Discrimination Including Momentum Transfer and Thermal Tagging

- **Transportable Discriminating Radar**
  - Demonstrate a Lightweight Radar with the Capability of Discrimination in the Early Ascent Phase

- **Miniature Kill Vehicles (MKV)**
  - Demonstrate an MKV Capability For Cost-Effective Negation of Multiple Objects
LADAR DEVELOPMENT FOR INTERCEPTOR SEEKER

Technology Segment

ADLT Compact Breadboard
- First Portable RRDI Ladar
- Indoor/Outdoor Testing
- Short Wavelength (1 μm)

ADLT Compact Flight Unit
- Miniature Opto-mechanical Design (Laser, Receiver, Pointing)
- Airborne or Space Flight Testing
- Full Discrimination Performance
TRANSPORTABLE DISCRIMINATING RADAR (TDR)

- TDR Can Measure Interactive Slowdown
- TDR Can Measure Induced Macro And Micro Dynamics (Coning / Wobble)

Dust

RV

TDR Can Track And Discriminate Early In Ascent Phase
MINIATURE KILL VEHICLE (MKV) CONCEPT

Enabling Component Technologies

- Compact Telescopic Optics
- Cooled, LWIR FPA
- Lightweight Power Sources
- G&C Algorithms
- MEMS Gyro
- MEMS Divert and Spin Thruster Ring
- MEMS Attitude Control Microthruster Wafer
- Monolithic Electronic Interface Wafers

Physical Characteristics
- Subkilogram Mass
- Size Of A “Softball”
- < 10 cm Diameter
- < 6 cm Length
- Efficient Shape

Performance Requirements
- Spinning Projectile
- Narrow FOV (~2-4 deg)
- 20-40 km Acquisition Range
- 50-100 m/s Δv
- Very Small Miss Distances
BUS SENSOR CONCEPT

Sensor Balancing
- Acquisition Range
- Target Tracking Accuracy
- Derived from DITP concept
  - 25kg objective (sensor & avionics)

MMKV size and weight provides opportunity to assign multiple KVs to each object

Balance Bus Sensor with KV Sensor
Balance Bus Handover with KV GNC

Continued Coordination with REDEAM Study
• Demonstrate And Field Airborne Laser
  – Could Make Available Emergency Capability (Block 2004)
  – Initial Capability (Block 2008)

• Define Sea-Based Boost Defense Concept Over 2-4 Years
  – Prepare For Product Line Decision (2003-05)

• Define Space-Based Boost Defense Concept Over 2-4 Years
  – Reduce Technical And Programmatic Risks (2004-05)
  – Prepare For Product Line Decision (2003-05)

• Conduct Space-Based Kinetic Energy Experiment (2005-06)

• Conduct Integrated Flight Experiment Of Space-Based Laser by 2012
ABL HAS FOUR LASERS

- Beam Control – Yb-YAG Target Illuminator Laser
- Beam Control – Nd-YAG Beacon Laser
- BM/C^4I – CO₂ Laser Ranger
- Laser – COIL High-power Laser
KE BPI TECHNICAL ISSUES

Technology Segment

Space Surveillance

Multi-Mode KV

Predicted Intercept Point Generation
- Uncertain Staging Times, Target Pitchover and Acceleration Profile

Endgame
- Plume-to-Hardbody
- Aiming Point Selection
- GN&C
- Lethality

Multi-Stage ICBM Threat
- High Speed
- Complex Phenomenology

KE BPI Weapon System

Flexible/High Performance Propulsion
- Booster and DACS
- Optimal GN&C

Airborne Surveillance

High Speed Interceptor >6 km/s

Autonomous Weapon BMC
- Weapon Autonomous Mode
- Low Latency Comm Network
- BPI Rules of Engagement

Launcher Compatibility

All-Weather Surveillance
- Detect
- Track
- Classification
- ID

Launch Site

500 km (mid term goal)-1000 km (long term goal)
GLOBAL DEFENSE

Technology Segment

- Space Based Passive Surveillance (Support to SBIRs-Low)
  - Higher Resolution Optics
  - Increased Sensitivity Focal Plane Arrays
  - Long Life Cryocoolers
- Space Based Active Tracking System
  - Bifocal Relay Mirrors
- Airship Sensor
- Space Based Interceptor (SBI) Concept Development
- Technology Development for Space Based Laser System Concept
  - Deployable Optics
  - Advanced Jitter Control
SPACE RELAY MIRRORS

Technology Segment

Crosslink range: 8500 km
RM capture: 0.45

Crosslink range: 4200 km
RM capture: 0.87

For each relay mirror:
Input/output diameter: 3 m
Optical transmission: 0.78
Strehl: 0.9

Uplink range: 2000 km
Atmospheric transmission: 0.85

Transmitter diameter: 3 m
Xmtr opt. trans.: 0.8
Adaptive optics Strehl: 0.6

Energy on target: 0.5
## SPACE BASED LASER (SBL) SYSTEM

### Technology Segment

<table>
<thead>
<tr>
<th>Notional Space Vehicle</th>
<th>Mission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unfolding Primary Mirror</td>
<td>• Boost Phase Intercept Capability For Global Continuous Ballistic Missile Defense</td>
</tr>
<tr>
<td>Chemical Laser</td>
<td></td>
</tr>
<tr>
<td>Tracking Subsystem (Not Shown)</td>
<td></td>
</tr>
<tr>
<td>Beam Control Subsystem</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>System Issues</th>
<th>Technology For Operational System</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Affordability</td>
<td>• Lightweight Deployable Mirrors</td>
</tr>
<tr>
<td>• Launch Vehicle (Size / Weight)</td>
<td>• High Energy Laser At Shorter Wavelength</td>
</tr>
<tr>
<td>• Integrated Flight Experiment (IFX)</td>
<td>• Extraordinary Jitter Control</td>
</tr>
<tr>
<td></td>
<td>• Advanced Acquisition, Tracking And Pointing Subsystem (ATP)</td>
</tr>
</tbody>
</table>
ENABLING TECHNOLOGY SUPPORT

Technology Segment

- Advanced Technology
  - Radar
  - Multi-application FPAs
  - Materials, Structures and Power
  - Space Experiments

- Applied Research
  - Innovative Science & Technology
  - Interceptor/Surveillance Applied Research

- Statutory & Special Interest Programs
  - SBIR
  - HBCU/MI
  - Technology Applications
  - Congressional Interest Projects
WIDE BANDGAP TECHNOLOGY

Electronic And Photonic Materials

Wide Bandgap Materials For High Performance Radar Systems

Gallium Nitride Power Amplifier

- Projected 2 To 4X Increase In Radar Range
- 8X Increase In Power Density
BMD'S SMALL BUSINESS INNOVATIVE RESEARCH (SBIR) PROGRAM

Technology Segment

BACKGROUND

- Mandated At Not Less Than 2.5% Of Agency’s Extramural RDT&E Funding
- Cannot Use Non-SBIR Awards To Meet SBIR Goals
- Program Structure
  - Phase 1  Feasibility – Maximum Award $100K for Six Months (Avg. is $65K)
  - Phase 2  Development – Maximum Award $750K For Two Years

ISSUES

- Management Resources Needed To Track Several Hundred Awards Each Year
- Payoff To BMDO Not Clear
  - Component Level Work (Proposed By Small Business’) Difficult To Connect To Major Projects (Under Development By Prime Contractors)
  - Program Emphasis Is Industrial Commercialization First (High Volume, High Profits), Then Military Application
- Program Now Dominates BMDO (Discretionary) Investments in Technology
  
<table>
<thead>
<tr>
<th>FY 00</th>
<th>FY 01</th>
<th>FY 02</th>
</tr>
</thead>
<tbody>
<tr>
<td>$60M</td>
<td>$90M</td>
<td>$154M (Projected)</td>
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</table>
Regional Defense Of Allies
High-speed Interceptor Can Be Driven Through The Atmosphere To A Point In Front Of A Threat Cloud. Engagement Of RV Takes Place After The Atmosphere Filters The Associated Penaids

Miniature Kill Vehicles
Mini-KVs Are Smart Bullets Delivered By A Carrier Vehicle Then Released To Engage Incoming Threats (RVs And Decoys)

Air Based NMD Sensors And Weapons
Air Ship Can Carry Sensors For Midcourse Surveillance Or Be Configured To Carry Sensors And Weapons For Boost Phase Engagement

Space Relay Mirrors
A Constellation Of (Bifocal) Relay Mirrors In Space Can Be Used To Direct Laser Beam For "Birth To Death" Tracking Of An RV. Potential Also For Boost Engagement Using A Ground HEL

Space Based Interceptor (SBI)
Modern Design Of Space Platform Capable Of Launching Multiple Kinetic Energy Interceptors

Space Based Laser (SBL)
Concept Of Space Based High Energy Laser System To Engage Ballistic Missile Threats In Boost Phase
SUMMARY OF BALLISTIC MISSILE DEFENSE TECHNOLOGY TRENDS

Technology Segment

- COMPONENT LEVEL
  - Miniaturization Leading to the Downsizing of All Sensors and Weapons

- SYSTEM LEVEL
  - Today’s Passive Electro-Optical Sensors Enhanced by LADAR Systems

- WEAPON TYPE
  - More Emphasis on Directed Energy

- PLATFORMS
  - More Emphasis on Space Systems
It takes courage to do something that's never been done before. To attempt a feat that goes beyond conventional thinking. But, it also takes planning and a complete understanding of all the problems that may arise. No one has a better firsthand knowledge of the inherent risks of daring enterprises than we do... So the next time you wake up, mind ablaze with an idea that nobody's attempted to pursue before, contact BMDO/ST. We're the segment that helps challenging ventures get off the ground.