AFRL Space and Nuclear Technology

Integrity ★ Service ★ Excellence

Distribution A. Approved for public release; distribution unlimited (377ABW-2013-0538 27 Jun 2013)

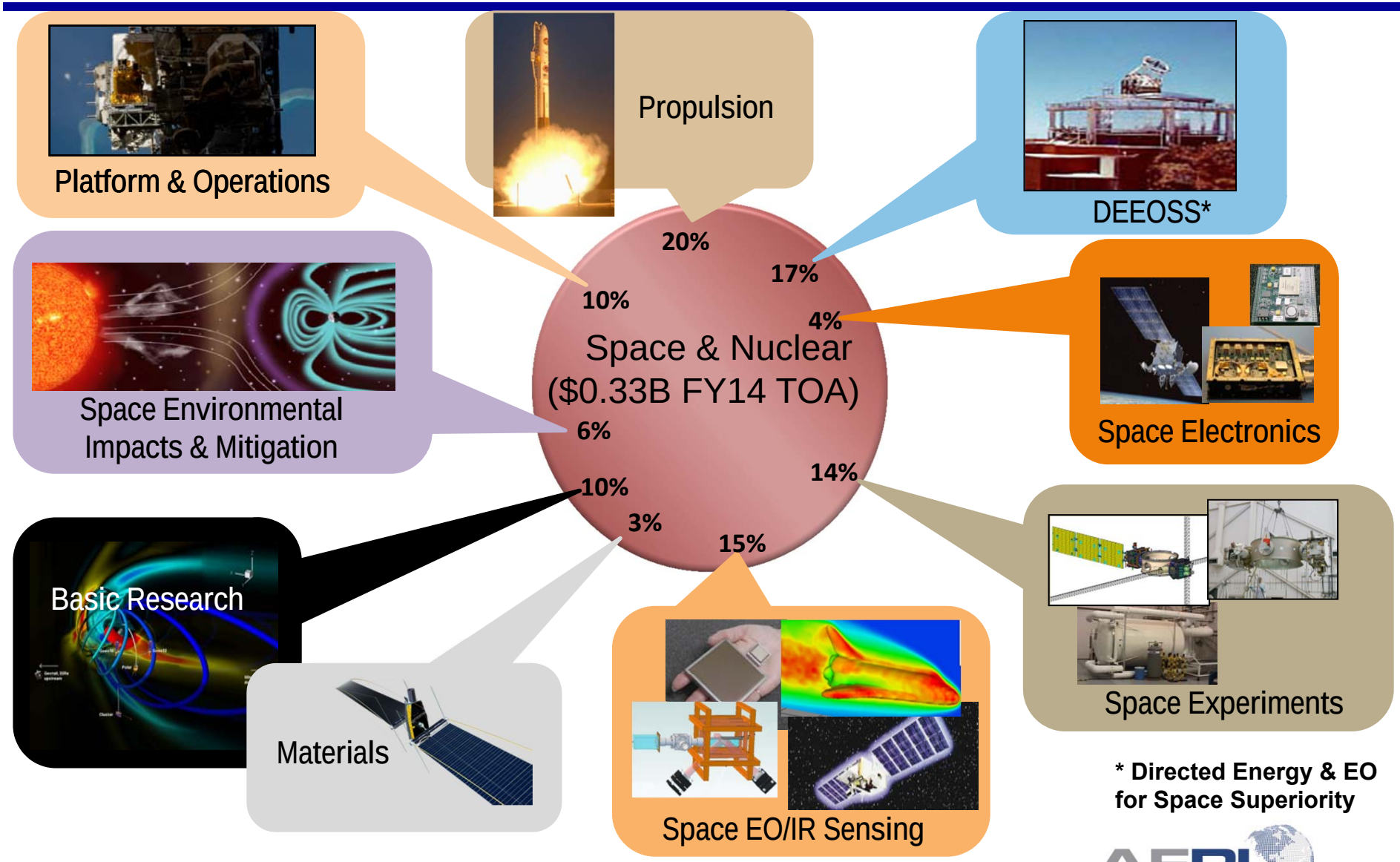
Space and Nuclear Technology Focus Area

- **Space and Nuclear Technology Purpose:**
  - **Operate, protect, & defend the Air Force spacecraft fleet**
  - **Sustain/modernize the nation's nuclear force**

- **Space and Nuclear Technology Vision:**
  - **Maintain/modernize current AF space capability at lower cost**
  - **Provide timely characterization to support space events**
  - **Protect current AF space by adding resiliency to current spacecraft**

Distribution A. Approved for public release; distribution unlimited (377ABW-2013-0538 27 Jun 2013)

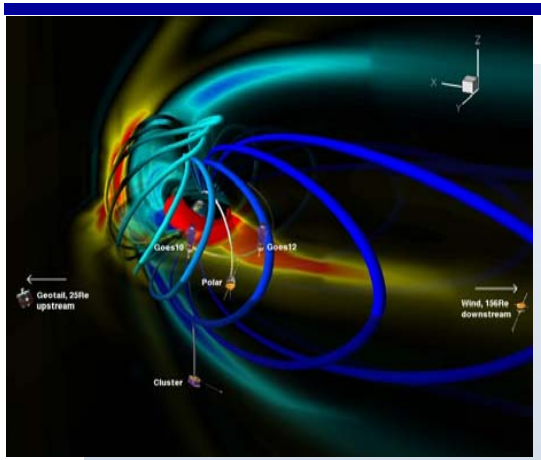
Space and Nuclear Core Technical Competencies (CTCs)



*** Directed Energy & EO for Space Superiority**

Distribution A. Approved for public release; distribution unlimited (377ABW-2013-0538 27 Jun 2013)

Space and Nuclear Basic Research ($33M)



S. Balasubramaniam has developed models to forecast solar flares & used flare parameters in a multivariate discriminant analysis to diagnose flaring probability

Motivation

- The global solar photospheric magnetic field distribution is primary input to *all* coronal and solar wind models.
- Develop physics-based space weather models to specify in real time and forecast conditions and system impacts
- Develop prediction model to locate space objects and identify new objects

Mission/Vision Statement

Mission: We discover, shape, and champion basic science that profoundly impacts the future AF

Vision: The AF dominates air, space, and cyber through revolutionary basic research

Goals/Objectives

Goals: Specify & forecast the geospace environment from the Sun to the Earth's upper atmosphere for situational awareness & for space control

Objectives: Understanding of fundamental space weather, detection, non-linear electromagnetic phenomena, imaging, and magnetic fields.

Technical Approach/Ideas

Fundamental science to support AF needs in multiple applications:

- Develop 72-hour space weather forecast to detect and understand the configuration and orientation of satellites & indications and intent of maneuvers
- Integrated wide-field-of-view search, identify and track sensors - imaging through atmospheric turbulence
- Synthetic/sparse aperture for high res imaging
- Understand scintillations caused by plasma irregularities in the ionosphere

Distribution A. Approved for public release; distribution unlimited (377ABW-2013-0538 27 Jun 2013)

Space and Nuclear

Space Platform and Operations Technologies CTC ($33M)

Heat Transfer Experiment on ISS

Motivation

- Space mission performance constrained by size, weight, power, and cost of platform component and bus options
- Improved structure, power and guidance, navigation and control subsystems, and data fusion and autonomy capabilities can enhance affordability, resiliency, and capability of AF missions

Mission/Vision Statement

- Mission: Improve affordability, resiliency and capability of space platform and ops technologies
- Vision: Engage academia, industry, & government to provide the best technology solutions

Goals/Objectives

- Minuteman III sustainment through 2030 for Global Strike Command need
- Air Force Space Command Core Function Master Plan calls for 60kW/m^3 solar arrays by 2015
- Energy storage solutions capable of 300 W-hr /kg by 2030

Technical Approach/Ideas

- Improved inverted metamorphic solar cell material systems to increase conversion efficiency by more efficiently absorbing energy across the spectrum
- Efficient and adaptable thermal transport approaches for design flexibility, shorter integration schedules, reduced cost, & on-orbit adaptability
- Improved solid-state strategic grade inertial sensors to increase mean-time between failure for inertial measurement systems, drastically reducing maintenance costs

Distribution A. Approved for public release; distribution unlimited (377ABW-2013-0538 27 Jun 2013)

Space and Nuclear

Space Platform & Operations Technologies CTC Goals

Near FY13-FY18	Mid FY19-FY24	Far FY25-FY35
60 kW/m^3 Solar Arrays	70 kW/m^3 Solar Arrays	100 kW/m^3 Solar Arrays
130 W/kg Solar Arrays	200 W/kg Solar Arrays	1000 W/kg Solar Arrays
33-37% Efficient Solar Cells	37-40% Efficient Solar Cells	>40% Efficient Solar Cells
150-180 Wh/kg Batteries	200-450 Wh/kg Batteries	>500 Wh/kg Batteries
Implement 100k all-on-all Conjunction Analysis < 1hr	20% SATCOM Bandwidth increase on WGS 7-12	
Reduce AFSCN scheduling time to < 1hr	Reduce ICBM maintenance actions by 80%	

Distribution A. Approved for public release; distribution unlimited (377ABW-2013-0538 27 Jun 2013)

Space and Nuclear Space Electronics CTC ($13M)

Future Comm Satellite (Picture is AEHF)

Advanced Digital, Mixed Signal and Radio Frequency Electronic Devices

Advanced Space Communication Technology (W/V-Band & Laser Comm)

Motivation

- Current capability: K-band Sat Comm, 400 MIPs Processors, 16 Mb SRAMs, 4 Mb NVRAMs
- Limitations: Insufficient comm bandwidth while demand is increasing; insufficient on-orbit processing to reduce bandwidth requirements
- New technology will enable more bandwidth and will enable advanced on-orbit capability for ISR/GPS/SSA/Comm systems

Mission/Vision Statement

- Mission: Research & develop space-qualified electronic components, subsystems, and systems to meet documented AF needs
- Vision: Lead the research, discovery, development, demonstration, and transition of reliable, affordable, state-of-the-art, rad-hard space electronic devices

Goals/Objectives

- Problem/challenges: increased system resilience and performance, decreased SWaP
- Deliver improved space-qualified electronic components & subsystems used in 95% of defense space and missile systems

Technical Approach/Ideas

- Key technical ideas:
  - W/V-Band Space Communications Systems
  - Advanced Space Communications Security Technology
  - Intra-Satellite Photonic Data Network
  - Higher-Performance Processing System Components (Processors, Volatile Memory, Non-Volatile Memory, etc.)
  - Higher-Performance Mixed-Signal System Components (e.g., Analog-to-Digital Converters, Digital-to-Analog Converters)
  - Space Cyber Subsystems

Distribution A. Approved for public release; distribution unlimited (377ABW-2013-0538 27 Jun 2013)

Space and Nuclear
Space Electronics CTC

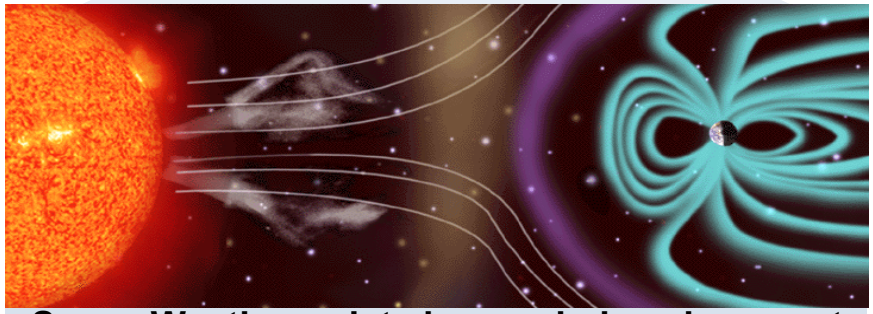
Near FY13-FY18	Mid FY19-FY24	Far FY25-FY35
• Determine AF computing & memory needs for future AF systems • Develop Volatile and Nonvolatile Memory to Support Advanced Mission Processing • Determine AF analog & mixed signal needs for future AF systems • Develop Next-Generation Space Processing Technology • Research advanced electronic materials and devices for gen after next development	• Develop analog and mixed signal devices, to include analog to digital and digital to analog converter (12 bits @ 1GHz) • Demonstrate 90nm E-Beam capability in on-shore foundry application • Investigate next generation of structured ASIC, to include both analog and digital building blocks	• Demonstrate advanced semiconductor devices and 3D integration of devices • Demonstrate 22nm or smaller E-Beam capability in on-shore foundry application • Develop ≥ 20M+ gate structured ASIC • Develop of 14nm FPGA

Distribution A. Approved for public release; distribution unlimited (377ABW-2013-0538 27 Jun 2013)

Space and Nuclear

Space Environmental Impacts & Mitigation CTC ($20M)

Space Environment (Sun to Earth)



Space Weather exists in coupled environment from the Sun to the Earth's atmosphere

Motivation

- DoD systems are under continuous attack from the space environment
- Air Force Space Command requirements call for specification and prediction of space environmental hazards.
- Current operational capabilities to specify and predict hazards are very limited

Mission/Vision Statement

- Predict, Attribute & Mitigate environmental impacts to DoD system

Goals/Objectives

- Develop tools that specify and forecast space environmental impacts on DoD systems for attribution, awareness, and planning.
- Establish feasibility of mitigating space environment hazards.

Technical Approach/Ideas

- Develop & integrate models, tools, and impact products for environment hazards that are highly variable in both location & time
- Provide environment specifications to understand, attribute, & mitigate effects
- Research in all relevant areas (Near-Earth space environment; Solar & Heliospheric environments; science to operations)
- Develop & demonstrate reduced SWAP, innovative environmental sensors

Distribution A. Approved for public release; distribution unlimited (377ABW-2013-0538 27 Jun 2013)

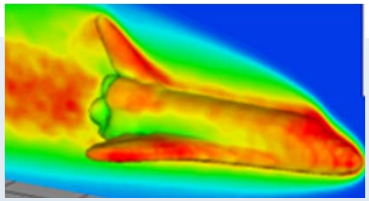
Space and Nuclear

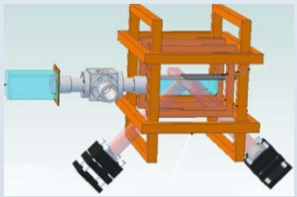
Space Environmental Impacts &Mitigation CTC

Near FY13-FY18	Mid FY19-FY24	Far FY25-FY35
• 1st generation environment anomaly attribution software • 1st generation SATCOM environmental interference tool • Expanded radiation environment design model greatly improved for LEO and MEO • Proof of concept demos of mitigation technologies	• Near term Forecast tools to include space environment hazards into DoD planning • Ionospheric mitigation and exploitation • Understand solar drivers of space hazards and orbital drag • Sensor capability to provide space environmental conditions	• Deep understanding of environmental hazards for robust system designs • Near-real time awareness of environmental impacts to space vehicles , COMM, PNT, C2, ISR & space object custody • Forecasting (3-day+) & mitigation of environmental affects on systems

Distribution A. Approved for public release; distribution unlimited (377ABW-2013-0538 27 Jun 2013)

Space and Nuclear
Space EO/IR Sensing CTC ($49M)





Motivation

- ASD(R&E) Strategic Guidance (Jan 12). Priority Area #1 – "Counter Anti-Access/Area Denial Capabilities" – countering the A2/AD threat in large AoRs …. [puts] a premium on exploiting space
- AFSPC prioritized capabilities needs: launch detection/ missile tracking, SSA & BA, DSC & space to surface ISR, terrestrial environmental monitoring, and nuclear detonation detection

Mission/Vision Statement

Develop new technologies for space sensing missions, such as space object detection & cold-atom timing/navigation devices. Includes improved focal plane arrays & cryocoolers, as well as next-gen model & code development

Goals/Objectives

Advanced sensing tech for top AFSPC requirements

- Models, algorithms, & space demos to enable all-weather launch/missile detection/SSA
- Next-gen atomic clock & inertial navigation technology for GPS-denied environments
- Higher ops temp & improved sensitivity of IR & visible sensor, & reduced SWAP on cryocoolers for space

Technical Approach/Ideas

- Create novel technologies in technical areas that directly support AF core missions. Partner with industry to maximize ROI
- All-weather missile launch detection technology
- Improved GEO object detection/characterization
- Next-gen cold-atom based timing & INS devices
- Ionospheric research supporting NG-OTHR
- Nuclear explosion monitoring research
- Fieldable radiation testing & optical calibration facilities supporting operational customers

Distribution A. Approved for public release; distribution unlimited (377ABW-2013-0538 27 Jun 2013)

Space and Nuclear
Space EO/IR Sensing CTC

Near FY13-FY18	Mid FY19-FY24	Far FY25-FY35
• Pursue world-class space-related signature characterization • Develop hardware & software for hypertemporal sensor payload • Perform observations, and develop new hardware & software tools to better detect and characterize GEO space objects • Develop thermodynamic cycle-independent modular cryocooler electronics	• Develop flexible modular SWIR/MWIR cryocooler to meet OPIR requirements • Provide AF with game-changer for GEO satellite detection & characterization • Develop tunable detectors across IR (8-25 μm) through <u>higher-temp & reduced SWaP alternative</u> to MCT tech • Develop and field cold-atom-based clock demo payload on AFRL or SMC launch	• Develop next-gen FPAs for high-temperature, sensitive detection, THz to UV, reducing requirements on cryocoolers & reducing SWaP • Develop monolithic FPA on-chip cooling capability • Develop SSA observation & analysis tools for exquisite knowledge of adversary intentions & operations • Field cold-atom-based clocks for next-gen GPS constellation & inertial navigation in GPS-denied environments, 5-10x better in stability

Distribution A. Approved for public release; distribution unlimited (377ABW-2013-0538 27 Jun 2013)

Space and Nuclear
Space & Missile Propulsion CTC ($66M)

Motivation

- Current capability:
  - Life limited strategic systems, empirical/statistical life assessment
  - 1960s space access propulsion
  - Fixed mission spacecraft propulsion
- ICBM global reach, >20% LCC savings
- High perf, lower cost space access
- Highly flexible spacecraft propulsion

Mission/Vision Statement

- Develop and demonstrate advanced rocket propulsion technologies addressing DoD mission requirements for space access, strategic and spacecraft systems

Goals/Objectives

- Be the technology provider for the rocket propulsion community and users
- Increase performance while reducing cost of all forms of rocket propulsion systems
- Expand the tech base in Industry, sustaining the US capability to develop rocket propulsion systems

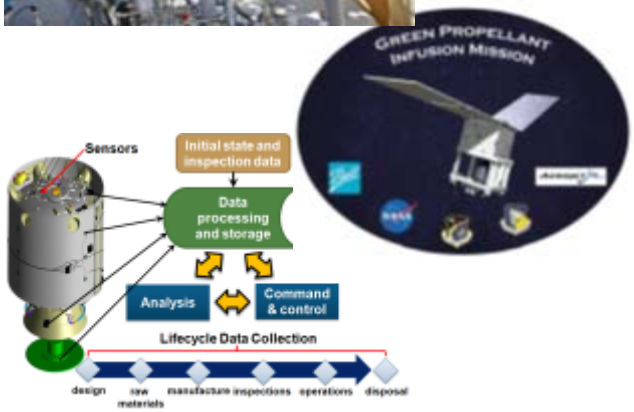
Technical Approach/Ideas

- Ox-rich Staged Combustion for space access
- Innovative cycles for future space access
- "Real-time" health monitoring for solid rocket motors – cradle to grave
- Sustainable strategic systems capable of global range
- Multi-mode spacecraft propulsion
- Non-toxic mono & bi-propellants

Distribution A. Approved for public release; distribution unlimited (377ABW-2013-0538 27 Jun 2013)

Space and Nuclear
Space & Missile Propulsion CTC

Near FY13-FY18	Mid FY19-FY24	Far FY25-FY35

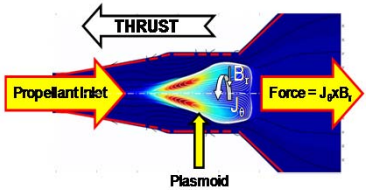


- AF-M315E non-toxic mono propellant
- Aging & Surveillance for ICBMs

- >20% LCC savings for ICBM
- Replacement of Hydrazine on spacecraft & missiles
- NASA SLS booster

- Adv. Mono/bi-propellants for spacecraft & missiles
- Adv. missile propulsion
- ORSC tech for liquid rocket engines

- Global range ICBM
- Global Strike – conventional
- EELV upgrade

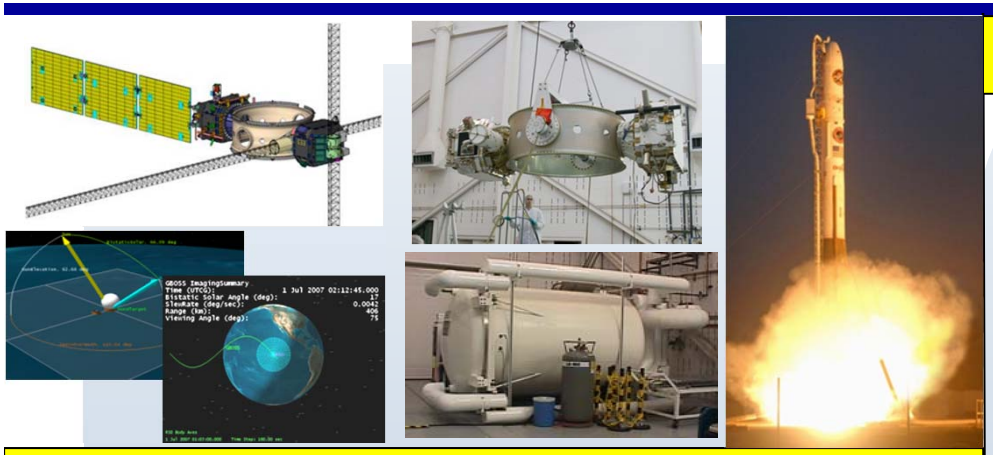


- Low cost space access
- Multi-mode propulsion
- Adv. missile propulsion

- EELV replacement
- MM III/GBSD

Distribution A. Approved for public release; distribution unlimited (377ABW-2013-0538 27 Jun 2013)

Space and Nuclear Space Experiments CTC ($46M)



Mission/Vision Statement

- Mission: Model/simulate, design, build, assemble, integrate, test, fly, & operate space flight experiments
- Vision: Showcase future capabilities with mil utility, transition space technologies, & meet CFMP needs

Goals/Objectives

- Challenge: Delivering high-performance, flight-qualified advanced technologies to space community spanning AF mission areas
- Knowledge: New space technologies, on-orbit capabilities, & CONEMPS for the warfighter
- Deliverables: Validated techs for resiliency & protection, small GEO-based object ID/characterization, advanced MW sensing, space Wx mitigation, PNT, increased space access

Motivation

- Current capability: PM/PIs experienced in integrated tech programs , multi-disciplinary M&S team, & unique AI&T facilities able to deliver integrated platforms & successful small sat flight experiments
- Limitations: Resources & funding
- What difference will new capability R&D make? New space tech capabilities in areas such as PNT, MW, Wx, SSA, & DSC

Technical Approach/Ideas

- Use MSE&A to guide tech investment decisions & develop new mission employment concepts
- Validate utility, cost, system engineering & design
- Create PMO w/experienced PM/PI's; contract for h/w & s/w; deliver to AFRL & assemble
- Conduct robust I&T -- test like you fly & train ops cadre to fly experiment
- Conduct on–orbit ops, acquire data, analyze, report

Distribution A. Approved for public release; distribution unlimited (377ABW-2013-0538 27 Jun 2013)

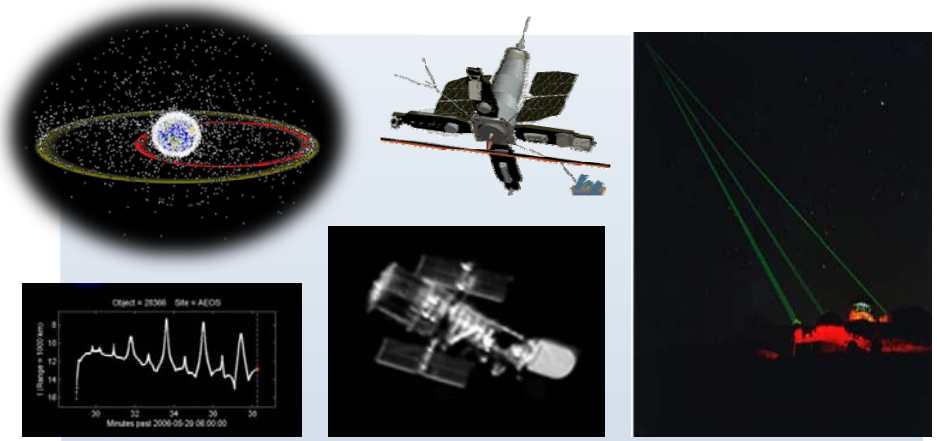
Space and Nuclear Space Experiments CTC

Advanced GPS Technology

Near FY13-FY18	Mid FY19-FY24	Far FY25-FY35
• Advanced L-Band Amplifier Technology for GPS • On-orbit Digital Waveform Generator	• 64 Mb Radiation Hardened Non-Volatile Memory • Advanced Radiation Hardened Digital to Analog Convertors for PNT Applications • Advanced Antenna Technology for GPS • Advanced Space System GPS Receiver Technology • Modular Encryption Technology for GPS	• Advanced Signal Combining Techniques for GPS • Photonics Technologies for PNT Applications

Distribution A. Approved for public release; distribution unlimited (377ABW-2013-0538 27 Jun 2013)

SPACE
DEEOSS CTC ($51M)



Motivation

- Space domain has become significantly more congested, contested, and competitive
- Space is an integral part of the fabric of our nation's infrastructure supporting both peacetime and wartime capabilities
- Directed energy and electro-optical technologies offer unique ability to find, fix, track, and characterize space objects anytime, anywhere

Mission/Vision Statement

- Develop directed energy and electro-optical technologies to improve the nation's space superiority capability

Goals/Objectives

- Optimize the performance of the baselined operational SSA architecture
- Cost-effectively augment the architecture
- Create affordable trade-space for eventual expansion of the architecture

Technical Approach/Ideas

- Detect, track, and ID small, dim objects in GEO and GEO-transfer orbits
- Timely characterization techniques to support space events
- Threat warning and assessment concepts to enable attribution and allow for response time
- New data integration and exploitation capability for the JSpOC Mission System Program of Record
- Dynamic and automated sensor tasking algorithms to enable optimal tipping/cueing of SSA assets
- Evaluate space system resiliency and protection options to include operational & material solutions

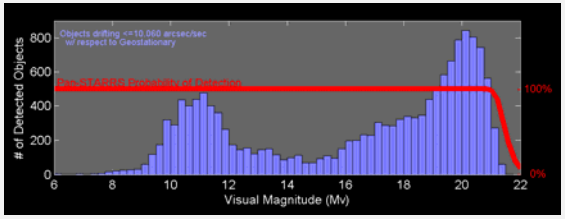
Distribution A. Approved for public release; distribution unlimited (377ABW-2013-0538 27 Jun 2013)

DEEOSS S&T Strategy
Capabilities / Deliverables

Near-Term	Mid-Term	Far-Term
Forensic →	Predictive →	Operationally Responsive →

Near-Term

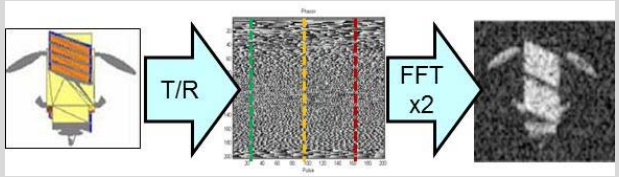
- **Space Catalog development**
  - Deliver new tools to JSPOC Operators
  - Processing for 150K+ Object Catalog
  - Rapid UCT (uncorrelated track) resolution



- **Use of EO imagery & signatures to understand satellite characteristics**
  - Extend high-resolution imaging of LEO objects for timely imaging of satellite objects.
- **Sodium Laser Guidestar**
  - Image dim objects and satellites 24/7
  - Detect small, dim objects next to larger objects at GEO

Mid-Term

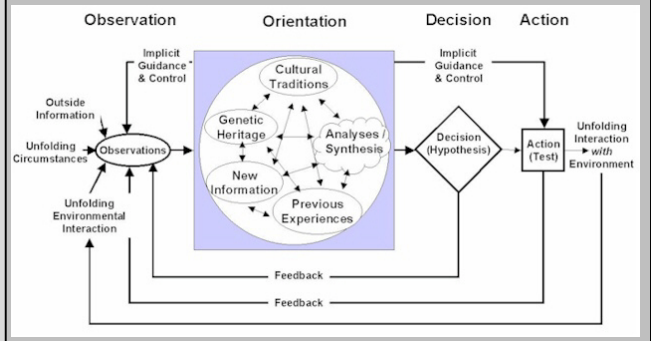
- **Tactical Persistent Monitoring**
  - Provide GEO awareness using ground-based optical telescopes
  - Dynamically task sensors to provide persistent surveillance and maintain custody from launch through insertion
- **Demonstrate High-Res GEO imaging**
  - ISAL – Inverse Synthetic Aperture LIDAR



- **Apply predictive signature modeling to enable Indications and Warnings (I&W) for SSA**
  - Deliver JSpOC applications to integrate EO signatures with non- EO data sources
  - Improve characterization and timely change detection of space objects
- **Protection and Resiliency**
  - Modeling of potential threats
  - Secure Comm in a denied RF environment

Far-Term

- **Exquisite characterization and predictive space event modeling**
  - Enable predictive awareness for space events and mitigation of hazards
- **Integrated and timely knowledge**
  - Ability for our space operator to rapidly close the decision loop during emerging space events – Operational Responsiveness



- **<u>Bottom Line</u> - Situational Dominance for Space Operations**

Techniques & Tools to Increase Speed & Fidelity of Knowledge for SSA

Distribution A. Approved for public release; distribution unlimited (377ABW-2013-0538 27 Jun 2013)

Space & Nuclear TFA Summary

- CTCs poised to provide technologies for future space and nuclear CTCs
  - Basic Research
  - Space Electronics
  - Propulsion
  - Space Platforms & Operations Technology
  - Space Environmental Impacts & Mitigation
  - Space EO/IR Sensing
  - Space Experiments
  - Directed Energy & Electro Optics for Space Superiority
- For more information contact:
  - Matt Fetrow
    - AFRL/RDM
    - Email: Matt.Fetrow@Kirtland.af.mil
    - Phone: (505) 853-3523

Distribution A. Approved for public release; distribution unlimited (377ABW-2013-0538 27 Jun 2013)