MDA Next Generation IR Detector Development

At QWIP 2006, An International Workshop on
Quantum Well Infrared Photodetectors

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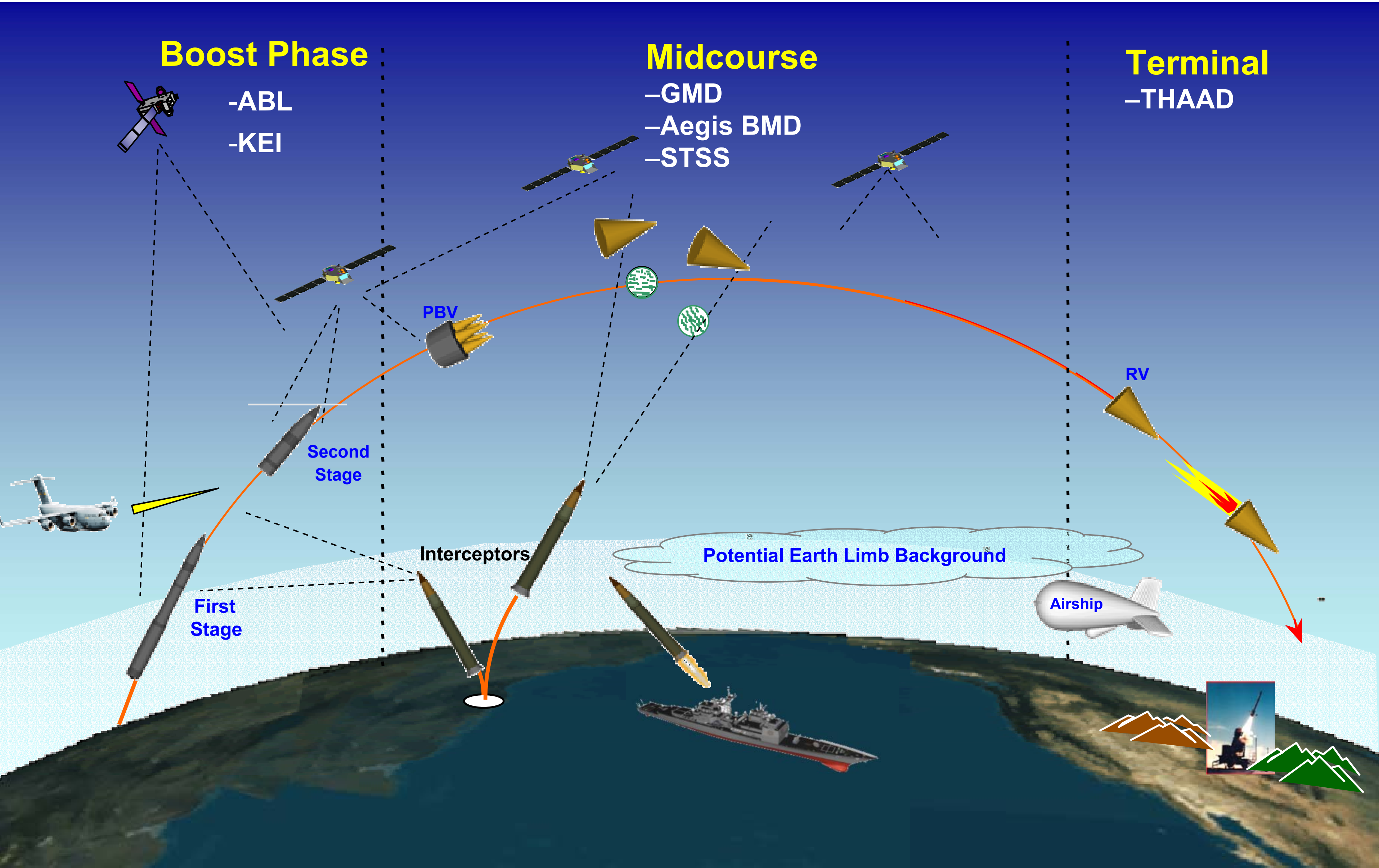
Outline

- IR Sensors are Very Important to Ballistic Missile Defense
- BMD IR Sensors are Very Challenging
- MDA/DV Passive EO/IR Program
- IR Sensors Developed in the Past Few Years and Transition Opportunities
- New IR Sensors Under Development for Blocks 2010 and Beyond
- Recent Progress on the Current IR Sensor Development
- Summary

Layered Missile Defense Systems



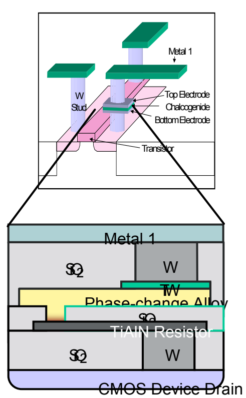
MDA/DV Passive EO/IR Sensor Program

- **Objective: Provide next generation passive EO/IR sensors for future ballistic missile defense.**
- **Challenge: develop sensors that are higher performance, faster, lighter, smaller, smarter, more compact, reliable, and affordable.**
- **Approach:**
  - **Work closely with BMDS to identify their need.**
  - **Investigate existing and alternative IR materials that have potential for meeting BMD needs.**
  - **Leverage Services funding and industry IRAD.**
  - **Annual go, no-go decisions.**
  - **From year 2000-2004, developed VWLIR HgCdTe, two-color LW/LW HgCdTe, and some two-color Si:As and QWIP efforts.**
  - **Currently concentrate funding on developing 4 major IR materials.**
  - **Multiple contractors to induce competition and reduce risk.**
  - **Facilitate technology transition through lab testing, HWIL, simulated environmental and field testing.**
- **Actively participate in SBIR/STTR, MSTAR and BAA.**

Advanced Space Components Supporting STSS

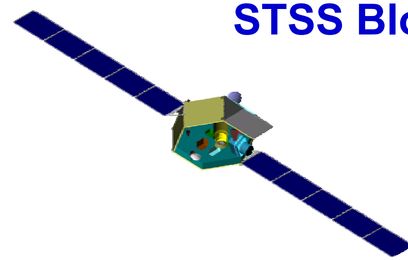
STSS Block 06 Sensors

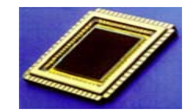
Flight Demonstration System (FDS)
Acquisition Sensors: SWIR, scanner
Track sensor: Vis (scan)-LWIR (starer)



Chalcogenide radhard visible. Transitioned to MP and STSS

STSS Block Upgrade Sensors

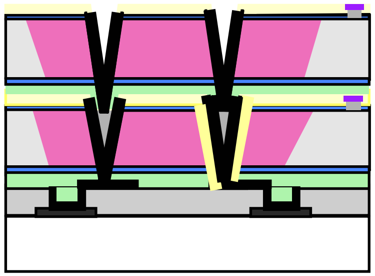




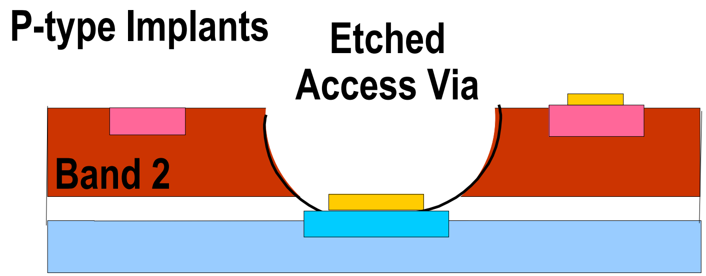
- **Advanced rad-hard FPAs extending to VLWIR**
- **Transitioned to MP and STSS for a second phase**

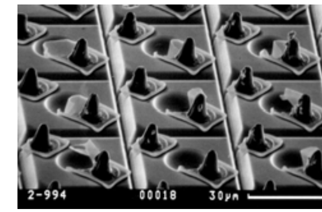
Two stage 35K/ 85K, and 10K pulse tube cryocoolers. NGST successfully demo a 35K/85K cryocooler for life testing at AFRL. DV is continuing funding NGST for a 10K cryocooler demo

Two-Color FPAs Have Potential for Insertion to EKV, MKV, and KI

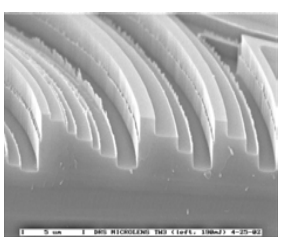


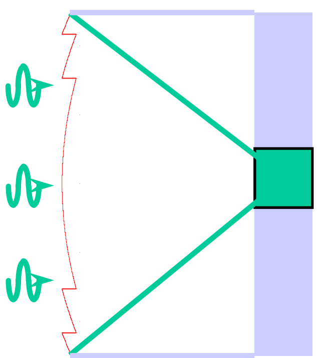
DRS two color HgCdTe
LPE via hole connection





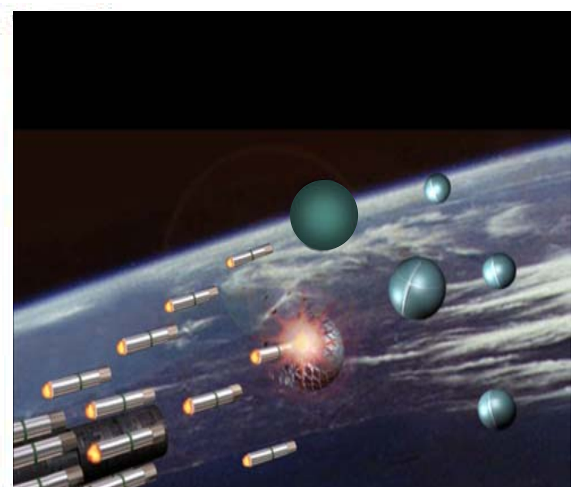
RSC two color HgCdTe, MBE with micro-lens. Sensor





DRS Anaheim two color
Si:As BIB lenslet

EKV



MKV

Current IR Material Limitations

- **HgCdTe on CdZnTe substrate**
  - Limited array size due to limited CdZnTe substrate size
  - Only one Japanese vendor can provide 211 MBE CdZnTe substrates
  - CdZnTe substrate is soft yet brittle, making processing very difficult
  - Difficulty in extending to very long wavelength
  - Limited material quality, array uniformity, operability, manufacturability, and yield
- **InSb**
  - Only works at MW and no intrinsic multicolor capability
  - Epitaxy thin film InSb with other elements have potential to extend it to longer wavelength
- **QWIP**
  - Current QWIP has very small quantum efficiency (η) and gain (g) ($\eta g < 2\%$), not enough for low background applications
  - Operating temperatures are lower than HgCdTe at similar cutoff wavelength, also related to the low quantum efficiency and gain product
  - Current QWIPs needs larger format for WFOV tactical applications
- **Si:As**
  - Can cover VLWIR, but only works at 10K, limiting its applications
- **Uncooled Microbolometers**
  - Limited sensitivity, speed, and multicolor capabilities

IR Sensors Need New Development

- **Desired IR Sensor Features**
  - Sensors with greater sensitivity, higher resolution, and larger FOV to increase detection and tracking ranges.
  - Easily producible, lower cost materials, devices and sensors.
  - Easy to extend to VLWIR and multicolor.
  - Elevated operating temperatures to reduce cooling need.
  - Ideally one single material to cover the entire IR spectrum with more customer support.
  - The industry does not depend on government to survive.

- **Material systems to be explored**
  - MCT on Si substrate
  - Type-II strained layer superlattice
  - High quantum efficiency QWIPs
  - Pb salt materials for FPAs

HgCdTe on Si

- Potential for large format, high performance HgCdTe FPA without lattice mismatch to the readout circuitry (means larger FOV, longer range, and more reliable)
- Direct drop-in insertion to upgrade current BMD IR sensor systems
- Program Goal: VLWIR FPAs for low background
- **Status:**
  - Significant progress made since program started
  - Buffer layer quality improved and etch pitch density reduced
  - FPAs delivered on schedule

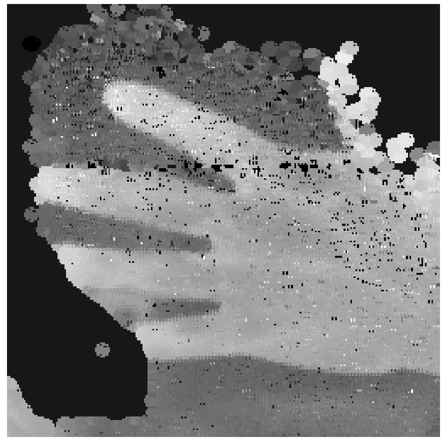
Type II Superlattice

- The SLS has the potential to be superior to HgCdTe, QWIP, and Si:As
- Bandgap can be tuned for strong broadband absorption throughout the 3-30 um range and can easily be designed for multicolor detection.
- Strong Auger suppression can give higher operating temperatures (lower cooling requirement)
- Potential for BMD system upgrades
- Program Goal: VLWIR FPAs for low background
- **Status:**
  - –Significant progress made since program started. Device design optimization in process. Higher QE achieved
  - –High performance single device demonstrated high values

Results of LWIR Type-II Superlattice FPA

These images and movies were taken from a long wavelength infrared (LWIR) Type-II Superlattice focal plane array (FPA), the first in the world.

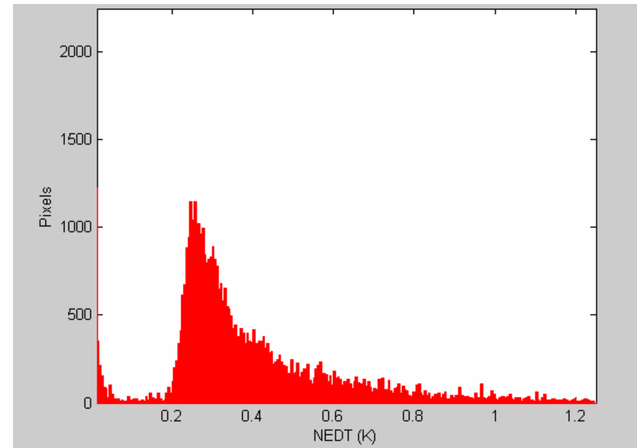
Thermal image of a Ph. D. student



Thermal image of a hand where the veins are shown.

Movie of a Ph. D. student

NEDT Histogram



InSb/GaAlAs Type-II SLS FPA

Format: 256×256

- Cutoff wavelength: 9 μm
- Operating temperature: 80 K
- Frame rate: 27.47 Hz
- Detectivity: 10^{10}-10^{11}cmHz$^{1/2}$/W
- Mean NEDT: 250 mK

Chart provided by Prof Razeghi from NW University who presented it at SPIE 2006 Orlando

QWIP

- Large format, very uniform, high operability and easy for multicolor
- Very suitable for high background applications (ABL and THAAD)
- Program Goal: very large format and multicolor FPAs MW/LW FPAs, improve quantum efficiency for strategic applications
- Status:
  - Delivered large format MW camera and mid format MW/LW two-color camera
  - Quantum efficiency improved
  - Large format FPA in fabrication
  - Two-color MW/LW ROIC in development and will be available to by the end of this year

QWIP Field Test in Aug 06

Planned joint DV/ABL/Boeing Test in Aug 06

Launch Site
White Sands Missile Range

Target:
- Terrier 1st Stage
- Black Brant 2nd Stage
- Other target opportunities

Camera

Observation Site Alamo

Integration

Objective: Transition QWIP to ABL

PbSnTe Program

- Another alternative material that has potential to out perform HgCdTe at VLWIR due to its stronger tolerance to material defects and composition variation
- Goal: VLWIR IR FPAs at low background
- Status:
  - Achieved successful growth of PbSnSe/PbSeTe/ZnTe/Si with 10μm cutoff
  - Demonstrated best-ever structural quality as measured by double crystal X-ray diffraction
  - demonstrated excellent electro-optical quality
  - P-type doping is well understood
  - Alternate hot wall epitaxial growth technology has been initiated

Camera Integration and Testing

- Government funded independent contractors for FPA verification, validation
- Facilitate technology transition through HWIL and relevant environment testing
- Cryocooler Team: Develop a 10 K cryocooler with high efficiency. Characterize and qualify cryocoolers for independent assessments and transition to the BMDS elements
- Independent lab testing at high and low background and radiation tolerance testing in a relevant environment
- Hardware in the loop testing in relevant BMDS environment
- Integrate advanced FPAs into a testbed and support laboratory and MDA field tests
- Field test QWIP and HgCdTe sensors at White Sands Missile Range
- QWIP analysis for BMD environmental test

Summary

- IR sensors are very Important to ballistic missile defense.
- BMD IR sensors are very challenging.
- MDA/DV Passive EO/IR Program is developing new IR sensors
  - MCT on Si Substrate
  - Type II SLS
  - High QE and Large Format two-color QWIPs
  - PbSnTe
- Significant progress is being made.

QWIPs for Ballistic Missile Defense?

For the Panel Discussion at the QWIP 2006 Workshop

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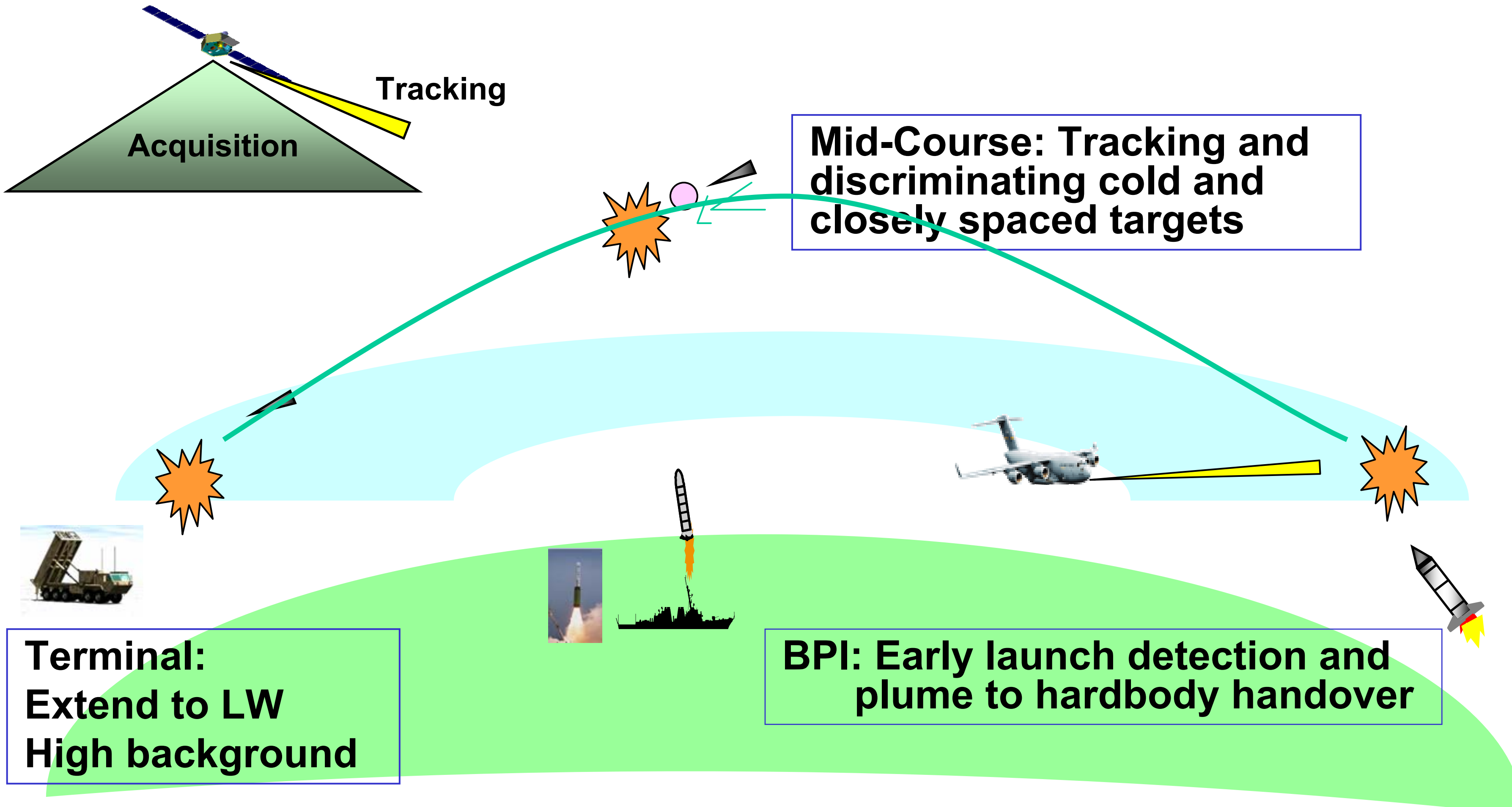
BMD Needs IRFPAS

Long range acquisition, tracking and discrimination of cold and closely spaced targets



Suggested Questions for Discussion

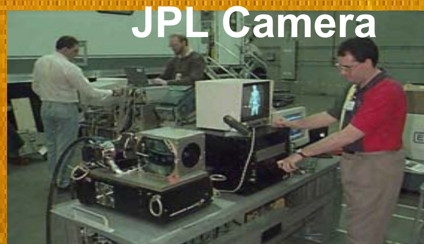
- Should QWIP compete with MCT, or complement with MCT?
- Should we continue funding QWIPs, or focus funding on SLS?
- QWIPs have tremendous difficulties breaking into US military market, is this technology limited, funding limited, or politics limited?
- How to get QWIP into military systems ?
  - get QWIPs into tactical systems
  - get QWIPs into relevant environment testing: HWIL, ground, airborne, flight, SBX,….
  - work with other IR communities including system engineering, phenomenology, algorithms, and test and evaluation to evaluate QWIPs at a system level
  - do not over sell
- Improve quantum efficiency for low background applications
  - What are the achievable quantum efficiency and conversion efficiency?
  - How high is high enough?
  - How much funding and how much time are need to prove the theoretical estimate?

Good News: We are Making Progress Transitioning QWIP to ABL

Planned joint DV/ABL/Boeing Test in Aug 06

Launch Site
White Sands Missile Range

JPL Camera



Target:
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Observation Site Alamo

ABL/Boeing Integration