

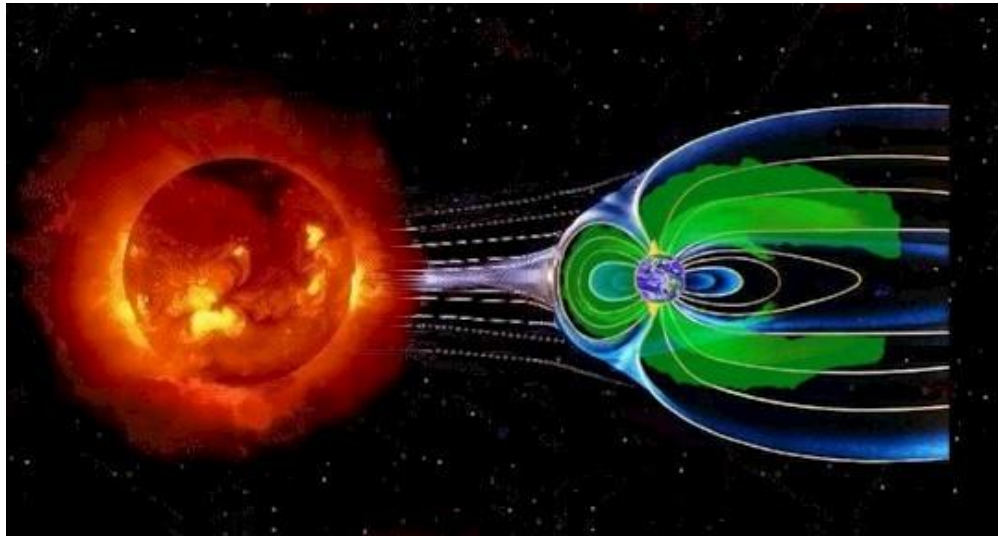


**DoD Space S&T  
Community of Interest  
Presentation to National Defense University  
30 September 2015**

**Dr. John Stubstad  
Space S&T COI Chair  
Director, Space and Sensor Systems  
Office of the Assistant Secretary of Defense for  
Research and Engineering**



# Space Is Unique



- Space is an operating environment; not a technology area
- Space supports all aspects of the Joint Engagement Sequence (JES)
- Space has no “repair shop”
- Space asset behavior is predictable
- Multiple threats – natural, man-made, and adversary

**Military Space Enables all Facets of DoD Operations**



# DoD Space S&T Strategy



DEPARTMENT OF DEFENSE  
SPACE SCIENCE AND TECHNOLOGY  
STRATEGY  
2015

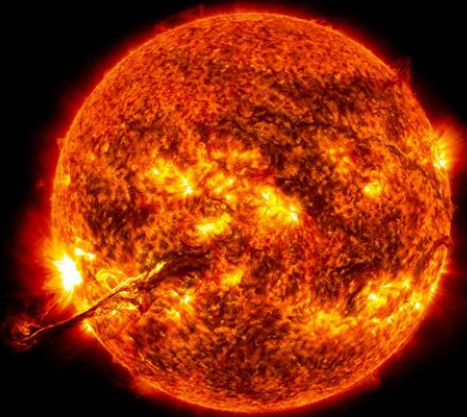


Photo: Coronal mass ejection as recorded by NASA, August 31, 2014

- Biennial report to Congress – updated 2015
- Guides the development of the space-unique technologies that are essential to maintain existing U.S. conventional and asymmetric military advantages enabled by space systems at the strategic, operational, and tactical levels
- Looks across the entire DoD Space S&T Enterprise
- Prepared with the assistance of the DoD Space S&T Community of Interest



# Space is no longer uncontested



## Space Threats

Threat
RF Jamming
Low power laser dazzling
High Power Laser Kill
LEO ASAT
GEO ASAT
On-Orbit Jammers
Co-orbital kinetic ASAT
Adversary attachment
Cyber attack
Space nuclear detonation

## Capabilities needed to deliver the Threats

Capability
Ground surveillance networks
World-wide ground SSA coverage
Precision Tracking capability

- In last 5 years, potential adversary threat capability has sharply increased.
- National Space Policy (2010): We will protect our Space Capability from adversary hostile actions.



# Space S&T COI Portfolio Overview



- **COI Description**

- The goal of the Space COI is to 1) Facilitate collaboration and leveraging of complementary investments of the space S&T efforts across the community in support of the intent of the nation's Space interests; and 2.) Identify gaps, establish and maintain a set of S&T roadmaps to guide Space Community research program investments, perform portfolio assessments, and provide future resource recommendations to leadership

- **COI Purpose**

- The Space S&T COI is a forum for sharing new ideas, technical directions and technology opportunities, jointly planning programs, measuring technical progress, and exchanging advances in space S&T

- **Portfolio Focus**

- DoD S&T investments in space-unique technologies that are essential to maintain and advance existing U.S. conventional and asymmetric military advantages enabled by space systems at the strategic, operational, and tactical levels

**COI Taxonomy**

Technology Sub-Area 1  
**Satellite Communications**

Technology Sub-Area 2  
**Missile Warning, Missile Defense, Kill Assessment and Attack Assessment**

Technology Sub-Area 3  
**Positioning, Navigation and Timing**

Technology Sub-Area 4  
**Intelligence, Surveillance and Reconnaissance**

Technology Sub-Area 5  
**Space Control and Space Situational Awareness**

Technology Sub-Area 6  
**Space Access**

Technology Sub-Area 7  
**Space and Terrestrial Environmental Monitoring**

Technology Sub-Area 8  
**Command and Control; and Satellite Operations**

Technology Sub-Area 9  
**Space Enablers**

Technology Sub-Area 10  
**Space Resilience (new subarea in FY15)**



# Space COI Sub-Areas

## 1 of 2



### Satellite Communications

- Provide seamless, end-to-end, space-based communications that is integrated and interoperable
- **Technical Challenges**
- Reduce SWaP-C and improve thermal management
- Develop V/W band RF and laser comms

### Missile Warning, Missile Defense, and Attack Assessment

- Provide timely and unambiguous detection of ballistic missile launches and nuclear detonations from space
- **Technical Challenges**
- Improved sensors for whole Earth staring
- Improved data fusion algorithms

### Positioning, Navigation and Timing

- Generating and using signals to enable determination of precise location, movement, and time
- **Technical Challenges**
- Improved anti-jam capability
- Improved atomic clocks
- Enhanced orbital navigation technology

### Intelligence Surveillance and Reconnaissance

- Space-based systems for SSA and GEOINT& SIGINT; National Technical Means, Commercial/Foreign Family of Systems, and small, rapid-response opportunities
- **Technical Challenges**
- Increased persistence of ISR
- Improved data compression
- Integrated space, air, ground based ISR integration

### Space Control and Space Situational Awareness

- Provide freedom of action in space to ensure: resilience to threats, ability to perform in degraded environment, and deny the adversary's use of space against our forces in conflict
- **Technical Challenges**
- Improved space object detection and monitoring of potential threats

### Space Access

- Provide delivery, maneuvering, and recovery of payloads to and from space in a responsive, reliable, flexible manner, ensuring assured access to space in peace, crisis, and through the spectrum of conflict
- **Technical Challenges**
  - Reduce cost and time cycle
  - Higher performance on-orbit propulsion
  - Enable fully reusable launch systems



# Space COI Sub-Areas

## 2 of 2



### Space and Terrestrial Environmental Monitoring

- Provide remote sensing and monitoring of the operational Space environment and Earth weathercasting
- **Technical Challenges**
- Improved awareness of Earth/Sun environment
- Enable real-time threat warning due to weather
- Enable marine Meteorology and ocean conditions

### Command and Control; and Satellite Operations

- Provides the ability to operate over space forces and resources to monitor, assess, plan, and execute space operations at all echelons of command
- **Technical Challenges**
- Increased autonomy to reduce manning
- Space robotic capabilities for servicing/repair

### Space Enablers

- Development of pervasive technologies that facilitates the technical ability to perform successfully in the Space Arena
- **Technical Challenges**
- Standardized and miniature components and interfaces
- Carbon-based nanotechnology
- Ultra-high efficiency power systems

### Space Resilience

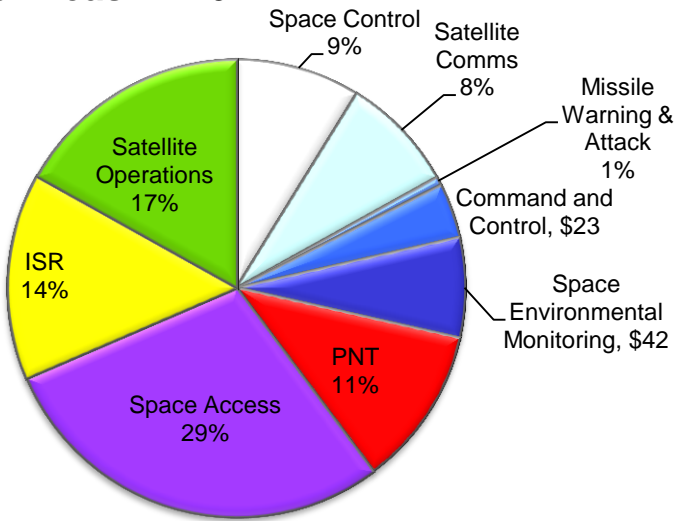
- Provide the ability to support the functions necessary for mission success in spite of hostile action or adverse conditions
- **Technical Challenges**
- On-board adaptive planning
- Local area imaging sensors
- Laser survivability



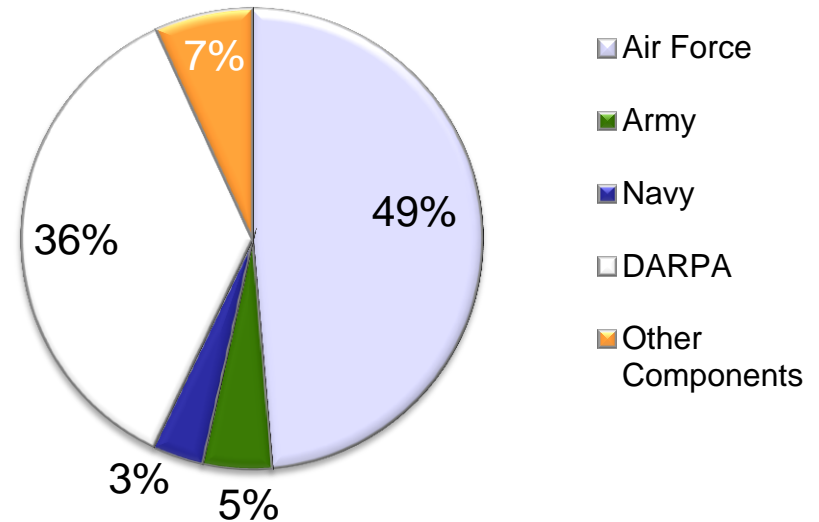
# Space S&T COI Investment and Performers



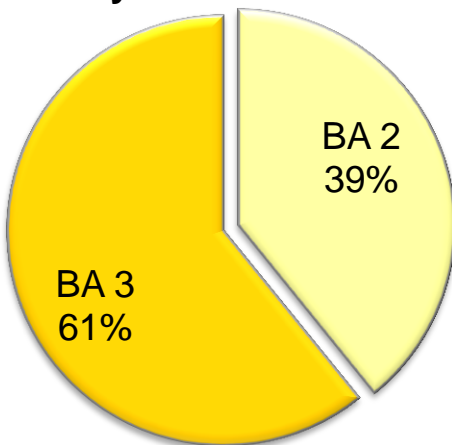
## COI Sub-Areas PB16



## Component Investment



## Budget Activity



## Intramural vs. Extramural split:

- Army - 6.2 47/53; 6.3 38/62
- Navy - 6.2 60/40; 6.3 40/60
- Air Force - 6.2 48/52; 6.3 20/80

## Major Performers:

- Aerojet-Rocketdyne, APL, BAE Systems, Ball Aerospace, Boeing, Dynetics, Honeywell, Lockheed Martin, MIT-LL, Northrop Grumman, NRL, Orbital/ATK, Raytheon, Sandia National Laboratory, Teledyne Brown

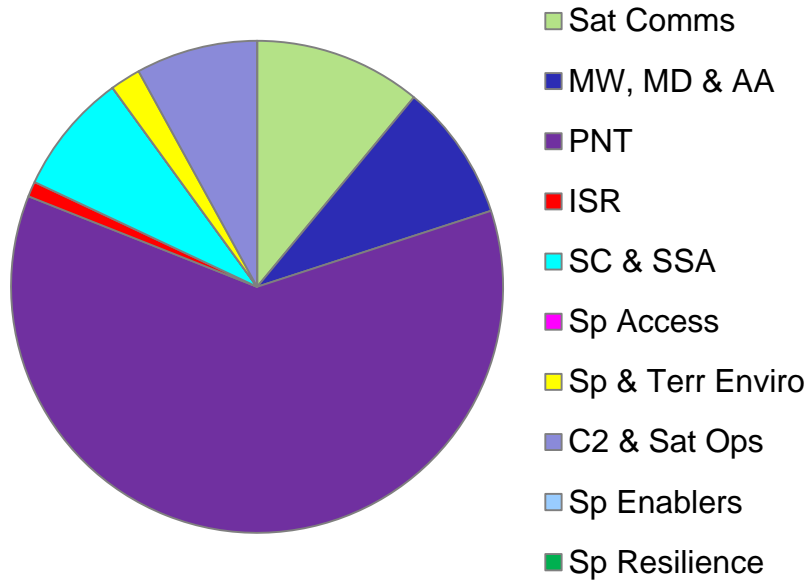




# SBIR Investment FY14 Phase I and II Awards



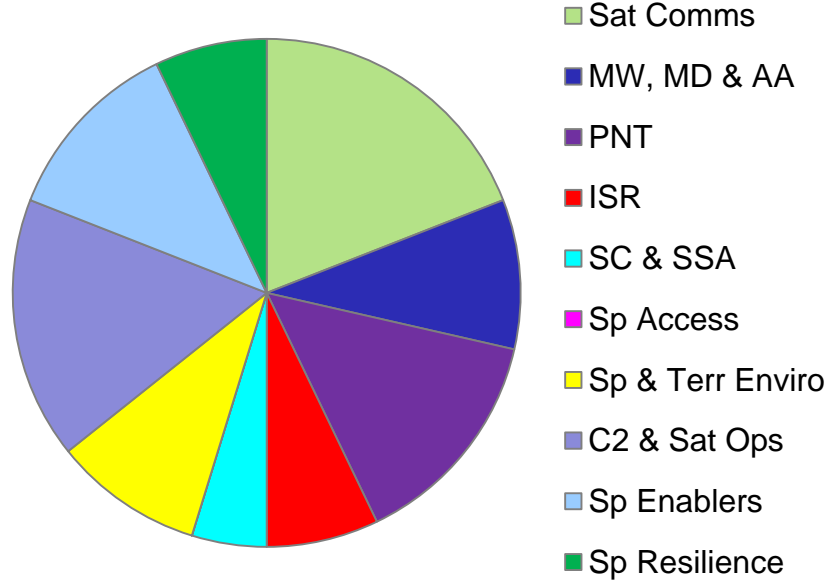
## FY14 Phase I\*



**100 Awards**

\*SBIR Phase I (project feasibility) awards normally do not exceed \$150,000 total costs for 6 months.

## FY14 Phase II\*

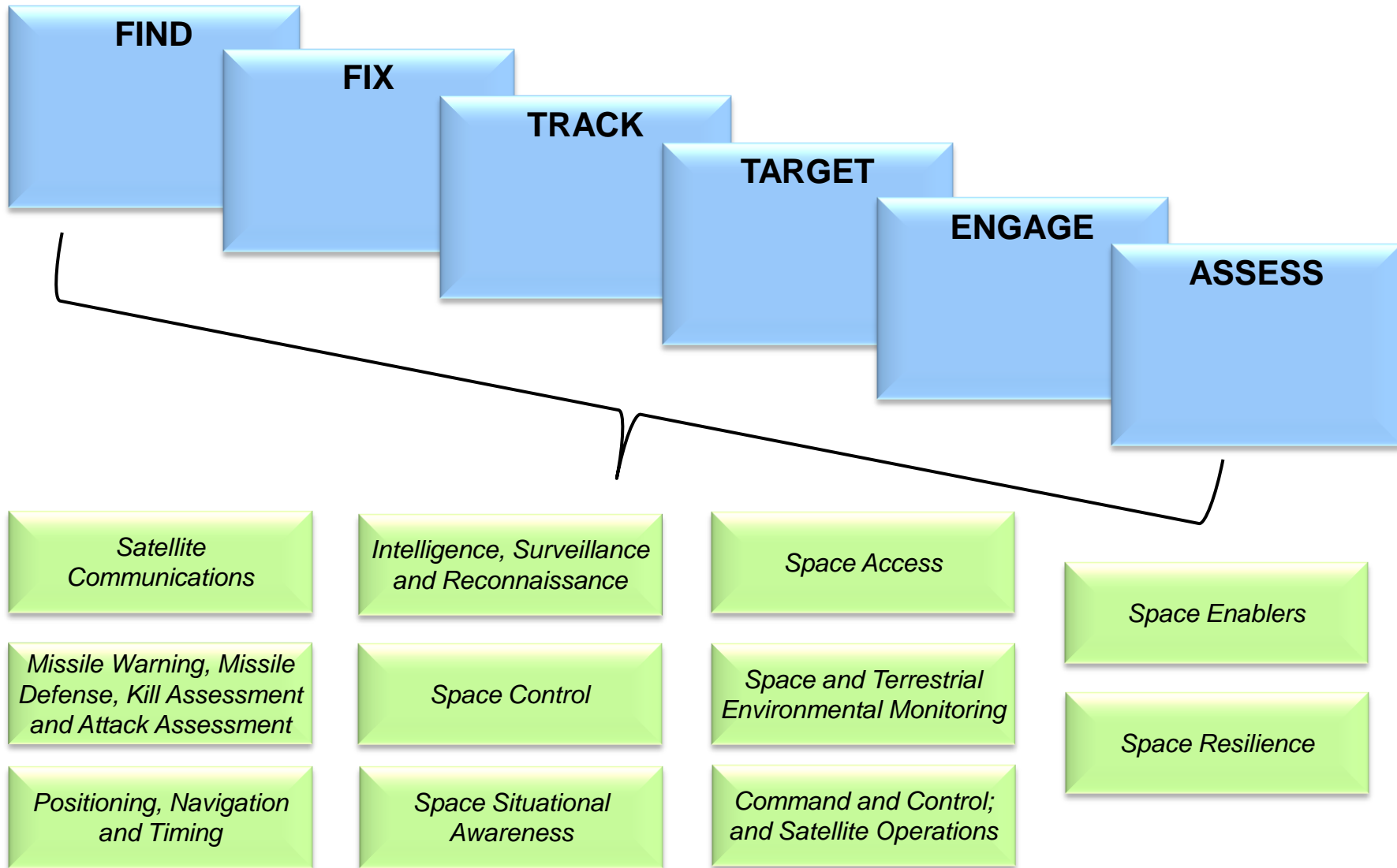


**42 Awards**

\*SBIR Phase II (project development to prototype) awards normally do not exceed \$1,000,000 total costs for 2 years.



# Space COI Relationship to Kill Chain





# Space COI Relationship to Kill Chain



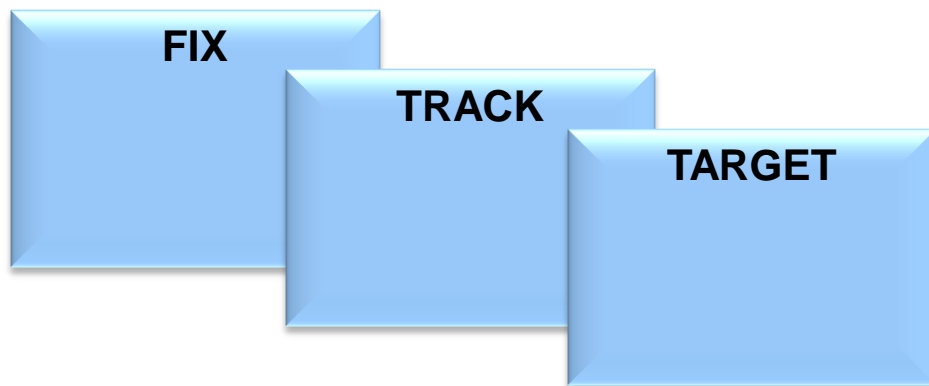
**FIND**

*Intelligence, Surveillance  
and Reconnaissance*

*Space Situational  
Awareness*



# Space COI Relationship to Kill Chain



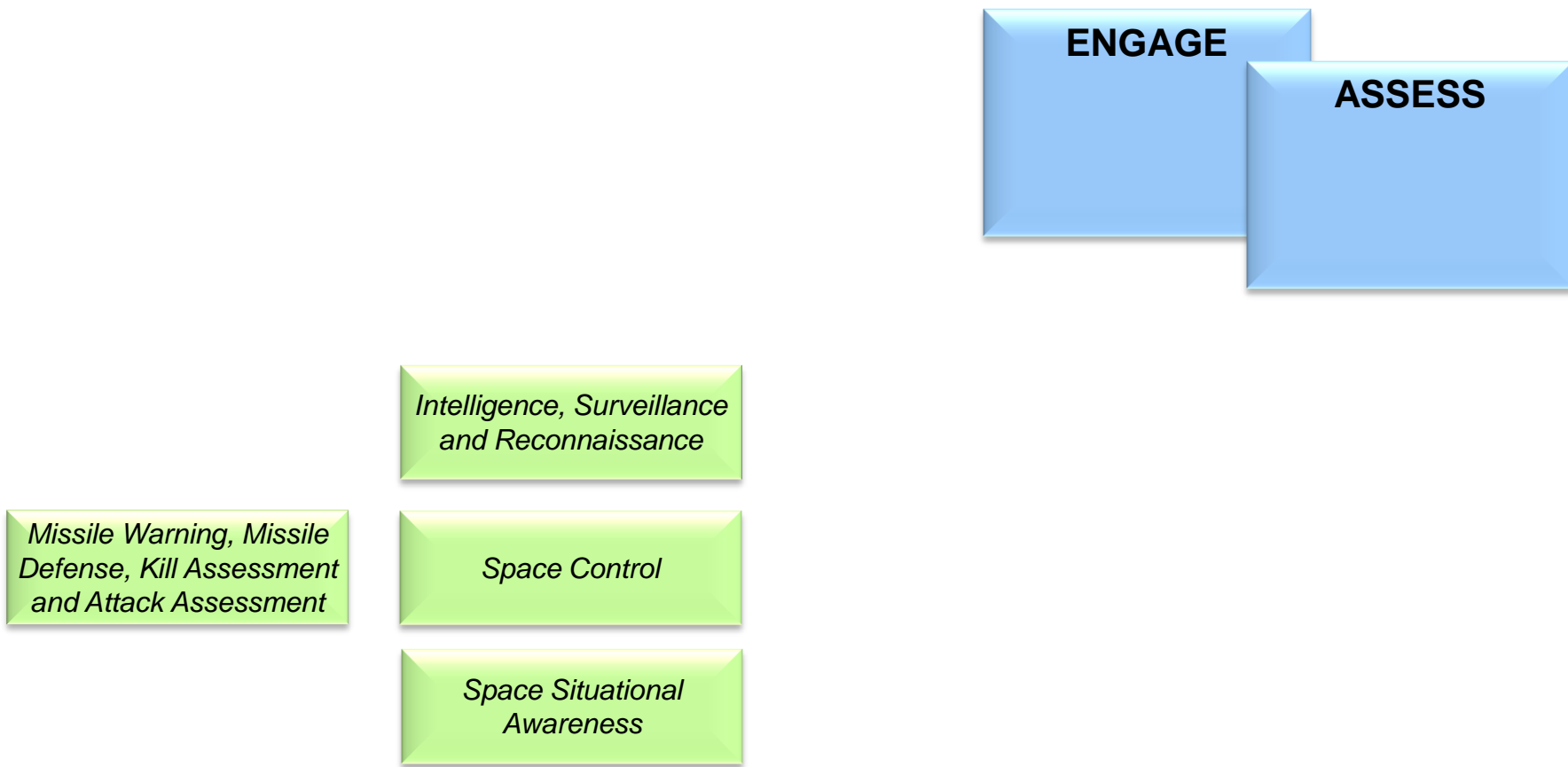
*Intelligence, Surveillance  
and Reconnaissance*

*Missile Warning, Missile  
Defense, Kill Assessment  
and Attack Assessment*

*Space Situational  
Awareness*



# Space COI Relationship to Kill Chain





# Gaps



- **Understanding Allied Investments**
  - NATO countries
  - Long-term Allies & partners
  - Other cooperating nations
- **Understanding Investments of Potential Rivals**
  - Intent, Doctrine, ROEs & TTPs
  - Technical performance of systems
- **Understanding Benefits and Risks of Employing Commercial Systems**
  - Security, availability, responsiveness
  - Cost, limitations
- **On-Orbit Servicing & Repair**
  - DARPA Orbital Express – what's next?
- **Trade-off: Cost v Schedule v Lifetime**
  - 10+ year on-orbit lifetime = high first cost but long replenishment schedule
  - Other paradigm – short life = low initial cost but short replenishment schedule
  - Which paradigm is the future?



# Current Challenges Driving Space S&T Investments



- **Cost-effective manufacturing and acquisition of spacecraft**
  - Very few spacecraft (~3/year) – custom built vs. production line
  - Requirement is for highly specialized payloads – multi-year development required
- **Lower launch cost**
  - Reducing overall launch cycle time – traditional queues can be 2+ years or more
- **Adding protection and resiliency to our current space fleet**
  - Avoiding expensive block upgrades
- **Low data rate comms to dispersed units**
- **Cost-effective sustainment of existing constellations**
  - Budgets declining across the department
- **Improve Ability to forecast terrestrial and space weather**



# Risks for Space S&T Public vs. Protected



- **Investing ahead of others and converse**
  - Many nations now acquiring space-based capabilities
  - Commercial systems offering ISR services
  - Cubesats are good – low cost test platforms and capabilities
  - Cubesats are bad – low cost enable many to test & develop space capabilities that were cost prohibitive in the past
- **International collaboration**
  - US space S&T collaboration with allies and international partners continues to increase
- **Classifications**
  - US space S&T conducted at multiple security levels



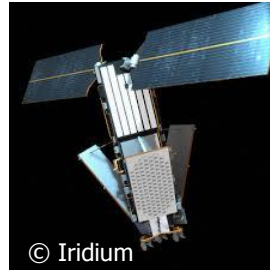


# S&T Opportunities

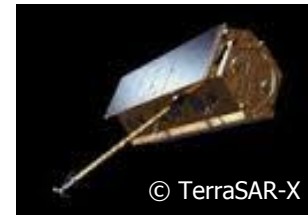


- Exploiting expanding commercial space
- Ever growing and lucrative commercial satcom and ISR markets (GEO, MEO, and LEO)

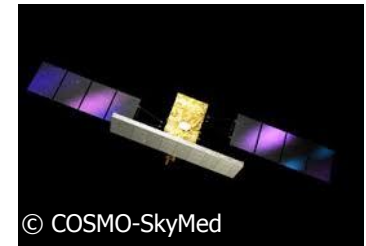
- Digital Global Systems
- TerraSAR-X
- COSMO-SkyMed



© Iridium



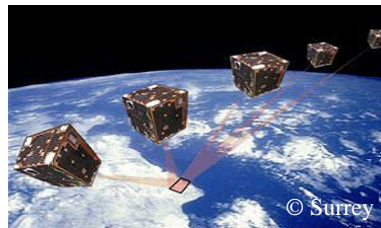
© TerraSAR-X



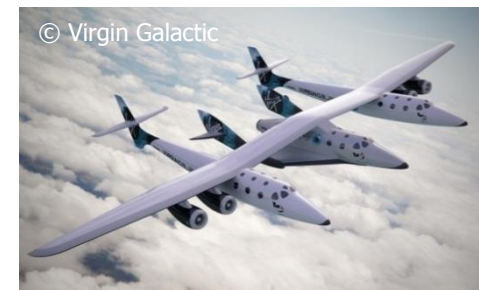
© COSMO-SkyMed

- Wealthy visionaries are investing in space tourism and transportation
- Commercial startups and international entrants are expanding micro and small sat capabilities

- Future large “micro” & “small sat” constellations
  - SpaceX –4,000 satellites
  - OneWeb – 2,400 satellites
  - Planet Labs – 128 satellites
  - SPIRE – 125 satellites
  - Black Sky - 60 satellites
  - Skybox – 24 satellites



© Surrey



© Virgin Galactic

- NASA investments are buoying new entrants for orbital and suborbital markets



# Space Test Program Recent Accomplishments



- **NRL Electrically-Controlled Solid Propulsion Experiment Low-Cost Demonstration and Qualification - Successfully deployed Dec 14**
- **AFRL Automated Navigation and Guidance Experiment for Local Space - Successfully launched in July 14**
- **Successfully launched in Nov 13:**
  - **AFRL Strip Sensor Unit**
  - **NRL Small Wind and Temperature Spectrometer**
  - **U.S. AF Academy Integrated Miniaturized Electrostatic Analyzer**
  - **NASA/NOAA Total Solar Irradiance Calibration Transfer Equipment**
  - **AFRL Joint Component Research**
  - **AFRL De-orbit Module**
  - **Cubesats from BlackKnight-1 (West Point)**
  - **Cubesats from Solar Cell Array Tester (Naval Postgraduate School)**
  - **NASA 13U Cubesats**
- **Two payloads on SpaceX Cassiope commercial mission via NASA - Successfully launched Sep 13:**
  - **AFRL Drag and Neutral Density Explorer (University of Colorado Boulder)**
  - **AFRL CUSat (Cornell)**



# Army Space S&T Themes

Software Defined Radios



*Low Size, Weight and Power,  
High Capacity, Flexible*

Imagery



*IR, Low Light, MSI*

Satellite Down Link



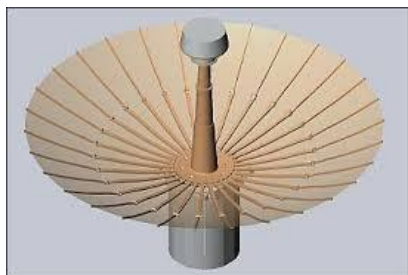
*Very High Data Rates*

Encryption



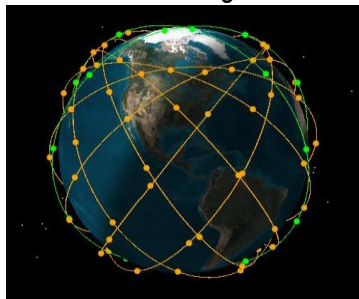
*High Throughput*

Deployable Antennas



*Reliable, High Gain, CubeSat  
Compatible*

Constellation Management



*Highly automated, common architecture,  
optimized planning and tasking*

Tactical Launch



*Low cost, responsive*

**Innovative, Affordable Space Technologies Support Future Battlefield Dominance**

# Navy Space S&T Themes - Research



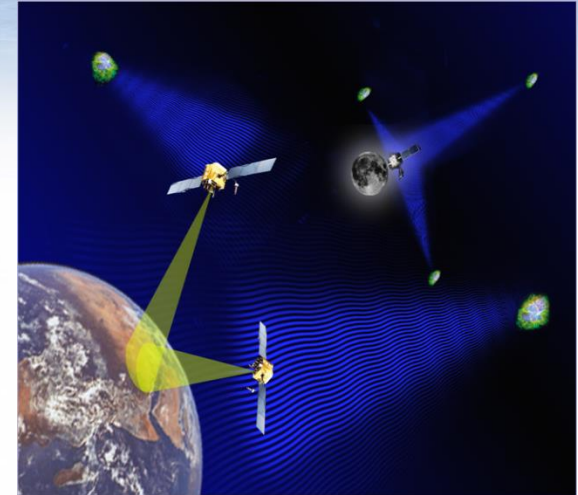
## Geospace

Observe and forecast, for enhanced situational awareness



## Heliospace

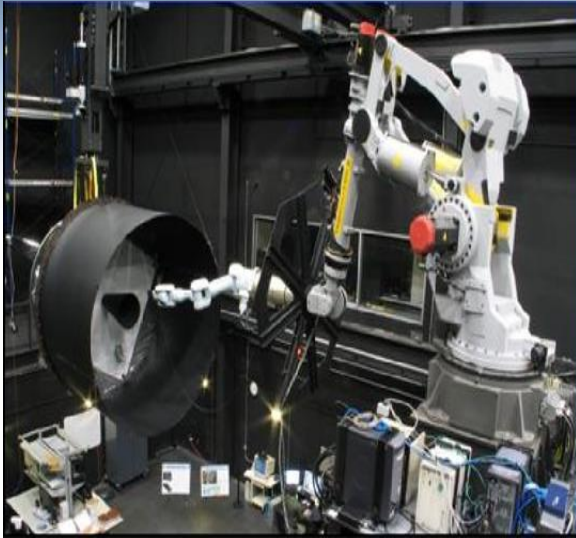
Develop improved sensors, specification, monitoring and prediction tools for operational impacts and real-time threat warning



## High Energy Space

Measure, simulate and model natural and artificial radiation and rad/nuke signatures, for detection and remediation

**Experimentally-led sensing R&D integrated across three environmental areas that underpin, connect, and inform successful operations, with metrics to increase TRL from 0-1 to 2 and to identify transition potential**



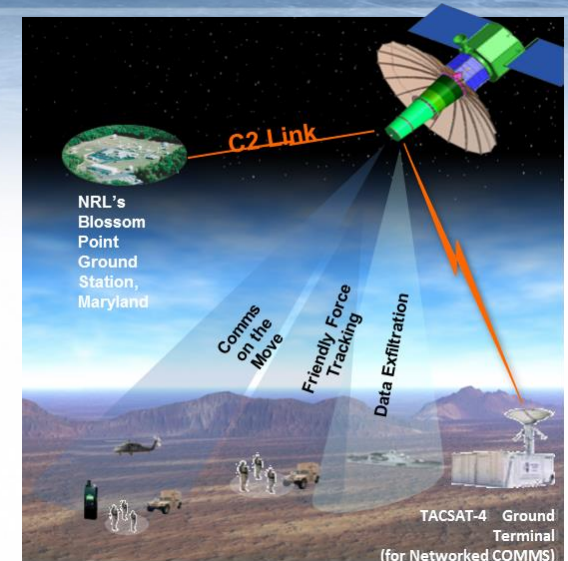
## Advanced Spacecraft Technologies

Sub-systems, for new and prototype building-blocks; propulsion & control, towards precision maneuvering while minimizing fuel; materials resiliency characterization



## Payloads & Sensing

Next-generation, to improve monitoring for threats

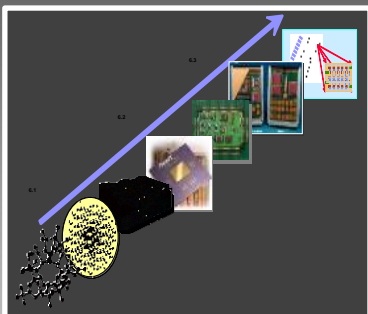


## Connectivity

High-bandwidth, space-based, for disadvantaged users

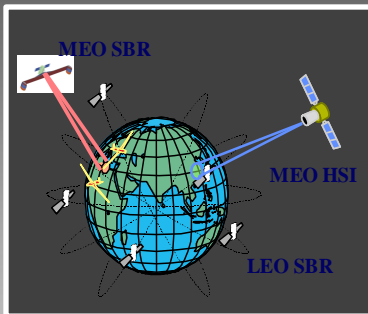


# Air Force Space S&T Themes



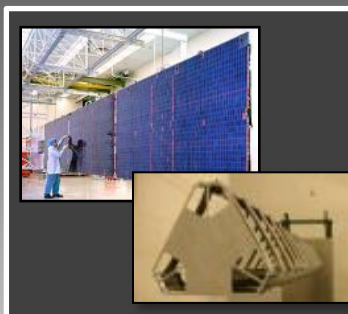
**Space Electronics**

- Space electronics physics to understand failure modes and improve reliability
- New space processors, solid-state amplifiers for GPS/Comm, A-D converters, memory



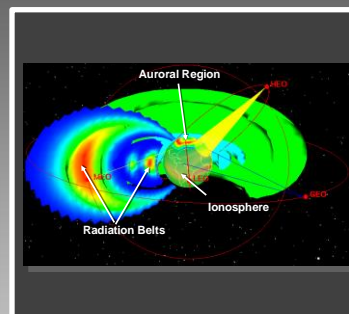
**Space Remote Sensing**

- Exploitation of collected photons (temporal, spectral, polarimetric)
- New sensors and components for missile warning
- Detectors, cryocoolers, algorithms, optics
- Nuclear explosion monitoring



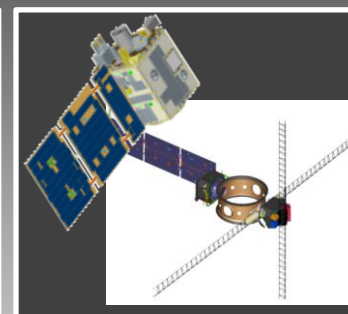
**Space Platform & Ops Tech**

- New technology to support AF-specific missions
- Solar arrays with 8X lower volume
- High-capacity thermal control
- Guidance, navigation
- Autonomous systems



**Space Environment Impacts & Mitigation**

- Models for spacecraft shielding and lifetime
- Anomaly resolution
- Astrodynamics for collision avoidance
- Reentry environment
- Space plasma physics & chemistry



**Space Flight Experiments**

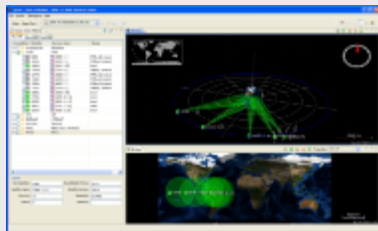
- Space system & payload development
- Integration, test, & flight
- Modeling & simulation
- Space system engineering

# Air Force Space S&T Snapshot



## Near Term

- **SSA:** Local GEO SSA using ANGELS spacecraft
- **SSA:** Resolved imaging of GEO from ground telescopes
- **Protection:** Space testing of new tech-insert options
- **Comm:** New thermal technology to increase WGS bandwidth by 25% (at Boeing)
- **GPS:** Higher transmit power to increase A2/AD jam resiliency
- **JSpOC:** Rapid all-on-all conjunction analysis



- WGS and Commercial Comm
- GPS III SV 9+
- JMS Increment 3

## Mid Term

- **SSA:** Robust space Indications and Warnings for Battlespace management (BMC2)
- **Protection:** Autonomous Resilient spacecraft bus
- **Comm:** Increase frequency trade-space into the W/V band
- **GPS:** All-digital GPS payloads lowers cost, increases acquisition options, increases anti-jam
- **Missile Warning:** Detect difficult theater missiles under clouds



W/V payload (Ktr: NG)

- Protected Tactical Comm Service
- GPS – Next
- SBIRS and WFOV OPIR

## Far Term

- **Comm & GPS:** Software agile systems for A2/AD
- **Pervasive:** e-Beam lithography for custom and trusted space electronics

Detecting difficult theater missiles under clouds



- AEHF Follow-On
- Staring OPIR for Battlespace Awareness



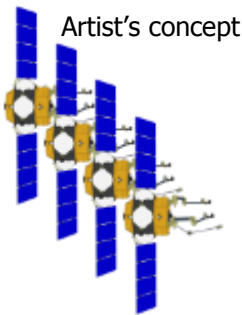
# DARPA S&T Theme GEO Servicing

SERVICING



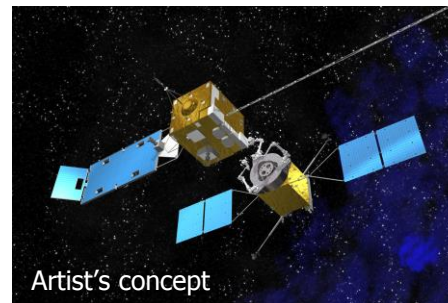
Artist's concept

First robotic capability in GEO



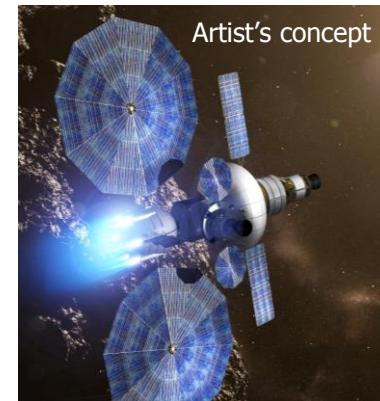
Artist's concept

Commercial providers expand coverage



Artist's concept

Automated, scheduled refueling



Artist's concept

LEO-to-GEO space tug

Technology development and investment

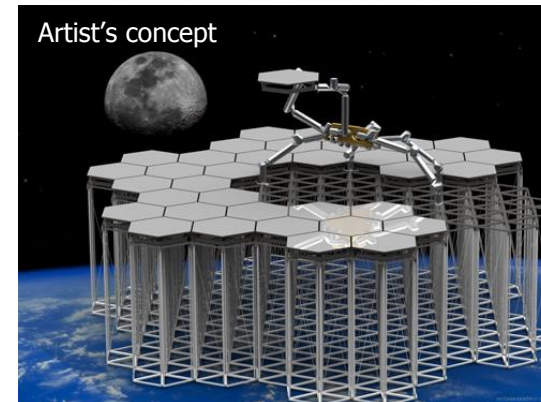
NEW ARCHITECTURES

- On-orbit replaceable units
  - Modular spacecraft



- Reduced redundancy
- Lightly fueled at launch
- Assembly experiments

Large apertures, structures and bases



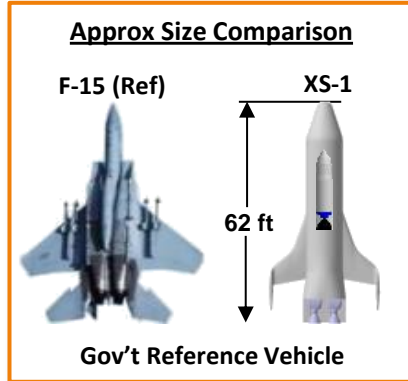
Artist's concept

**Space robotics = national-level growth potential**

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.



## Experimental Spaceplane (XS-1)



### PROGRAM OBJECTIVES

- Reusable 1<sup>st</sup> stage, expendable upper stage
- Fly XS-1 10 times in 10 days (no payload)
- Design for recurring cost 10X < Minotaur IV  
> 3,000 lb payload  
< \$5M/flight
- Launch subscale orbital demo payload once

Enable routine space access and testing of hypersonic aircraft technologies

## Airborne Launch Assist Space Access (ALASA)



Enable small satellites to be deployed to orbit from an airborne platform, allowing performance improvement, reducing range costs, and flying more frequently, which drives cost per launch down

### PROGRAM OBJECTIVES

- Mature and demonstrate technologies for cost effective, routine, reliable access to low earth orbit (LEO) from airfields
- Reduce cost to \$1M/flight in the 100 lb mass payload class
- Improve responsiveness to a 24-hour call-up to fit in the air tasking order cycle
- Deliver capability to launch into any Low Earth Orbit
- Demonstrate ability to disperse from a threatened launch airfield and execute mission from elsewhere

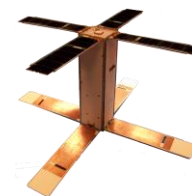


# Army Program Assured Communications

## Operational/Technical Problem:

- Continued need for beyond line of sight (BLOS) communications for disadvantaged users in remote areas
- Exfiltration of ground sensors can result in soldiers exposing their data receive position
- Demand from one Combatant Command can limit another Combatant Command's communication access

Nanosatellites  
10x10x34cm, 5.5 kg



## Program Milestone Plan:

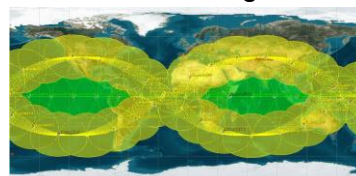
MILESTONES	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5
Non-recurring design & procurement	▶		▶		
Build of Nanosatellites	▶			▶	
Ground test			▶		
Launch					▶
On orbit checkout and Tech Demo					▶▶
Operational Demo					▶▶
Joint Military Utility Assessment					▶▶

## Technology Focus Areas:

System / Subsystem
Software Defined Radio
Propulsion
Encryption
Power Generation
High Gain Antenna
Ground Station

## Enabling Technology Areas:

### Constellation Management



Future potential: 3 orbital planes  
for near global coverage

### Tactical Launch



Low cost, responsive



High data rate



# Army Program On-Demand Small Satellite Imaging

## Operational/Technical Problem:

Available Department of Defense & commercial imagery is insufficient to provide persistent Area of Responsibility surveillance, high priority to track targets. Imaging microsattellites could provide imagery data to support battlespace awareness, and battle damage assessment rapidly. Small, inexpensive satellites could be used in numbers to provide a persistent capability to the tactical warfighter.

## Needs from On-Demand Imaging:

1. Tactical warfighters need situational awareness during combat ops
2. Ability to support persistence as an imaging source
3. Low production cost to support sufficient numbers of assets

On-Demand, small, imaging satellite program needs to determine mission areas, develop requirements, make design, build satellite(s), deploy, and demonstrate benefit via a Military Utility Assessment (MUA).



## Program Milestone Plan:

*Infra-Red, Low Light, Multi-Spectral Imagery*

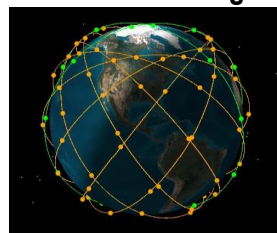
MILESTONES (THRUSTS)	Yr1	Yr2	Yr3	Yr4	Yr5	Yr6
Satellite Concept & Design Develop	3			4		
Satellite Assembly & Integration				5		
Functional Testing					6	
Space Qualification						7
Launch Integration & Deployment					7	
Initial Operations / Limited User Test						

## Technology Focus Areas:

System / Subsystem
Image Resolution and Waveband
Pointing Accuracy
Image Down Link Rate
Structure Mechanisms
Ground Station
Propulsion
Production Cost

## Enabling Technology Areas:

### Constellation Management



*Highly automated, common architecture, optimized planning and tasking*

### Tactical Launch



*Low cost, responsive*

### Satellite Down Link



*Very High Data Rates*

# Navy Success Story WindSat/Coriolis

- **WindSat/Coriolis demonstrated the capability of polarimetric microwave radiometry to produce Ocean Surface Vector Winds (OSVW)**
  - **Successfully operating for 12 years and counting**
- **NRL provided the science, payload development, mission operations, vehicle integration, data product algorithms, and calibration/validation**
- **The only USA sensor providing global OSVW**
  - Also provides soil moisture, sea ice age/concentration, imagery for tropical cyclone intensity/tracking, snow depth
- **WindSat data are operationally assimilated into numerical weather models and used for other DoD and civilian applications**

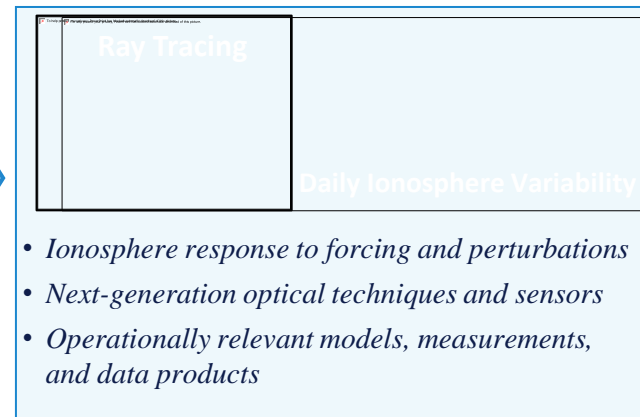
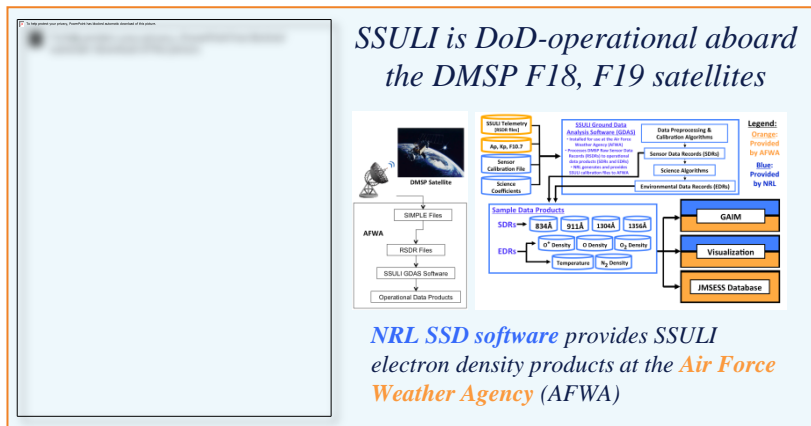


Launched January 6, 2003

# Navy Success Story SSULI

**SSULI: an advanced ionosphere remote sensing system that supports DoD operational needs**

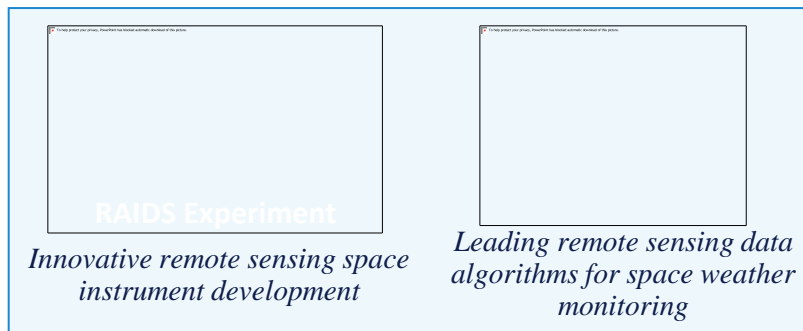
TRL  
6-9



TRL  
1-2



**Concept for operational global EUV/FUV ionosphere/thermosphere monitoring**



TRL  
1-2

**SSULI sensors and data analysis algorithms grew from NRL research investment 1980-2006. Ongoing DMSP USAF sponsorship is enabling NRL to provide the SSULI sensors and processed SSULI data for operations**

**Future: Next-gen ionospheric sensors for space weather science and myriad DoD applications**

to  
higher  
TRL

# Navy Success Story TacSat 4 & VMOC

**TacSat-4 Mission Overview**

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**TacSat-4: Providing Communications and Enabling ORS**

Augment National SATCOM with:

- Up to 5 Legacy UHF Channels
- Comms-on-the-Move without User Antenna Pointing
- Networked COMMS on SIPRNET thru PGT
- UHF Friendly Force Tracking (FFT) (Formerly Blue Force Tracking – BFT) Collection in Underserved Areas
- Data Exfiltration from Unattended Ground and Maritime Sensors
- Data Exfiltration using Oceanographic Data Telemetry Microsat Link (ODTML)
- Virtual Mission Operations Center (VMOC) used for tasking and C2 of TacSat-4

VMOC: SIPRNet Website for User Tasking

Low-HEO Orbit 2+ Hour Dwell 12,000x750 km x 63.6°

C2 Link

UHF Friendly Force Tracking (Formerly Blue Force Tracking – BFT) Collection in Underserved Areas

Comms on the Move

Friendly Force Tracking

Data Exfiltration

Blossom Point (MD) Ground Station

TacSat-4 Ground Terminal (for Networked COMMS)

2000-4000 MHz Diameter FOV

UNCLASSIFIED

- Space S&T COI met at NRL to review NRL’s investment portfolio
- As a result of this COI interaction, Army SMDC leveraged current investment in NRL’s Common Ground Architecture project Neptune and VMOC satellite C2 capability
- Army SMDC will realize an initial cost savings of approximately \$450K per Ka Ground Station
- By sharing world-wide antenna resources with NRL’s Blossom Point Tracking Facility, SMDC will avoid developing additional infrastructure which could cost up to \$100M.

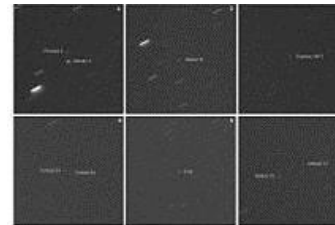
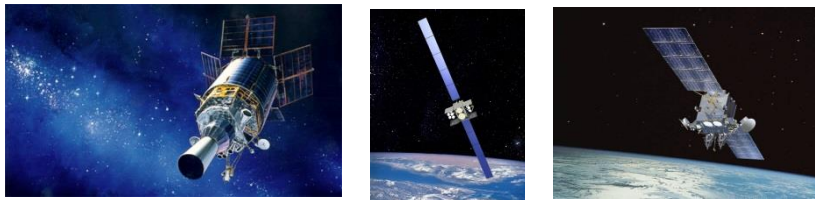
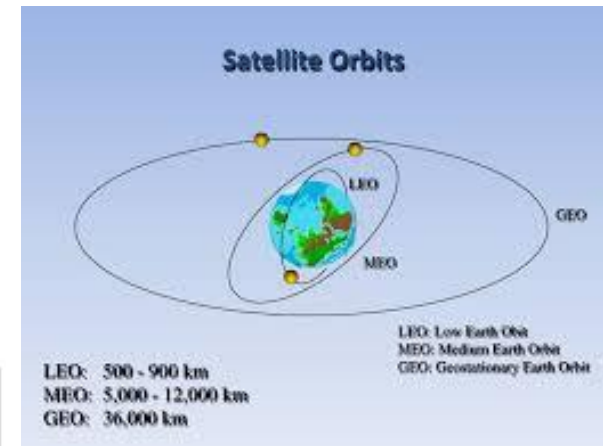
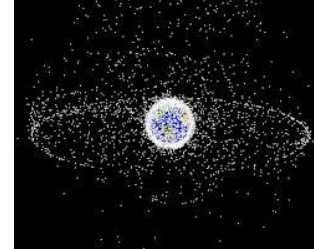
## Cross-Service Leveraging Resulting from COI Interaction

**BP Command & Control and VMOC Mission Planning**

- State-of-the-Art capabilities & automation ... working well

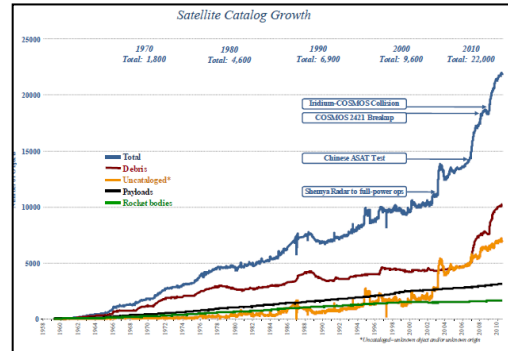
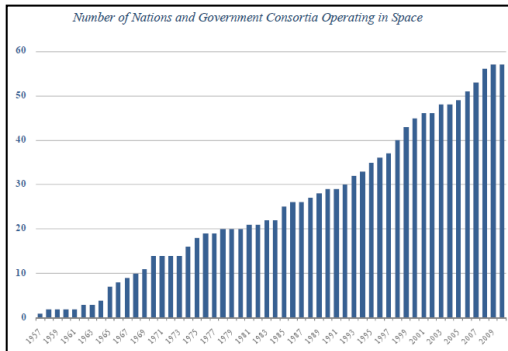


# Air Force GEO SSA Challenge



## Critical SATCOM and Missile Warning DoD Assets at GEO

## Sensing Challenge - GEO is 22,000 Miles from Earth



## Number of Nations/Gov Consortia Operating in Space (Left) and Satellite Catalog Growth (Right) per US National Security Space Strategy (2011)

- DoD tracks >22,000 man-made objects in orbit
- Approximately 60 nations and gov consortia that own/operate satellites

**Space is Becoming Increasingly Congested, Contested and Competitive.**

# Air Force Success Story

## Roll-Out Solar Array (ROSA)

### Revolutionary Solar Array Performance



#### Solar Cell Blanket

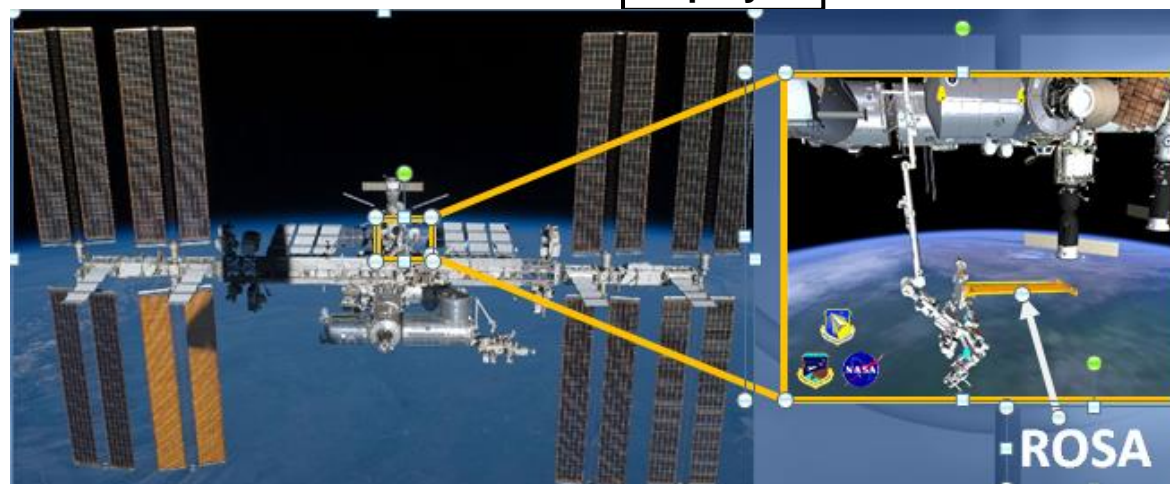
- Multiple solar cell types (rigid, flexible)
- Lightweight & high voltage capable
- Extremely thin and compliant package

#### Deployment and Support Structure

- Passively, elastically deployed array
- Lightweight, yet 4x stiffer than panels

#### Integrated Array

- Incredibly simple; 65% fewer fabrication drawings
- Very mass efficient
- Large deployed area from small stowed volume



**ROSA flight experiment on the International Space Station; launch planned for August 2016**





# *Army*

## *Future Space S&T Trends and Opportunities*

- The Space Operational Environment will become increasingly complex over time (both in capacity and capability). Friendly, Coalition, and Threat forces will vie for Space capabilities and seek to deny others
- The future Army Operational Environment (Asymmetric warfare, Mega Cities, non-state operators, etc.) will be increasingly more dependent on tactical Space capabilities in multiple Mission Areas.



# Navy Future Space Trends/ S&T Opportunities

- Multi-scale whole-atmosphere prediction of ionospheric effects, emphasis on Arctic and Tropical regions
- Terrestrial gamma-ray flashes observation base and background events modeling
- Characterize celestial pulsar sources for space-based GPS-stressed timing and navigation
- Investigate x-ray space-based communications
- Specification and prediction of geospace, heliospace, and high energy environmental effects for improved HF propagation, geolocation, SATCOM, orbital analysis, geomagnetic ULF resonance, and rad/nuke maritime detection and interdiction
- Imaging of GEO satellites from earth
- Cooperative, automatic space robotic capabilities
- Low-mass and novel active technologies for spacecraft propulsion systems
- Space sensor and analysis tools integrating on-orbit observations with modeling for improved SSA
- Lightweight articulation and sensing integrated space robotics architectures
- Spacecraft propulsion and control capabilities for precision maneuvering while minimizing fuel
- Low Earth Orbit radiation environment characterization payloads



# Air Force Future Space S&T Trends



- **Space Comm:**
  - S&T to reduce risk on LEO constellation technology to support Air Dominance
  - Alternatives needed to AFSCN TT&C
- **Launch detection**
  - Near-term AFSPC/SMC focus is on low-cost disaggregation approaches.
  - Long-term DoD focus is on tactical missiles. AFRL Hyper-temporal is a major contribution, but gaps still exist.
- **PNT**
  - Resiliency needed for GPS space and control segments
  - PNT user equipment
- **SSA**
  - Leveraging commercial observations (ground and space) crucial to improve persistence
  - Key challenges are data trust, fusion, and interoperability with AF operational systems
  - Space-based, GEO focused SSA
- **Space Access**
  - Space Access
  - On orbit propulsion
- **Space C2 & Ops**
  - Leverage commercial systems.
- **Pervasives**
  - Protection and Resilience technology
  - S&T approaches to accelerate spacecraft manufacturing



# DARPA Future Space S&T Trends

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## Launch:

- Flexible, affordable access
  - Affordable, routine and reliable access to space
  - Aircraft-like space access to lower cost and increase capabilities

## Satellite:

- Changing the paradigm of satellite operations
  - New satellite architectures for speed and robustness
  - GEO space robotics to repair and assemble very large satellites that could not be launched

## Space Domain Awareness (SDA):

- Real-time space domain awareness
  - Real-time detection and tracking versus catalog maintenance and days to weeks of forensics