



National Aeronautics and
Space Administration



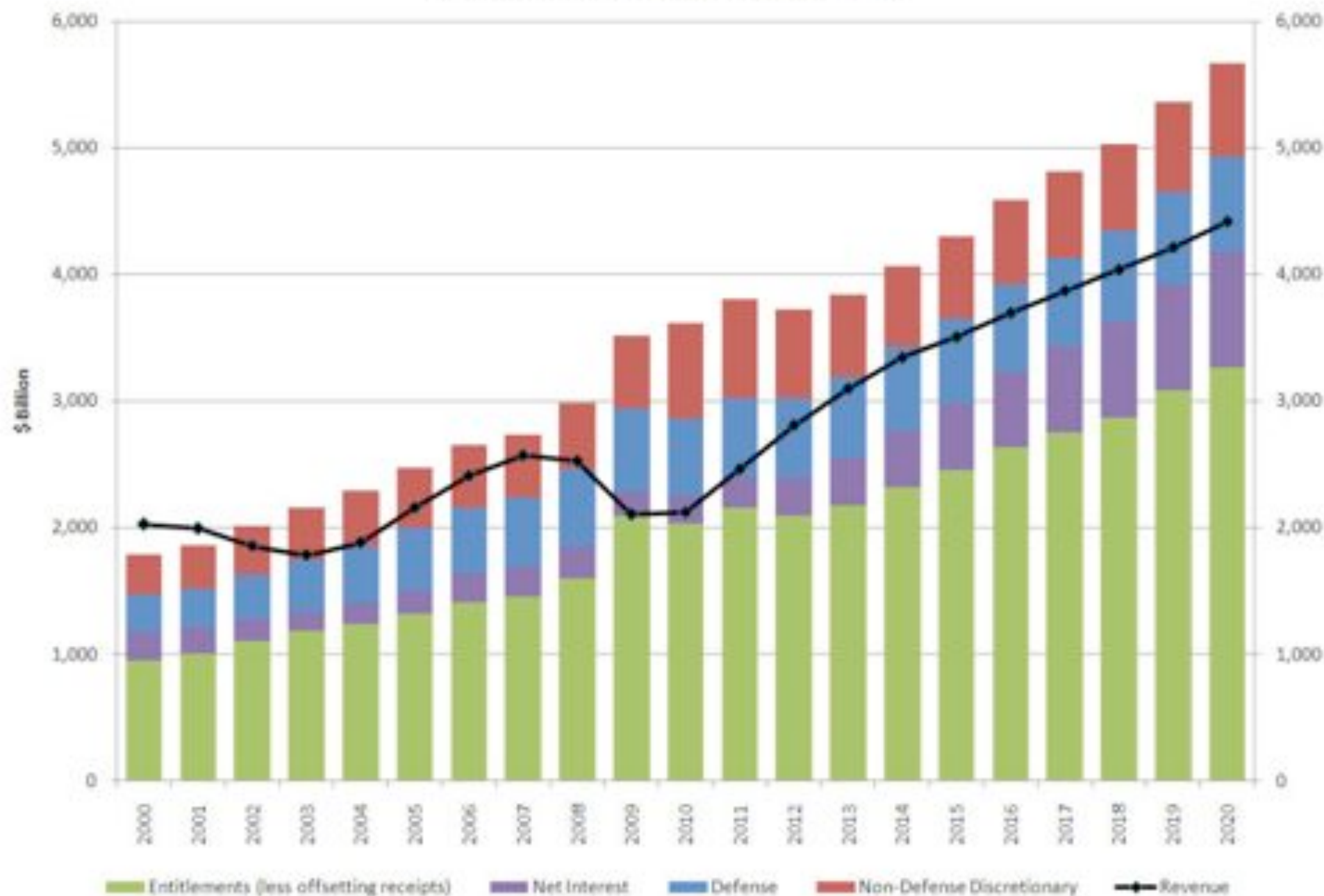
NASA and Small Satellite Research

- NASA's Interest in Small Satellites
- Nanosatellite Missions
- HQ Programs & Investments
- Future Missions & Opportunities
- Expanding Technology Portfolio



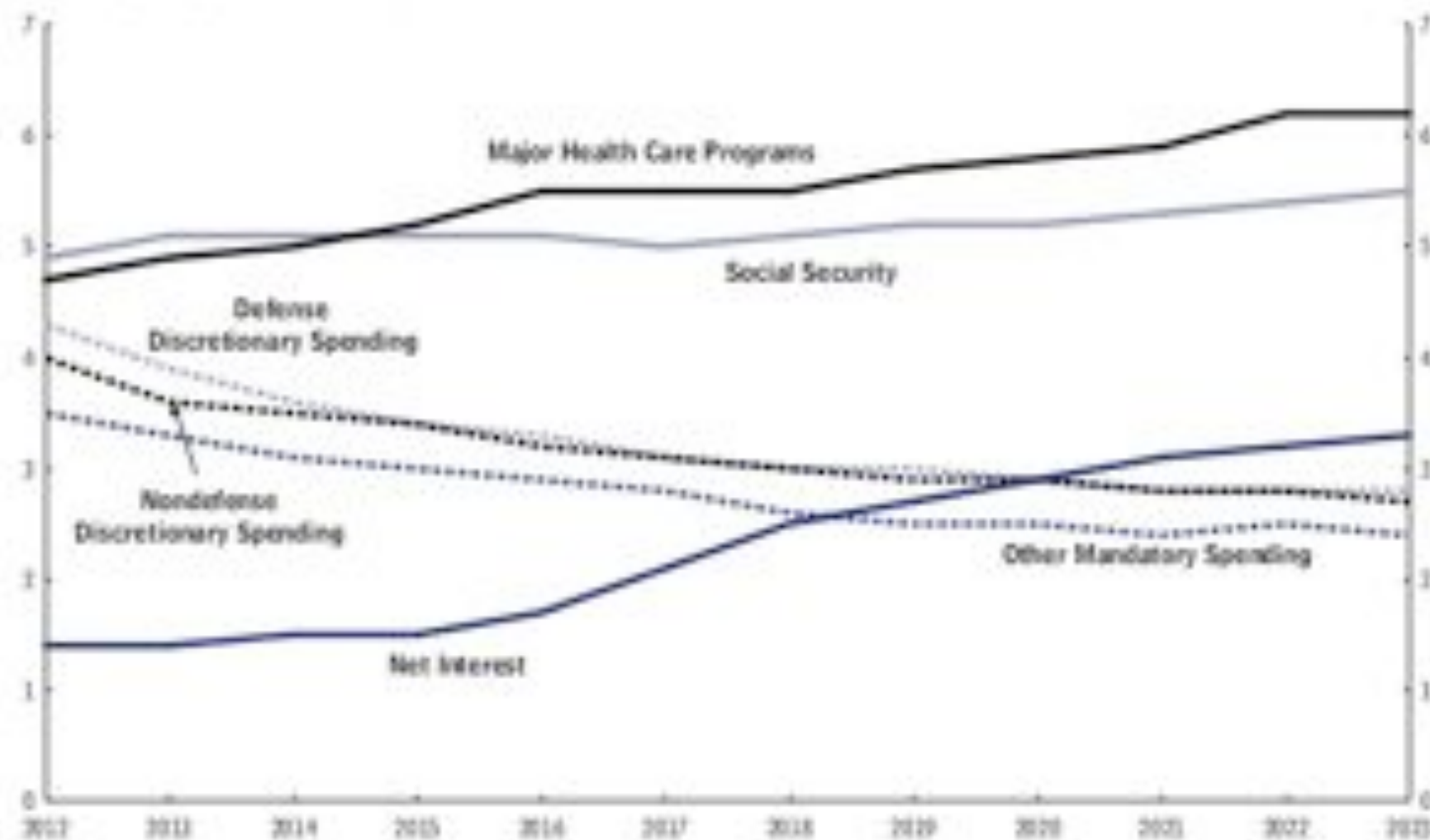
US Federal Revenues & Expenditures 2000-2020

Source: CBO (data after 2009 are projections)



Projected Spending for Major Budget Categories

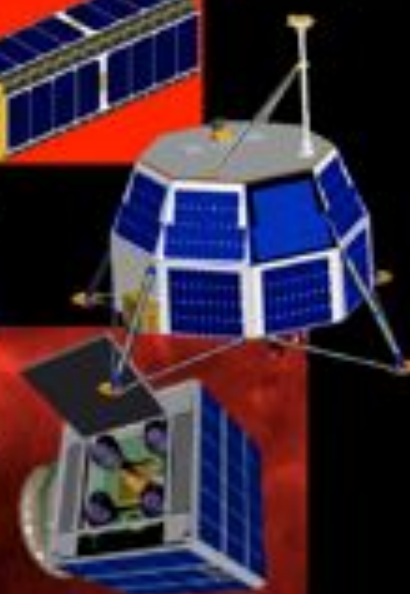
(Percentage of gross domestic product before BEA revisions)





Spacecraft Mission Sizing

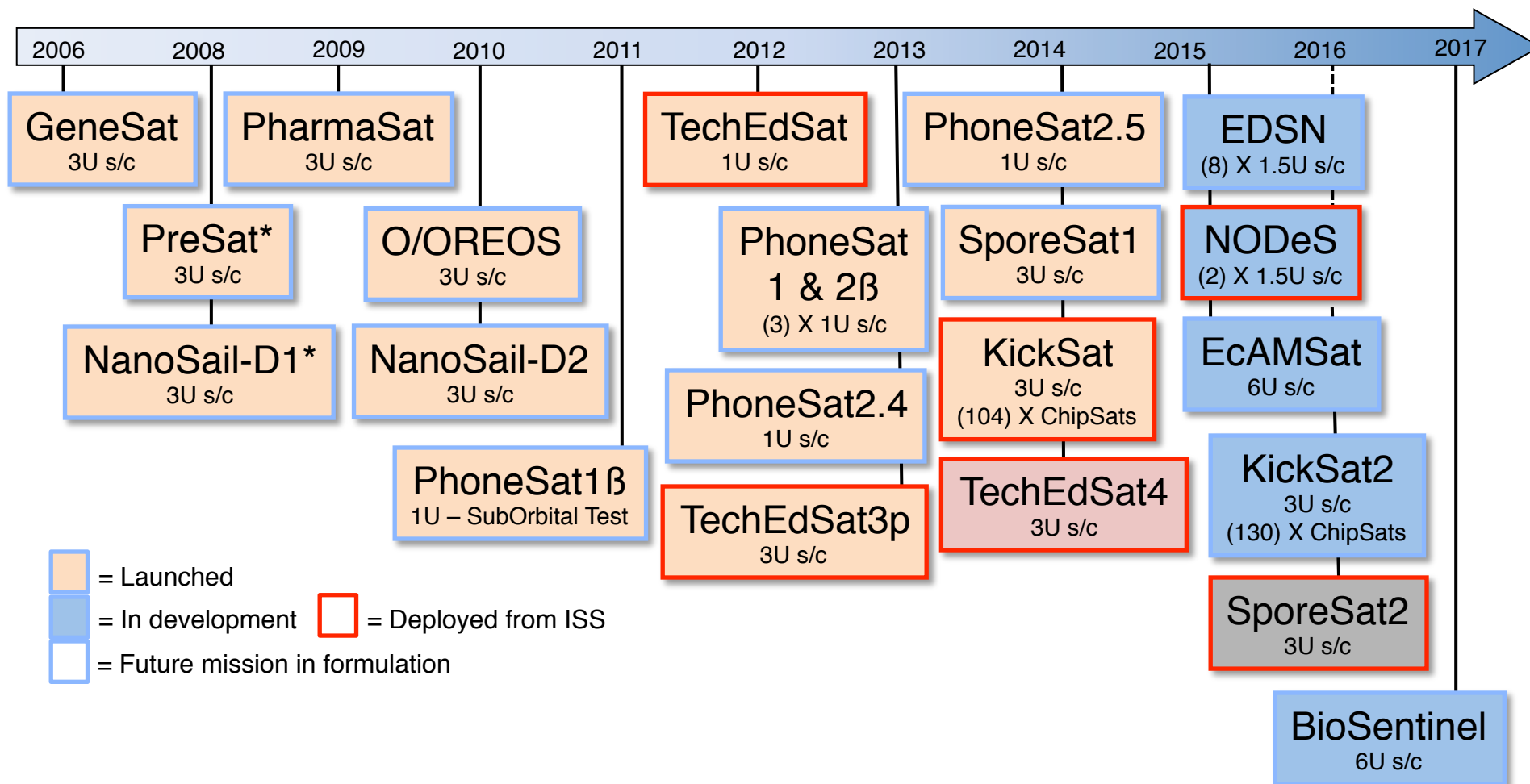
- **Larger Spacecraft Excel at:**
 - Large Diameter Sensors, Optics, Antennas, Detectors
 - Large Scale Investigations, Several Instruments
 - Lower calculated risk per individual mission
 - Lower cost per kilogram
 - Utilize "Proven Launchers"
- **Smaller Spacecraft Excel at:**
 - Simple Focused Missions, Science, Technology or Ops Demo
 - Unique Data Obtained In Near Term (Solar Cycle)
 - Short Duration Missions (<14 days for Landers, <2 years orbiters)
 - Diversity of operating sites, landing sites or Orbits
 - Lower Cost Enables Increased Number Of Missions
 - Faster Learning Cycle, Lead to Lower Costs
 - If New Technology Sooner, Lowers Cost of Flagship Missions
 - Smaller Teams, Fewer Interfaces, Improved Collaboration



ADVANCES IN MINIATURIZATION ARE CLOSING THE GAP!



Nanosat Missions





Space Biology Nanosats: *Testing Life in Space* *Validating and Enhancing ISS biological testing*

PharmaSat

- 3U Cubesat, launched May 2009, full mission success, 2U Biology payload
- Grew & characterized **yeast (*S. cerevisiae*)**; tracked metabolic activity in 48 μ wells

O/OREOS

- 3U Cubesat, launched November 2010, full mission success, 2 payloads
- Demo'd satellite bus & payload instrument functionality > 3.5 years in high-rad 15x ISS

SporeSat 1 & SporeSat 2 (*ISS deployed*)

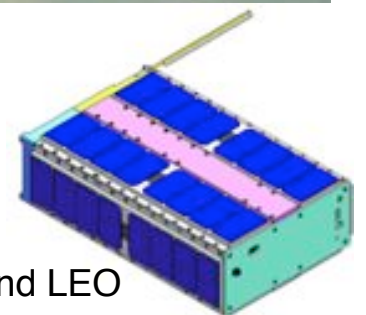
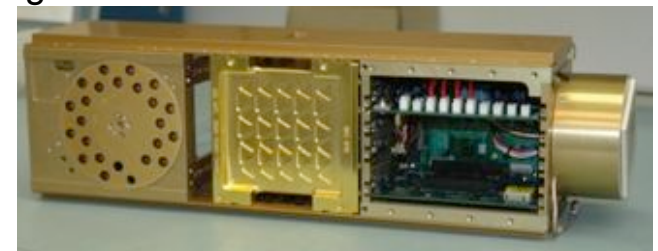
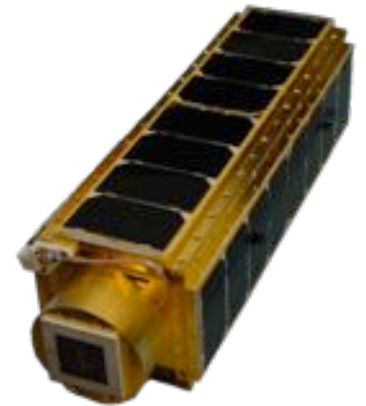
- 3U Cubesat, launched April 2014, 2nd spacecraft in Fall 2014
- Demonstrated growth of spores in gel medium, in variable-g

EcAMSat

- 6U Cubesat, launch ~ Spring 2015, 3U Biology payload
- Demonstrating *e Coli* antimicrobial resistance changes due to radiation and μ gravity

BioSentinel

- 6U Cubesat, launch ~ Fall 2018 on a Lunar mission , 4U Biology payload
- Demonstrate use of simple organisms as “biosentinels” to Inform of risks to humans beyond LEO

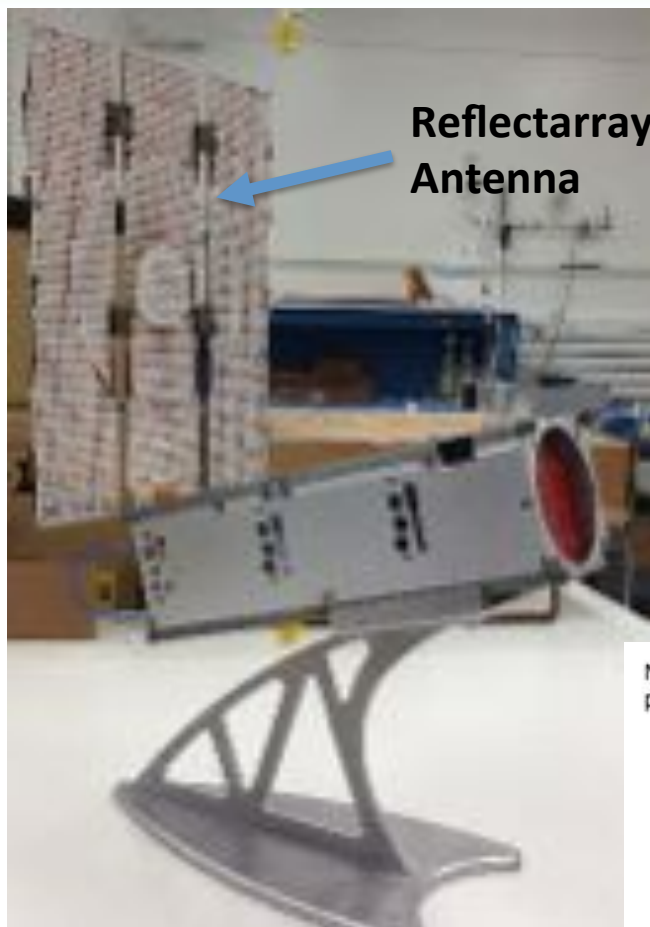




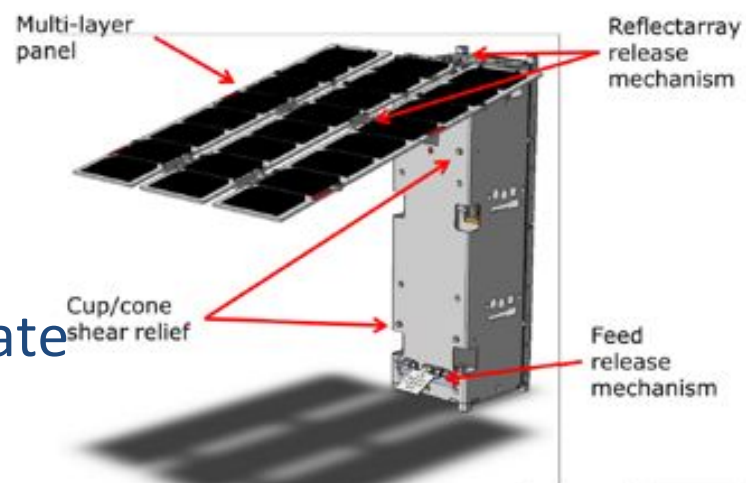
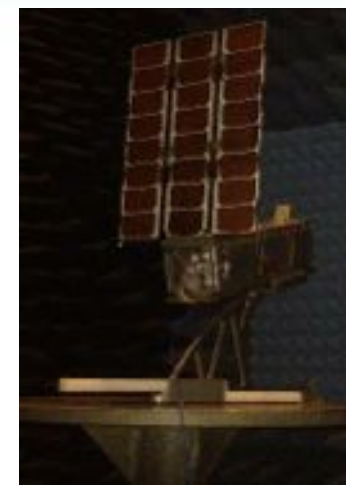
Integrated Solar Array and Reflectarray (ISARA) Tech Demo



Falcon 9 – FormoSat-5
(NET DEC 2015)



JPL Project – demonstrate
Ka Band downlink
Up to 100 Mbps





PhoneSats/EDSNs: *COTS Tech Demonstrators*

(Consumer-grade technology evaluation/validation for NASA use)

PhoneSat 1: First Phone-based spacecraft

- 2 x 1U Cubesats, Actual Nexus S phones as full Cubesat
- Launched April 21, 2013 on Antares-1. Achieved full functionality

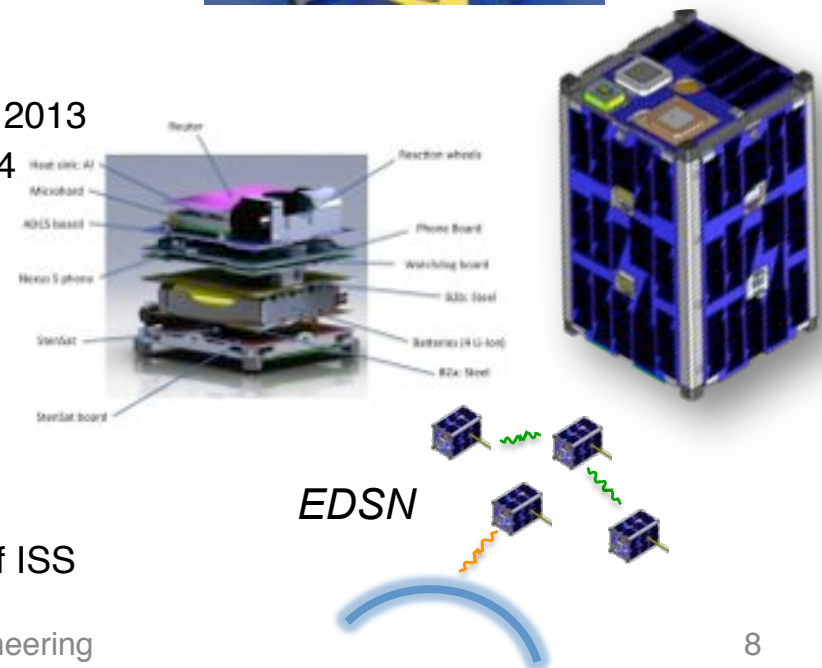


PhoneSat(s) 2B, 2.4, and 2.5

- 1U Cubesats, avionics derived from Nexus S Phone
- PhoneSat 2B Launched April 21, 2013 on Antares-1
- PhoneSat 2.4 launched on a Minotaur 1 – ELaNa 4 in Nov 2013
- PhoneSat 2.5 launched on SpaceX – ELaNa 5 in April 2014

EDSN: First Nanosat Swarm

- Phonesat as core of 8 x 1.5U Cubesats,
- EDSN Swarm satellites using PhoneSat 2 components



NODeS: ISS Nanosat Swarm demonstrator

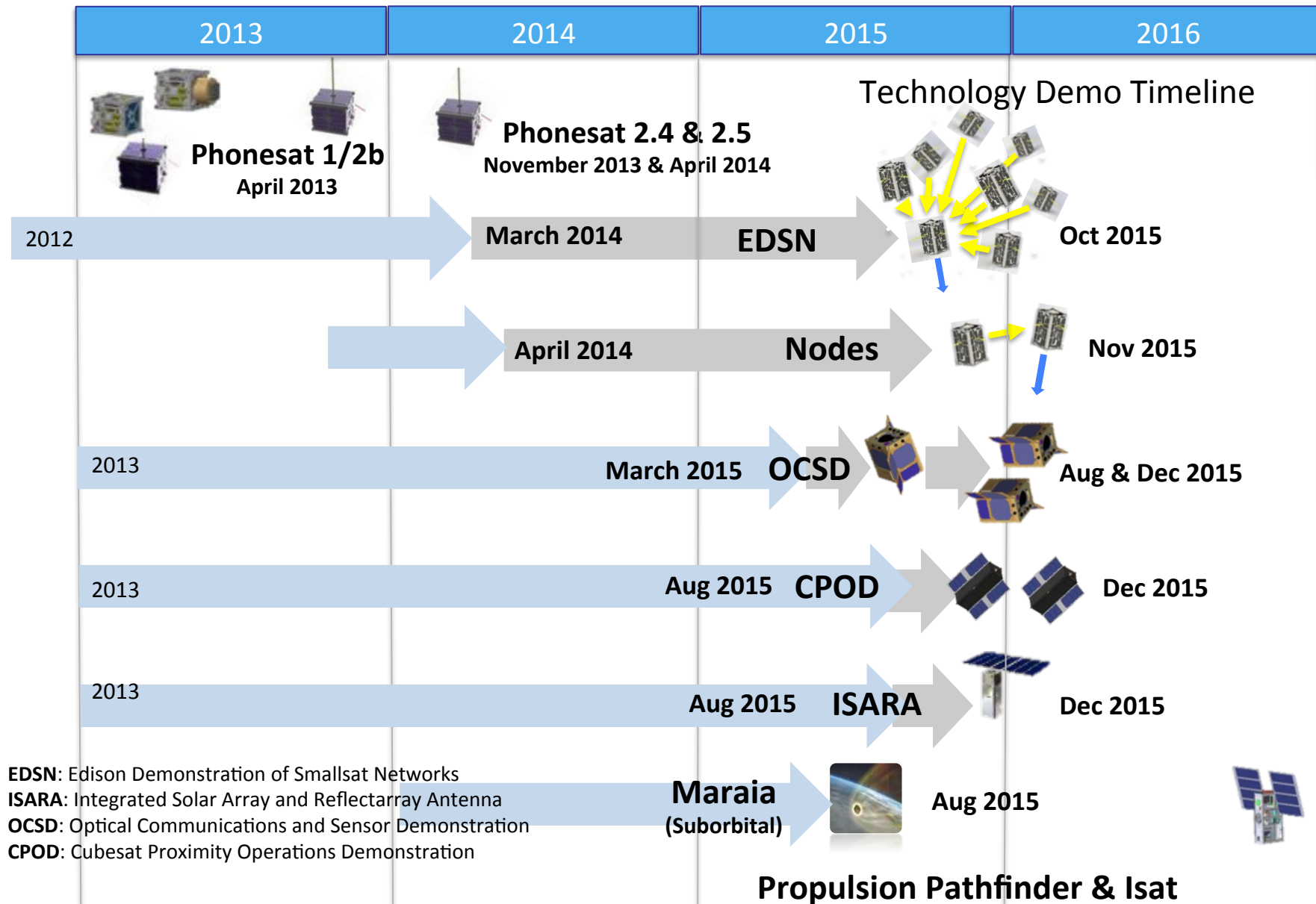
- 2 EDSN Nanosats with Advanced Software deploying off of ISS



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STMD Small Satellite Technology Program





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Ames

Discovery • Innovations • Solutions

CLSI

Cubesat Launch Initiative

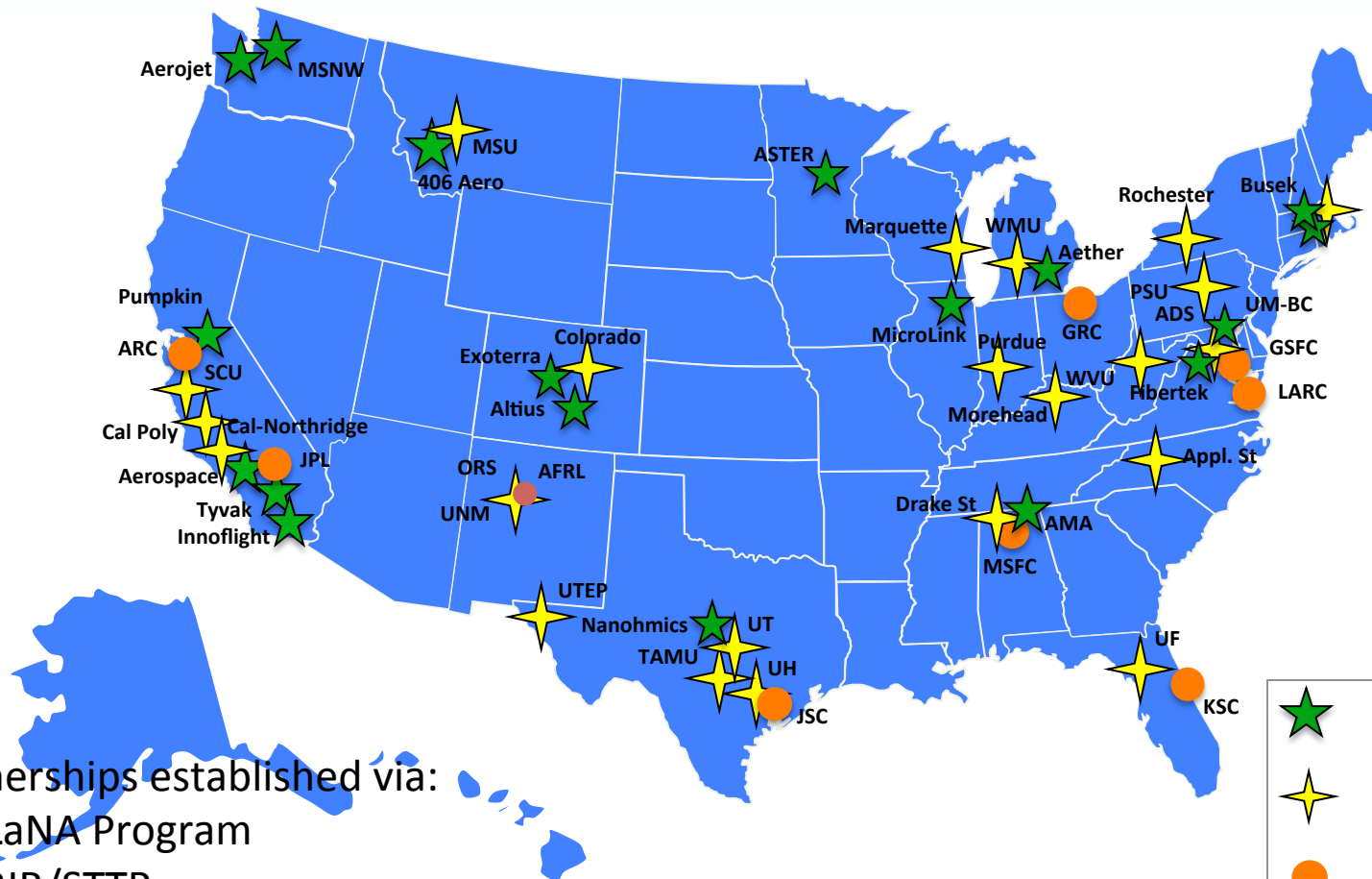


14 CubeSats selected from 12 US states and will fly as auxiliary payloads aboard rockets planned to launch in 2016, 2017 and 2018.

As part of the White House Maker Initiative, NASA is seeking to leverage the growing community of space-enthusiasts to create a nation that contributes to NASA's space exploration goals.

The aim is to launch 50 small satellites from all 50 US states in the next five years.

Small Spacecraft Technology Nationwide Participants and Partners



Partnerships established via:

- ELaNA Program
- SBIR/STTR
- MOU with other Gov't Agencies

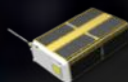
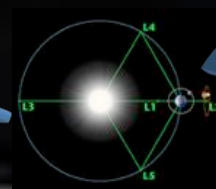
www.nasa.gov/smallsats

22 States	
	17 Companies
	22 Universities
	8 NASA Centers
	2 Other Agencies



L2

LEO



EXPANDING OUR KNOWLEDGE WITH CUBESATS

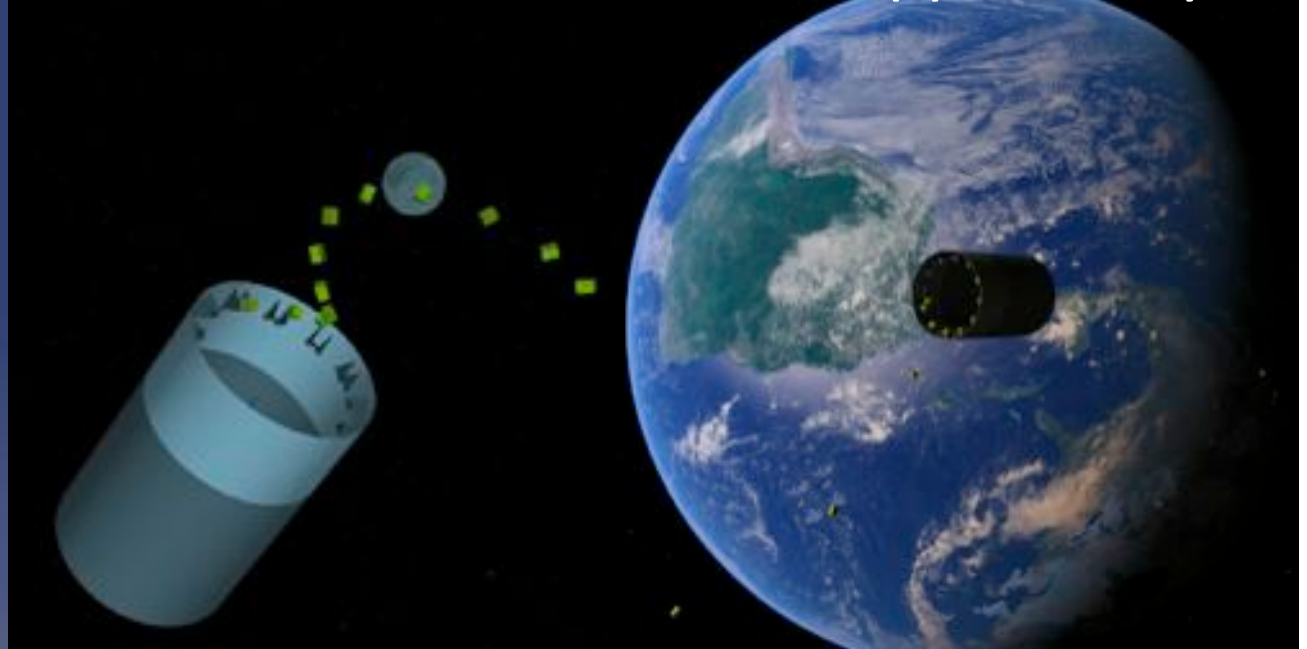
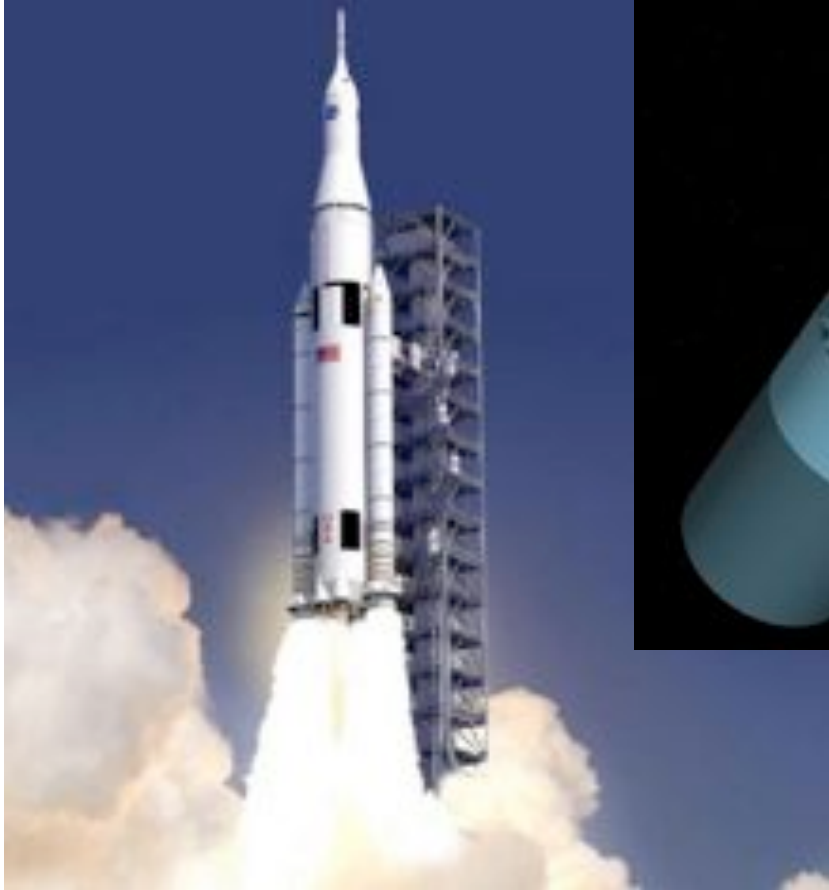


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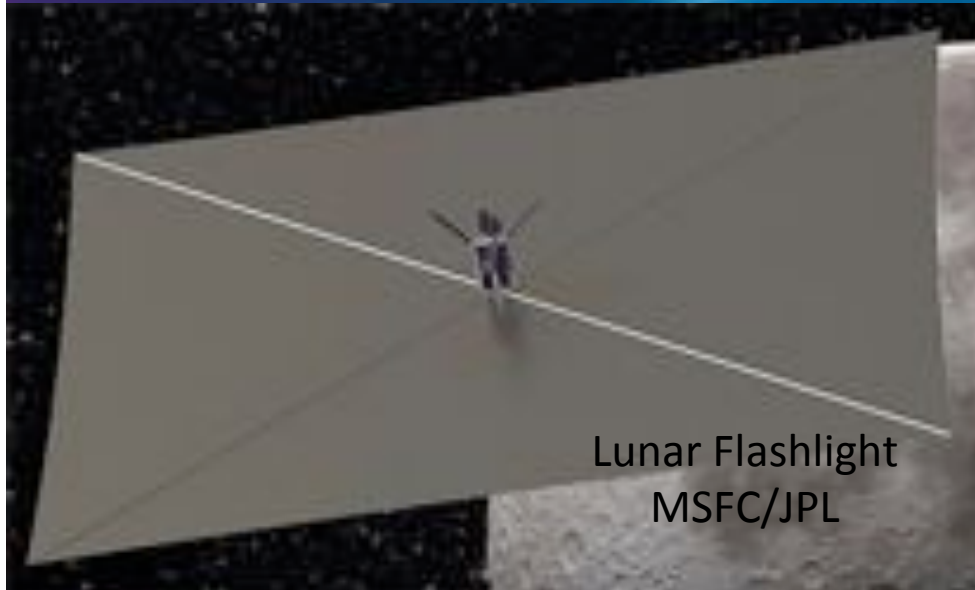
Deep Space Opportunity



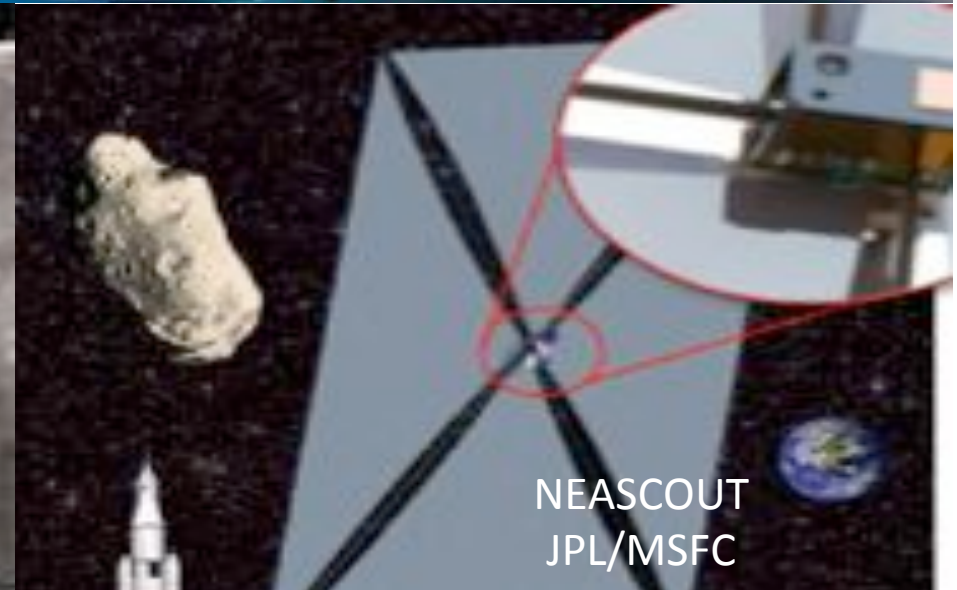
Cubesats Beyond LEO



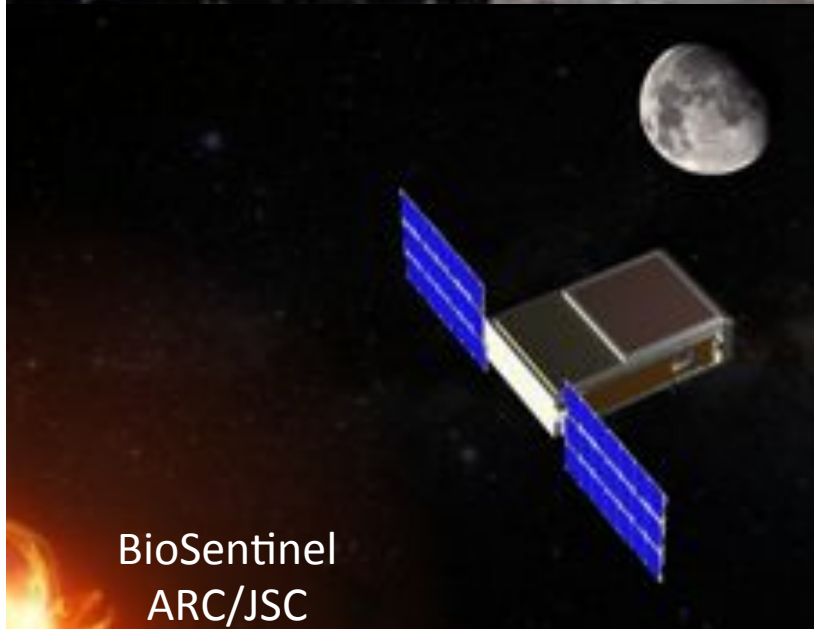
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Lunar Flashlight
MSFC/JPL



NEASCOUT
JPL/MSFC



BioSentinel
ARC/JSC

SLS EM-1 Opportunity LRD 2018

HEOMD/AES funded missions.

- Lunar Flashlight – Locate ice deposits in the Moon's permanently shadowed craters.
- NEA Scout – Flyby/Rendezvous and characterization of one NEA that is a candidate for a human mission.
- BioSentinel- Study Radiation Induced DNA of live organisms in cis-lunar space.



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Space Missions Directorate

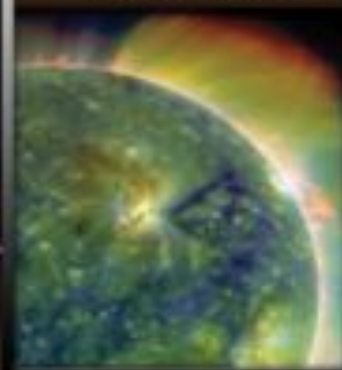
Earth



To develop a scientific understanding of Earth's system and its response to natural or human-induced changes, and to improve prediction of climate, weather, and natural hazards.

- [-Atmospheric Composition](#)
- [-Weather](#)
- [-Carbon Cycle & Ecosystems](#)
- [-Water & Energy Cycles](#)
- [-Climate Variability & Change](#)
- [-Earth Surface & Interior](#)

Heliophysics



Understanding the Sun, Heliosphere, and Planetary Environments as a single connected system

- [•Heliosphere](#)
- [•Magnetospheres](#)
- [•Space Environment](#)

Planets



Observation and discovery of our solar system's planetary objects. ...strategy based on progressing from flybys, to orbiting, to landing, to roving and finally to returning samples from planetary bodies

- [•Inner Solar System](#)
- [•Outer Solar System](#)
- [•Small Bodies of the Solar System](#)
- [•Mars Program Planning](#)

Astrophysics



Discover how the universe works, explore how the universe began and developed into its present form, and search for Earth-like planets.

- [Planets Around Other Stars](#)
- [The Big Bang](#)
- [Dark Energy, Dark Matter](#)
- [Stars](#)
- [Galaxies](#)
- [Black Holes](#)



SMD

- + Helio-1 "ELFIN-STAR" - Principal Investigator: V. Angelopoulos, UCLA ELFIN-STAR seeks to understand storm-time precipitation of radiation belt relativistic electrons and determine if electromagnetic ion cyclotron waves are responsible for the precipitation.
- + Helio-2 "CuSPP" - Principal Investigator: M. Desai, Southwest Research Institute CuSPP will study solar particles over Earth's poles to provide space weather relevant observations through combined interplanetary energetic particle and suprathermal source population observations at high cadence.
- + Helio-3 "TBEx" - Principal Investigator: R. Tsunoda, SRI, NASA's Goddard Space Flight Center TBEx will significantly improve the understanding of the role of atmospheric gravity waves on the formation of equatorial plasma bubbles.
- + Helio-4 "MinXSS" - Principal Investigator: T. Woods, LASP, NASA's Goddard Space Flight Center MinXSS will improve understanding of solar spectral irradiance to improve modeling capabilities and reduce uncertainty regarding where in the upper atmosphere of Earth solar photon energy is deposited.
- + Helio-5 "SORTIE" - Principal Investigator: G. Crowley, Atmospheric and Space Technology Research Associates SORTIE will investigate the underlying causes behind the appearance of plasma structures in the F-region of Earth's ionosphere, leading to equatorial plasma bubbles, and the evolution of these structures after formation.
- + Earth-1 "IceCube" - Principal Investigator: D. Wu, NASA's Goddard Space Flight Center IceCube is a sub-millimeter wave radiometer to advance understanding of ice clouds and their roles in climate change.



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HEOMD/AES NextSTEP Broad Agency Announcement.

SMD – Small Innovative Mission for Planetary Exploration (SIMPLEX)



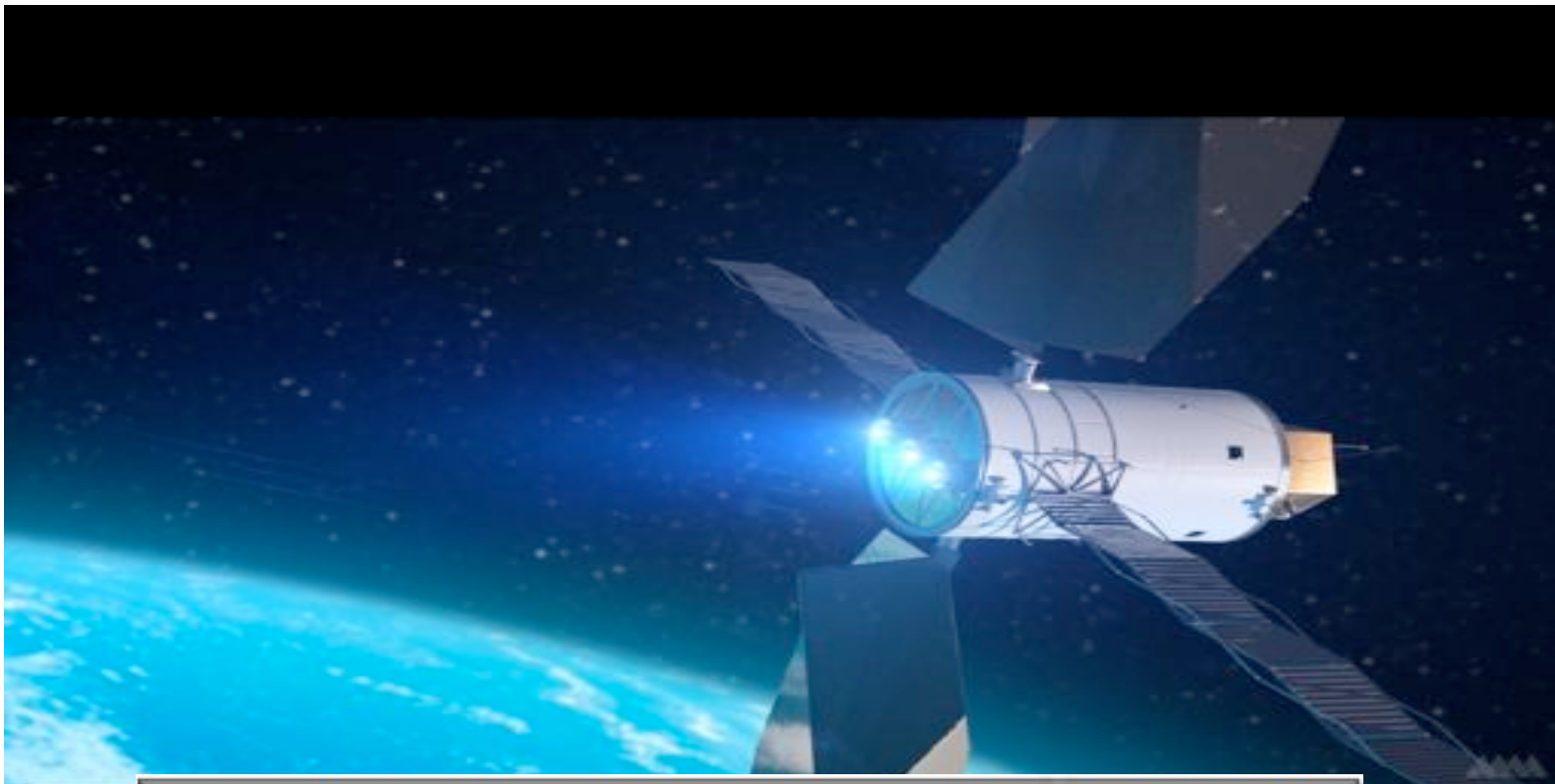


- What is needed
- Technology areas
- Products to support/enhance NASA Subtopic
- Missions (planned and projected
- Tools
- Efficient LC dev

Projections indicate substantial growth in nano/microsatellite launches, with an estimated range of 410 to 543 nano/microsatellites (1-50 kg) that will need launches globally in 2020 (compared to 92 in 2013)



ENABLING FUTURE MISSIONS & EXPANDING TECHNOLOGY PORTFOLIO



Projections indicate substantial growth in nano/microsatellite launches, with an estimated range of 410 to 543 nano/microsatellites (1-50 kg) that will need launches globally in 2020 (compared to 92 in 2013)

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Small Spacecraft Technology Program

Director, Andres Martinez

www.nasa.gov/smallsats

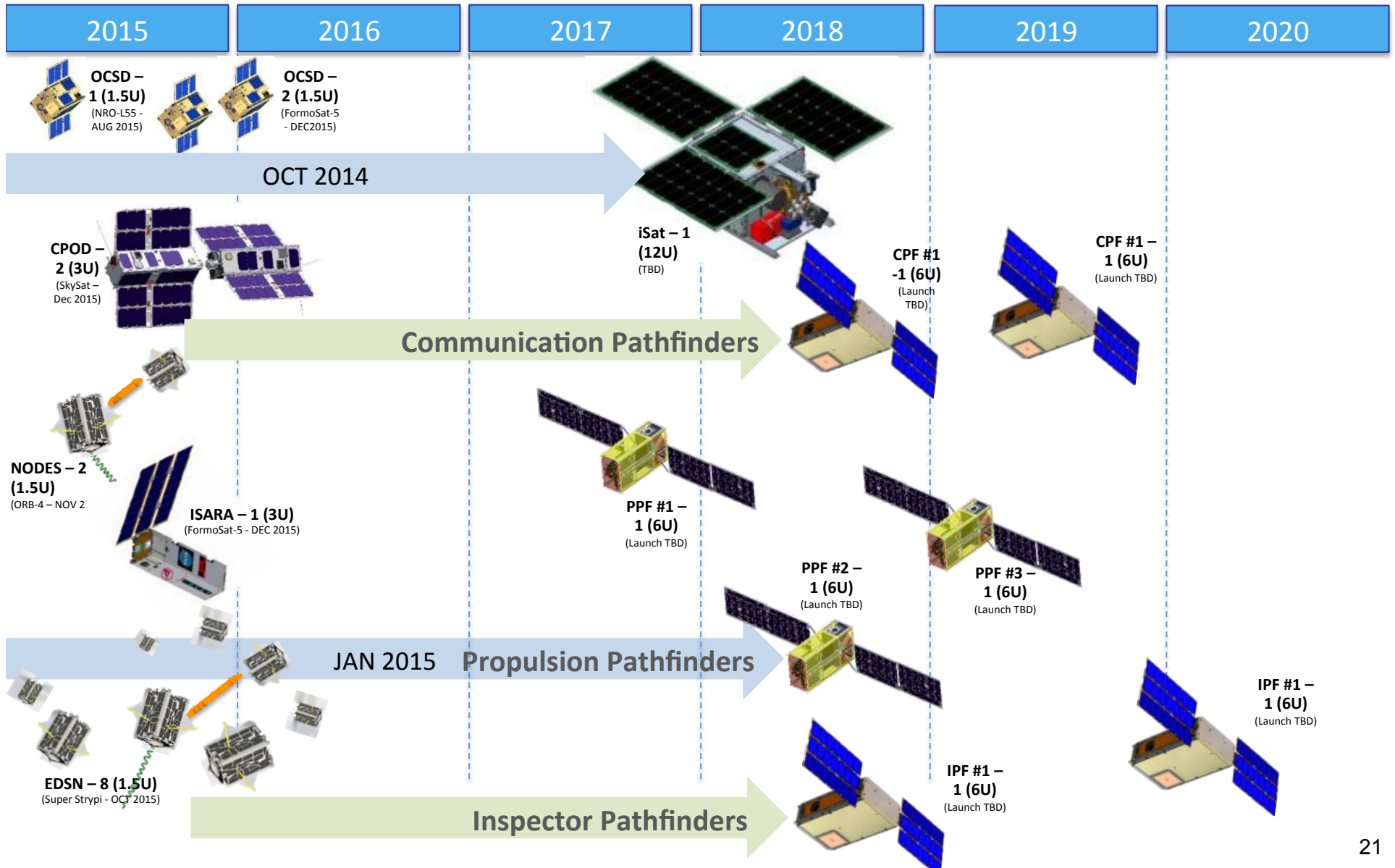


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SSTP Flight Projects: CY 2015-2020



Capability Driven Framework



Incremental steps to steadily build, test, refine, and qualify capabilities that lead to affordable flight elements and a deep space capability.

Mars: Ultimate human destination in the next decades

Planetary Exploration

- Mars
- Solar System

Exploring Other Worlds

- Low-Gravity Bodies
- Full-Capability Near-Earth Asteroid Missions
- Lunar Surface
- Phobos/Deimos

Into the Solar System

- Interplanetary Space
- Initial Near-Earth Asteroid Missions

Extending Reach Beyond LEO

- Translunar Space
- Geostationary Orbit
- High-Earth Orbit
- Lunar Flyby & Orbit

Initial Exploration Missions

- International Space Station
- Space Launch System
- Orion Multi-Purpose Crew Vehicle
- Ground Systems Development & Operations
- Commercial Spaceflight Development

Space Launch System
130 metric ton configuration

Asteroids

Surface Capabilities Needed

High Thrust In-Space Propulsion Needed

Long Duration Habitat Needed

2011-08-24 Rev. 08



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SPHERES RINGS



Visit us @ <http://www.nasa.gov/spheres>

Follow us on Twitter @NASA_SPHERES

Synchronized
Position
Hold,
Engage,
Reorient,
Experimental
Satellites



Q. What does it do?

A. RINGS uses two large Electro-Magnets to move around the ISS by attracting and repelling the SPHERES with respect to each other instead of using the built in CO₂ thrusters. Additionally, RINGS are also able to wirelessly transfer power between each other.

Q. Why is it important?

A. Being able to move around without the need of a consumable fuel source is very important for deep space missions. Most spacecraft carry a limited amount of fuel. By using Electro-Magnetic propulsion we no longer have to worry about running out of fuel.



UNIVERSITY OF
MARYLAND



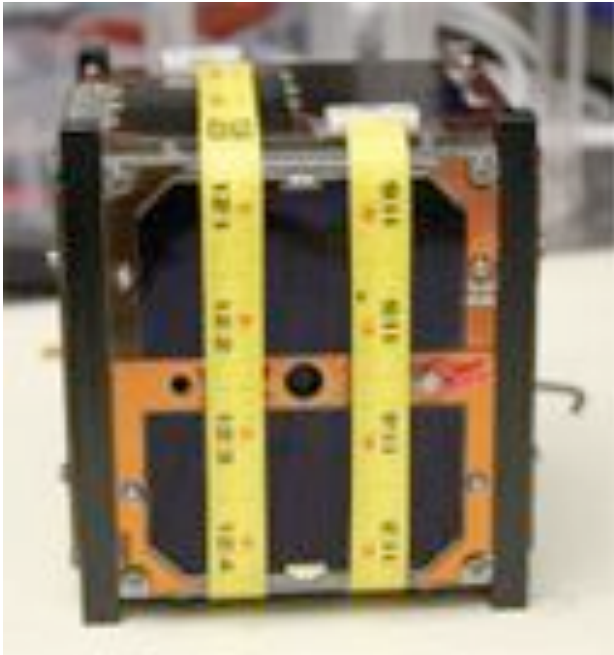
Ames Research Center



Aurora
FLIGHT SCIENCES



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COVE

Earth Science Invest

NASA's Earth Science Technology Office (ESTO) manages the development of a range of advanced technologies to meet future Earth science measurement requirements. ESTO technology investments attempt to address the full science measurement process: from instruments needed to make observations to data systems and information products and tools that make those observations useful.

EVI-3 - \$31M Cubesat Opportunity

This solicitation calls for proposals for complete PI-led science investigations requiring spaceflight instrument or CubeSat(s) development. The term "complete" encompasses investigation phases from project initiation, through development and science operations, to scientific analysis of space based data. These spaceflight missions will be used to conduct innovative, integrated, hypothesis or scientific question-driven investigations addressing pressing Earth system science issues.



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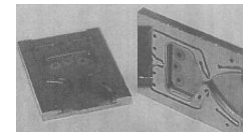


Spacecraft Technologies Development

- Advanced Bus Architectures
 - Plug and Play
 - Autonomous Operations
- Data Handling
- Communications
- Guidance, Navigation and Control
 - MEMS Accelerometers and Gyroscopes
 - Miniaturized GPS Devices
 - Propellantless Attitude Control
- Multisatellite Operations
 - Formation Flying/Constellations
- Power
 - Long-life, High-density, Scalable Power Storage
 - Deployable Solar Arrays
- Structure
 - Evolvable, Reconfigurable Satellites
- Thermal Management
 - MEMS-based



NanoThrusters



MicroPropulsion



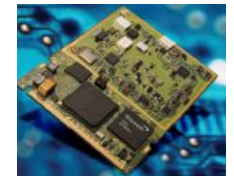
High-Capacity,
Lightweight Batteries



GPS
Receiver



High-Performance,
Low-Power Computing



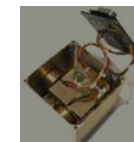
5.8-GHz Transceiver



Sun Sensor



Mini Star Tracker



Nano Reaction
Wheels



Ultralight-weight IMU

Enabling Science Missions:

Precision Formation Flying

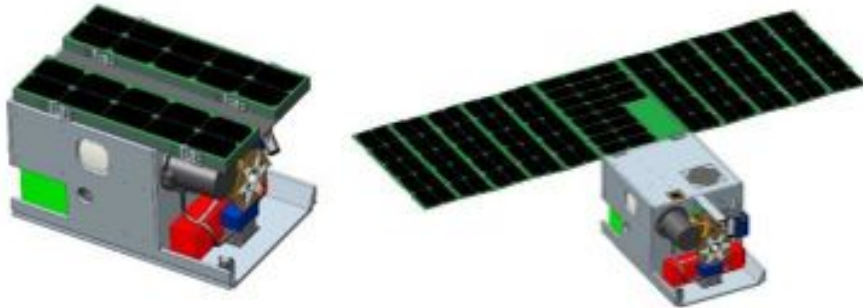
Remote Imaging: Earth/Lunar Science

Autonomous Satellite Maintenance

Space Physics & Astrophysics

Exploration: Lunar, NEOs, Comets

Iodine Satellite (iSAT)



Spacecraft Specifications

- Mass: 24kg
- Quantity: One 12U CubeSat
- Orbit: 700km initial orbit (SSO), 98.1880° incl.
- Size: 20cm x 20cm x 30cm
- Communication: S-Band

Mission Description

The iSAT Project is the maturation of iodine Hall technology to enable high ΔV primary propulsion for NanoSats (1-10kg), MicroSats (10-100kg) and MiniSats (100-500kg) with the culmination of a technology flight demonstration. The iSAT project has three major elements: iodine Hall technology development support, the iSAT flight demonstration and future technology risk reduction. In addition to the iodine Hall focus, this project recognizes the market growth potential for SmallSats and the gap in commercially off the shelf (COTS) options for higher capable spacecraft: higher power systems, additional thermal control, higher data rates, improved stability and attitude control, etc.

LCCE - \$12,757K

Status

The iSAT project completed its preliminary design review in December of 2014 and is working towards CDR in the summer of 2015. The current design and analysis cycle is showing positive margins in all areas and development is on plan.

Critical Milestones

ATP	SRR	PDR	CDR	FHR	FRR/ORR	Launch	Mission Ops	Mission Duration	Project Closure
7/18/14	7/28/14	12/9/14	TBD	TBD	TBD	11/1/2017	11/15/2017	6 Months	5/25/2018

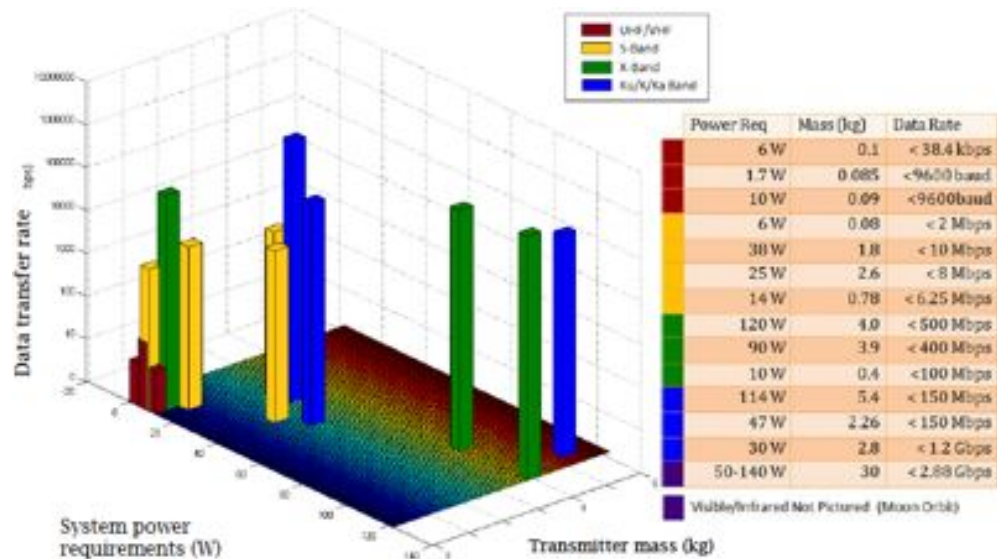
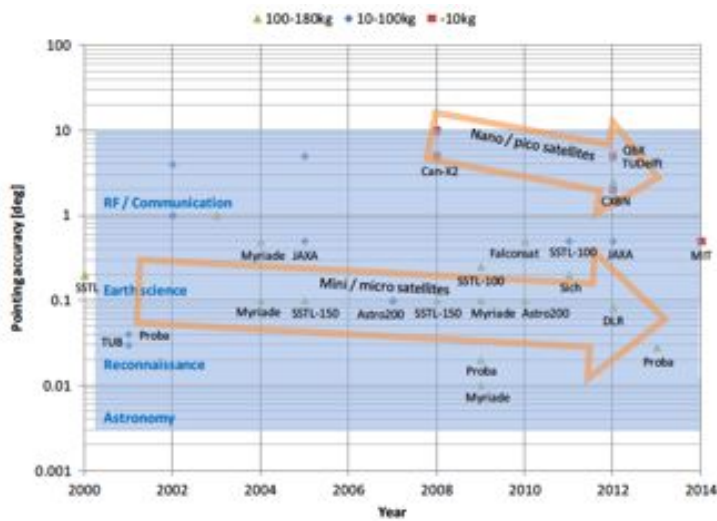
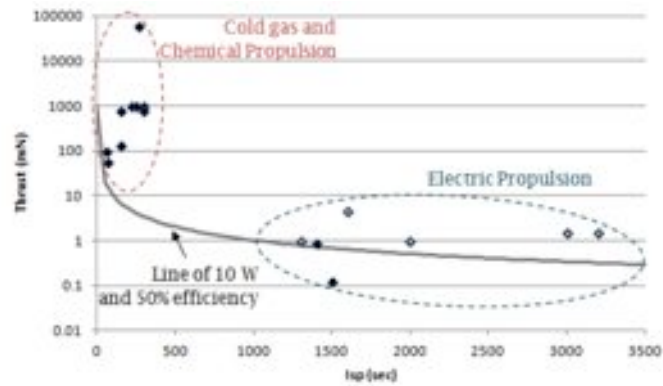
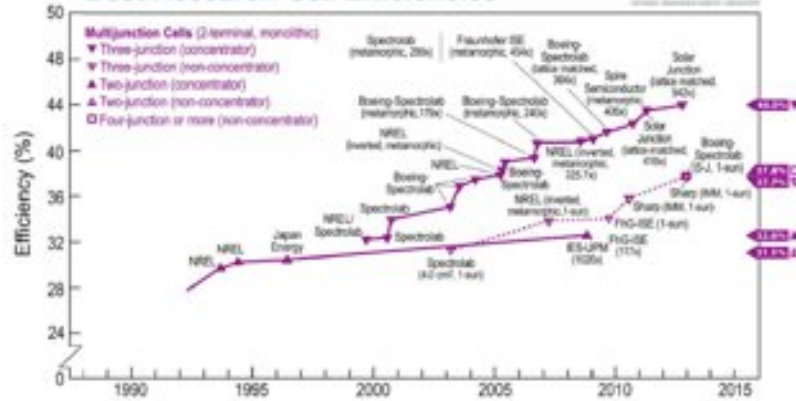


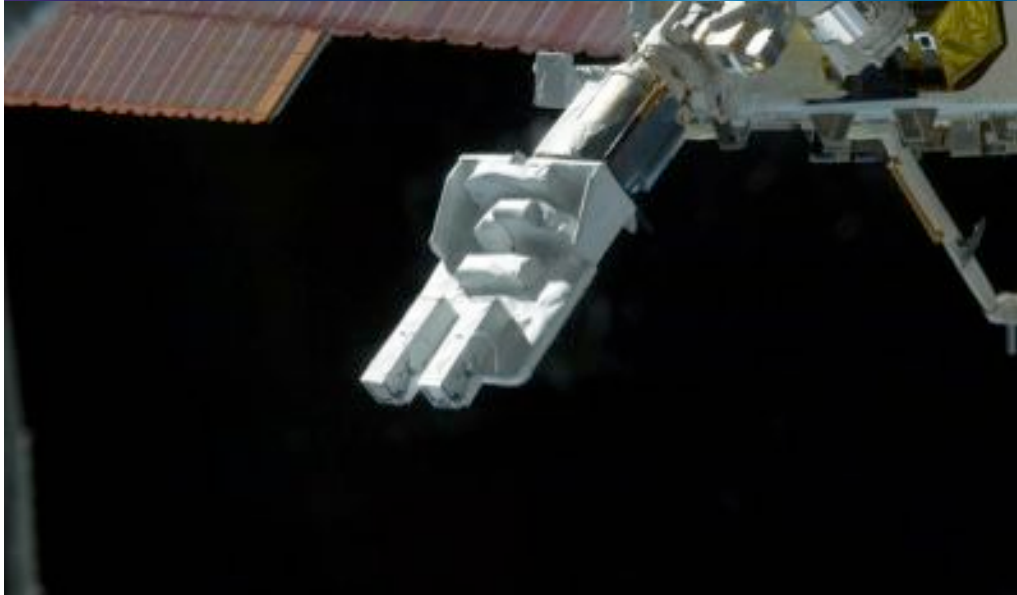
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Best Research-Cell Efficiencies





Continued Development of Small
Satellite Launch Capabilities





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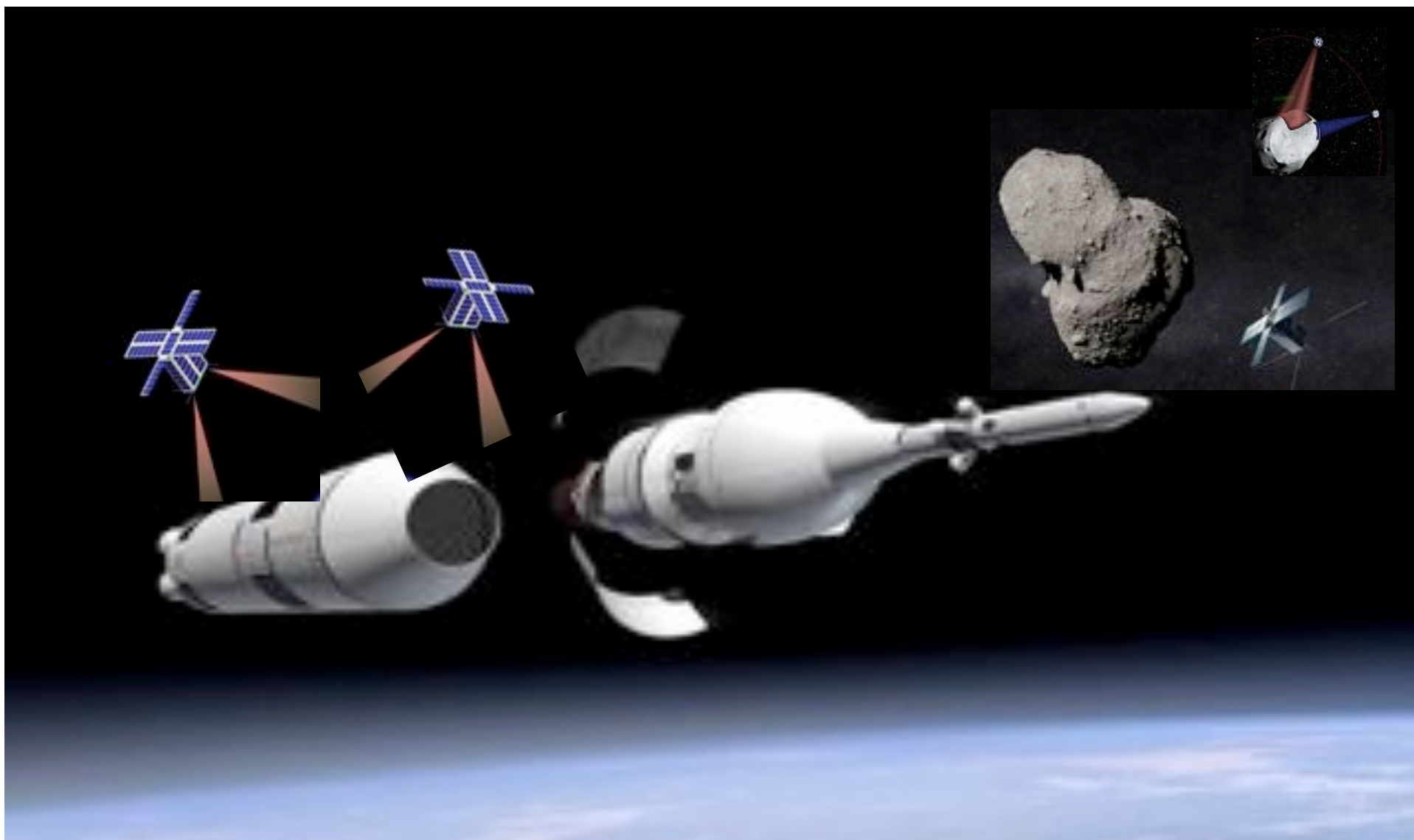


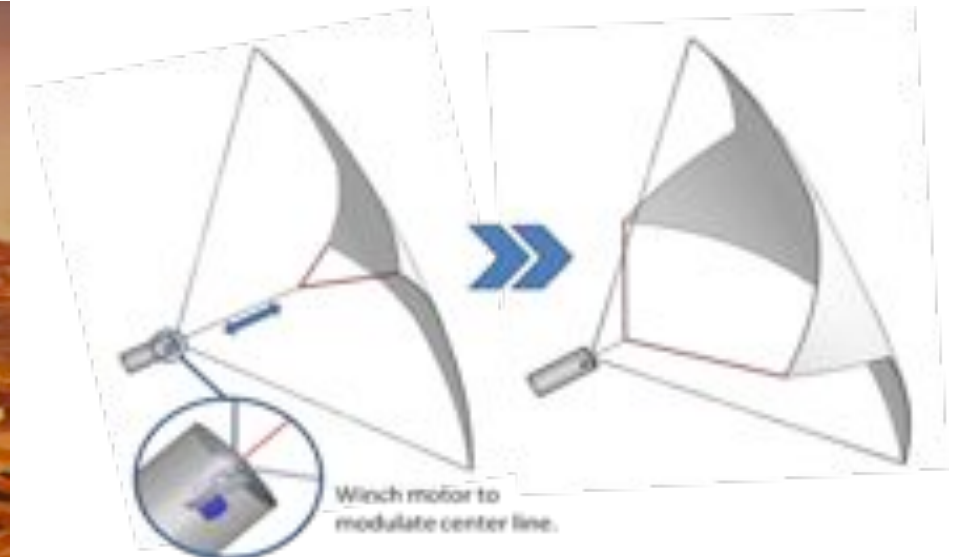
MISSION CONCEPTS





Proximity Operations & NEA Surveys





SAMPLE RETURN & EDL TECHNOLOGIES



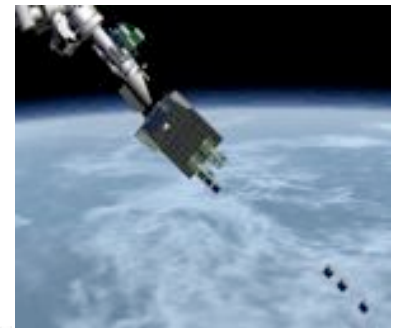


TechEdSats: *Re-Entry Technology Demonstrators*

ISS Downmass and EDL demonstrators

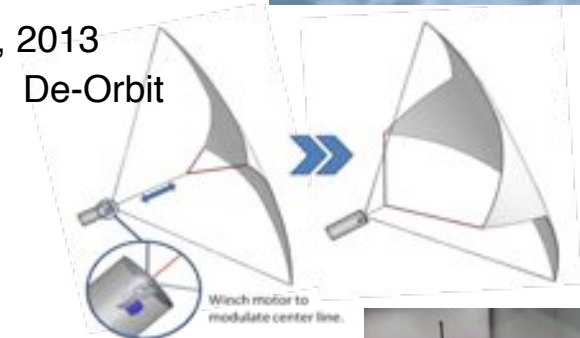
TechEdSat-1: First U.S. & NASA CubeSat launched from ISS

- 1U Cubesat at 1.2kg, Launched July 21st 2012, Deployed from ISS October 4th 2012
- Passed out of JAXA's ISS airlock, deployed from JAXA's robotic arm
- Standardized the Process for ISS Cubesat Deployments now used by Nanoracks



TechEdSat-3p: First 3U Nanosat from ISS

- 3U Nanosat, Launched August 4 2013 (HTV-4), ISS deployed on Nov 19, 2013
- First sub-scale Exo-Brake test; Iridium downlink/uplink test; validation burned up during Earth Re-entry



TechEdSat-4: Deploying from ISS summer 2014

- 3U Nanosat, to be launched ~July 1st 2014 on Orbital's Orb2 to ISS
- To be deployed from Nanoracks Cubesat Launch system
- Reflight of TechEdSat-3p Exobrake, updated Iridium & GPS hardware





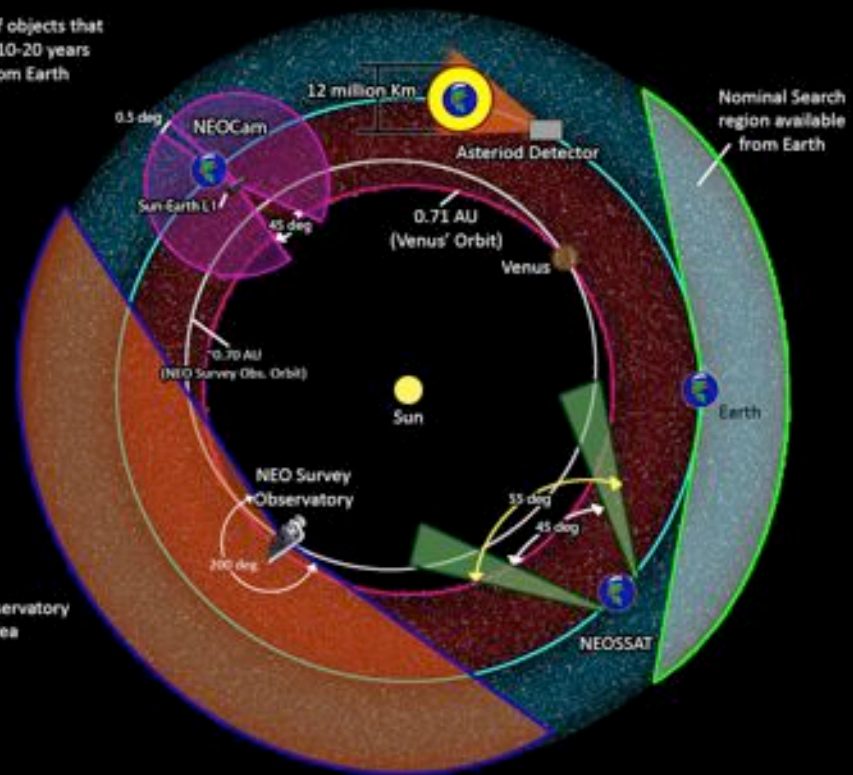
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Planetary Defense Asteroid Detection Investigation & Impact Mitigation

Thousands of objects that
could take 10-20 years
to see from Earth



Earth Science Observations

Super Resolution



Mosaic



Simultaneous Multi-point

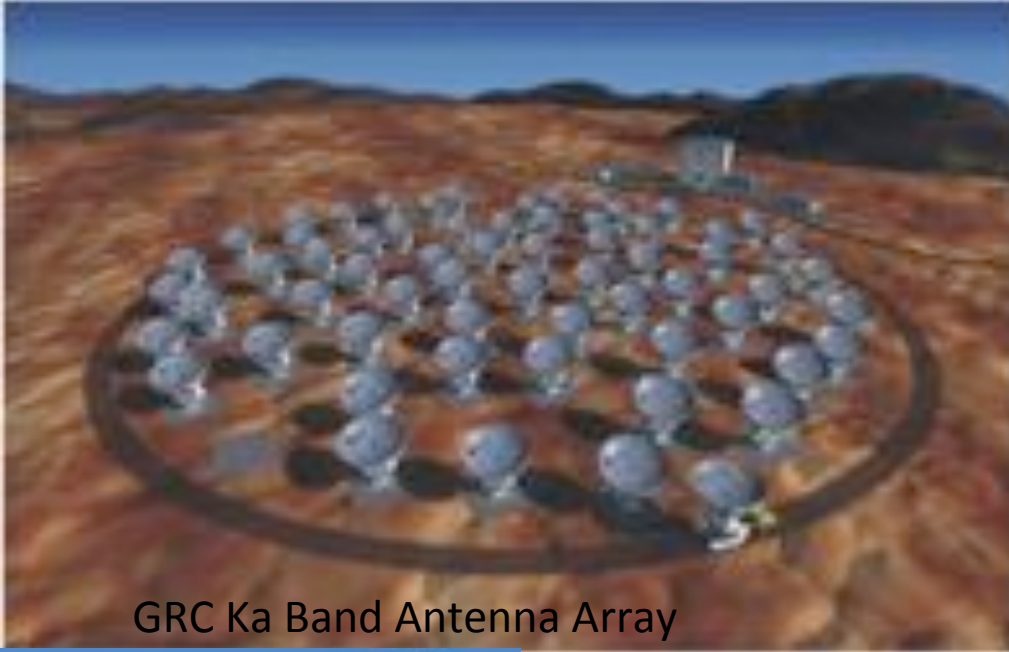


Multi-task





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GRC Ka Band Antenna Array



DSN Goldstone 70m



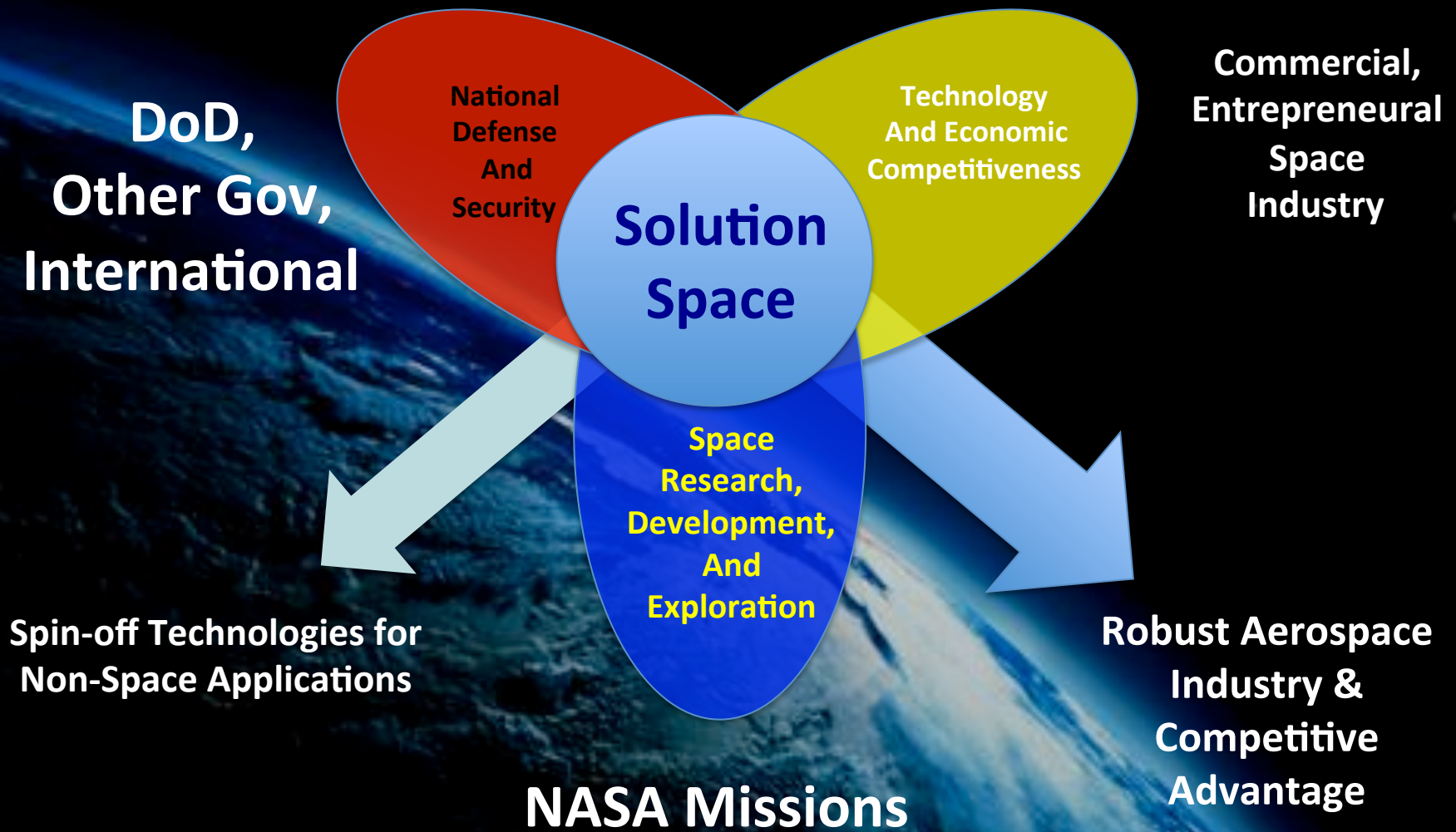
Morehead State 20m

Enhanced Communication and Tracking
Stations to support Multiple missions.



Technology and Innovation Strategy

... Addressing Global Needs





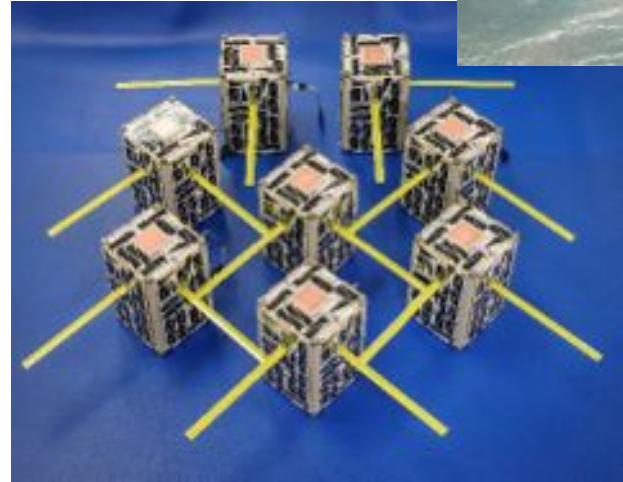
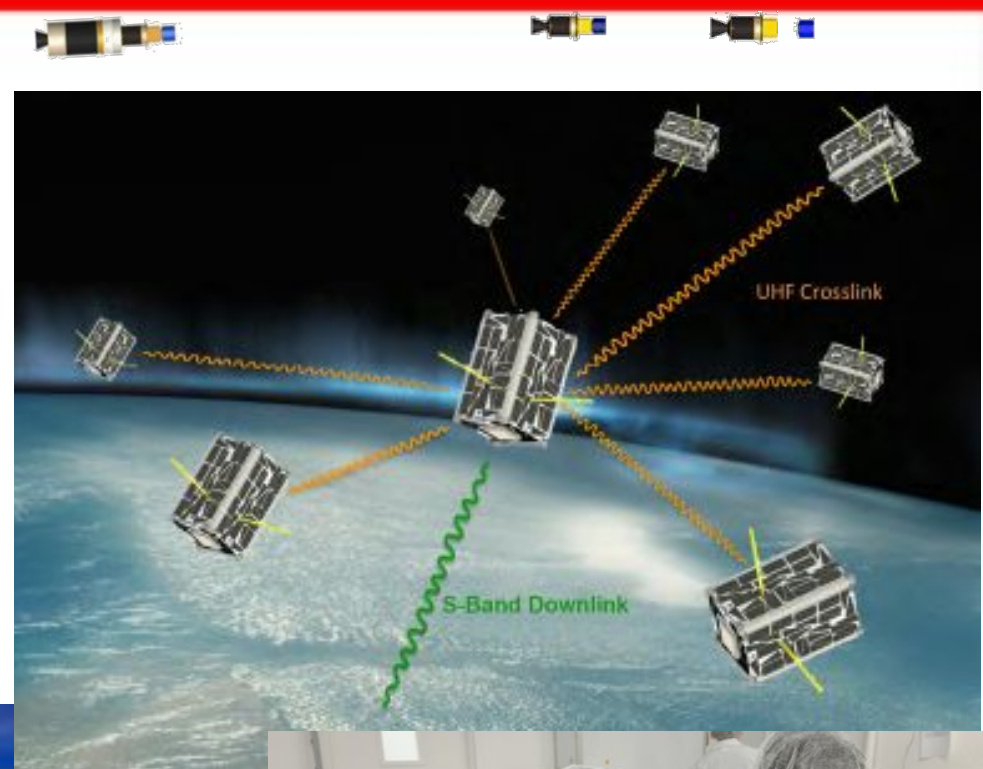
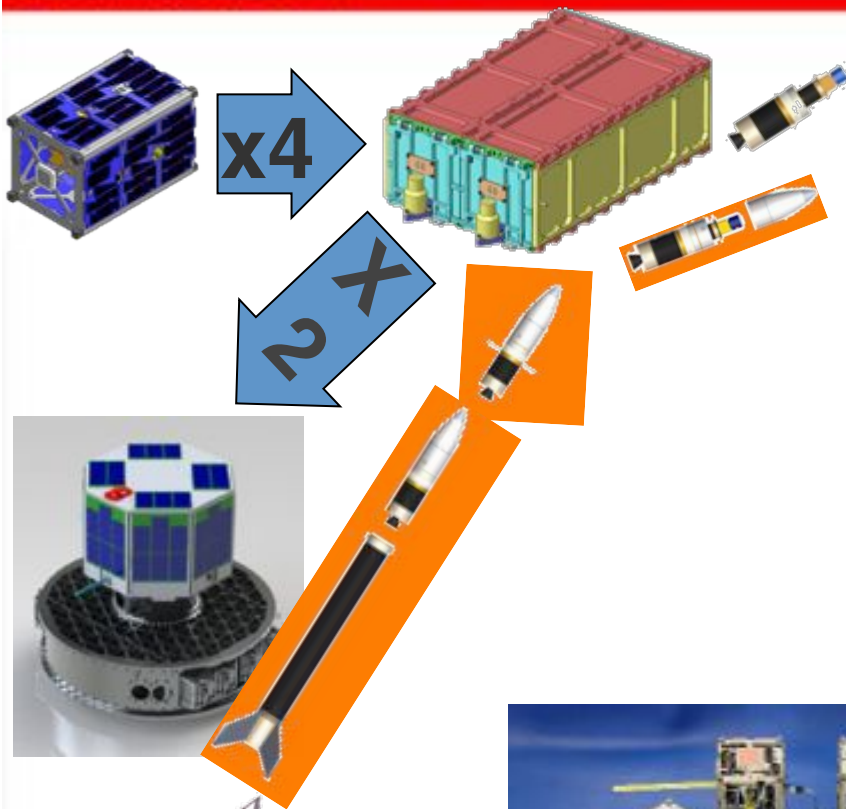
<http://www.nasa.gov/smallsats>

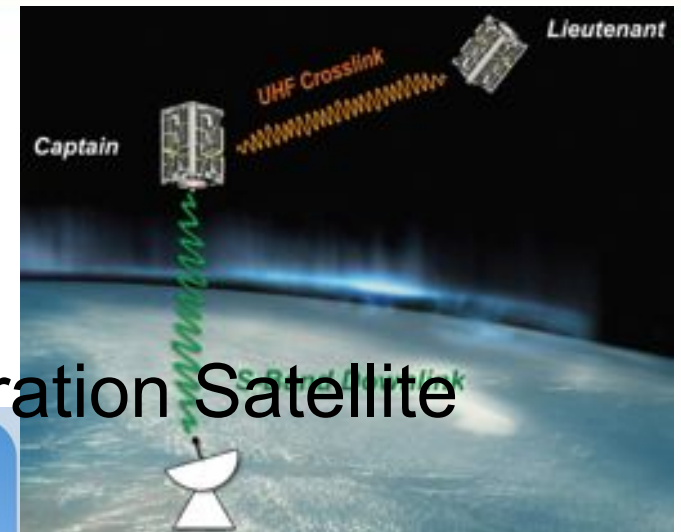
[http:// www.nasa.gov/spheres](http://www.nasa.gov/spheres)

<http://www.nasa.gov/sporesat>

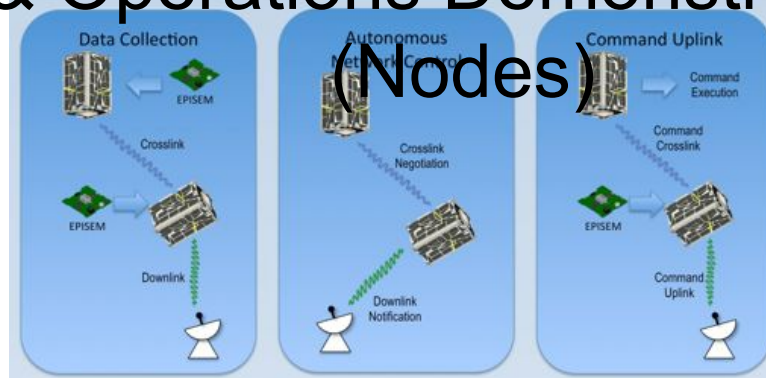
Andres.Martinez@nasa.gov

Edison Demon

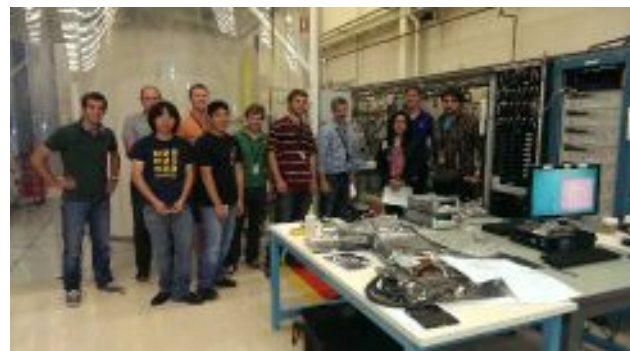




Network & Operations Demonstration Satellite (Nodes)



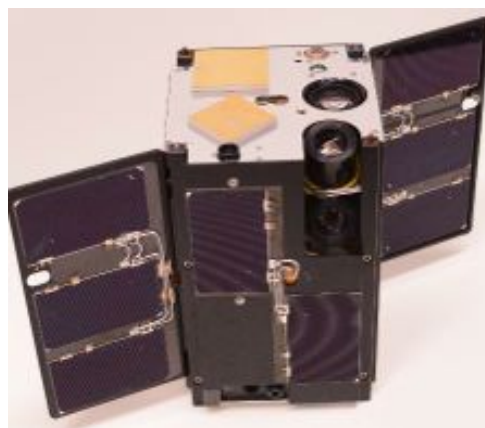
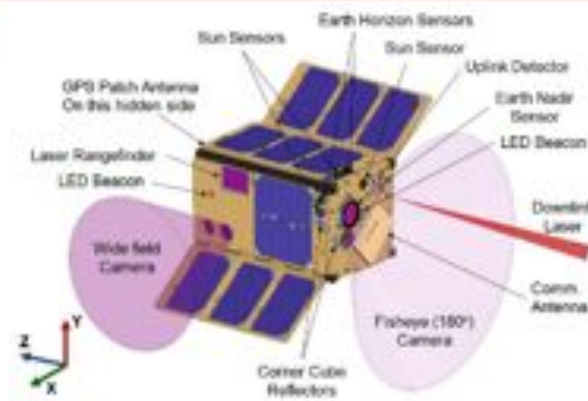
ISS CRS - Orbital 4



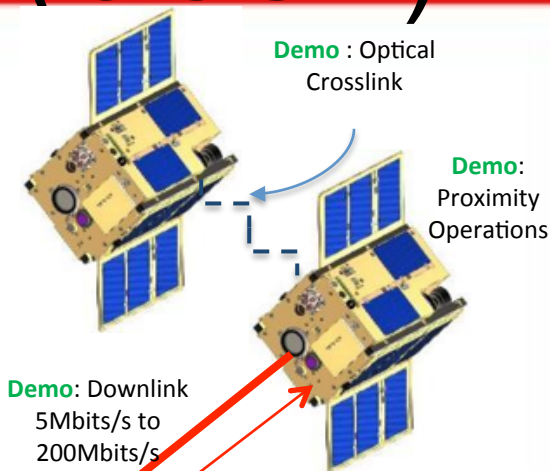
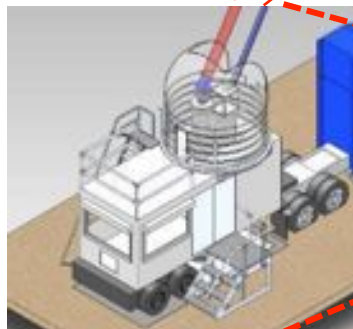
Optical Communications Sensor Demonstration (OCSD)



Falcon 9 – FormoSat-5 (NET DEC 2015)



Flight Unit #1

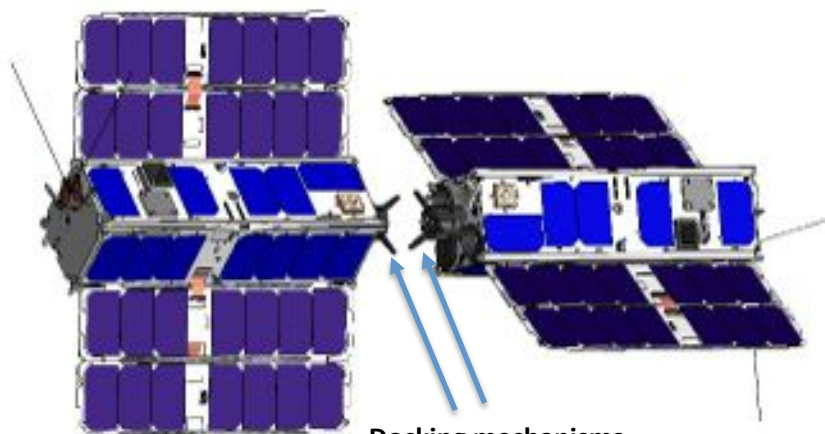


OCSD – 2 (1.5U)
(NRO-L55 - AUG 2015)

Demo: Uplink
10Kbits



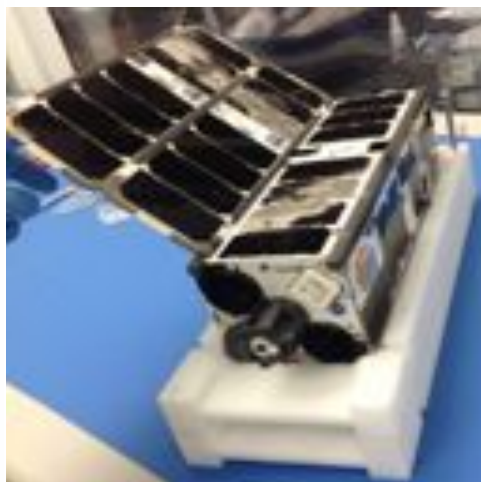
Cubesat Proximity Operations Demonstration



Docking mechanisms

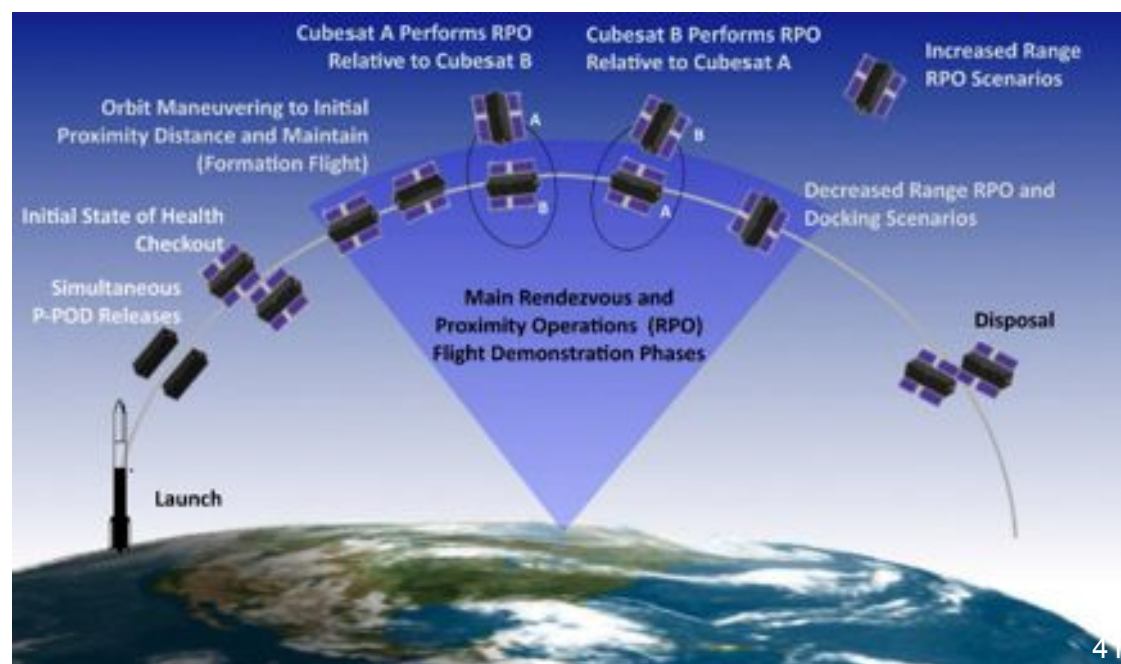


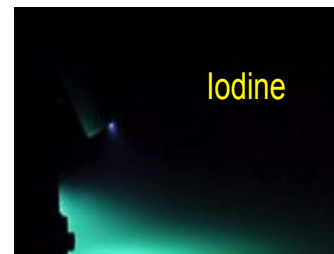
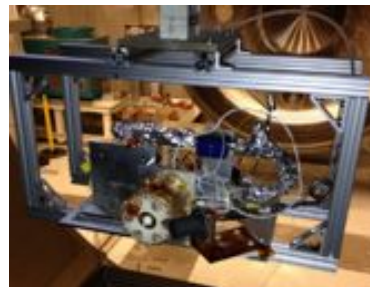
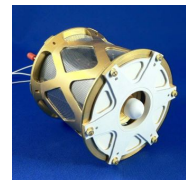
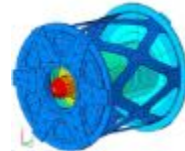
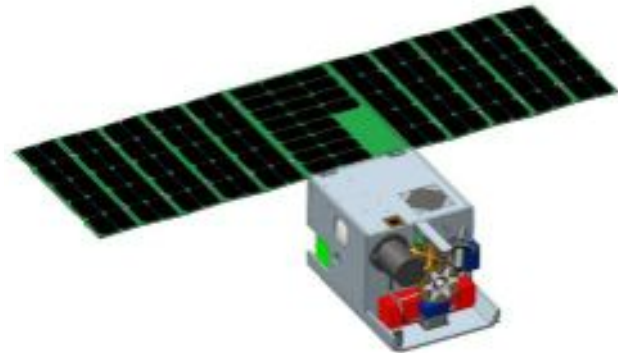
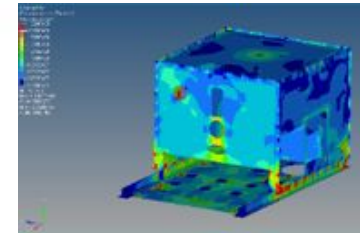
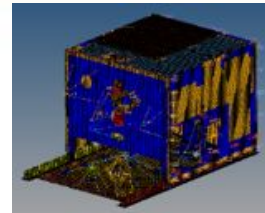
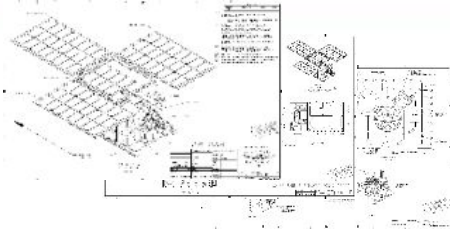
EDU Integration



Rendezvous, Proximity Operations and Docking (RPOD) Module

EDU Integration





Propulsion Pathfinder



Spacecraft Specifications

- Mass: 10-12kg
- Quantity: One 6U CubeSat (multiple demonstrations)
- Orbit: 350-800 km, 98° or 51° incl.
- Size: 50 x 9.1 x 13.5 (*inches*)
- Communication: S-Band

Mission Description

The Propulsion Pathfinder Project objective is to perform multiple Earth orbit flight missions with Cubesat-scale spacecraft to demonstrate the operation of, and characterize the performance of, a variety of propulsion technologies suitable for small spacecraft mission applications including precise pointing, proximity operations, targeted deorbit, and small and large orbital maneuvers. The propulsion technologies to be demonstrated include but are not limited to at least one version of miniaturized electrospray propulsion and an RF Ion propulsion system.

LCCE - \$30,102K

Status

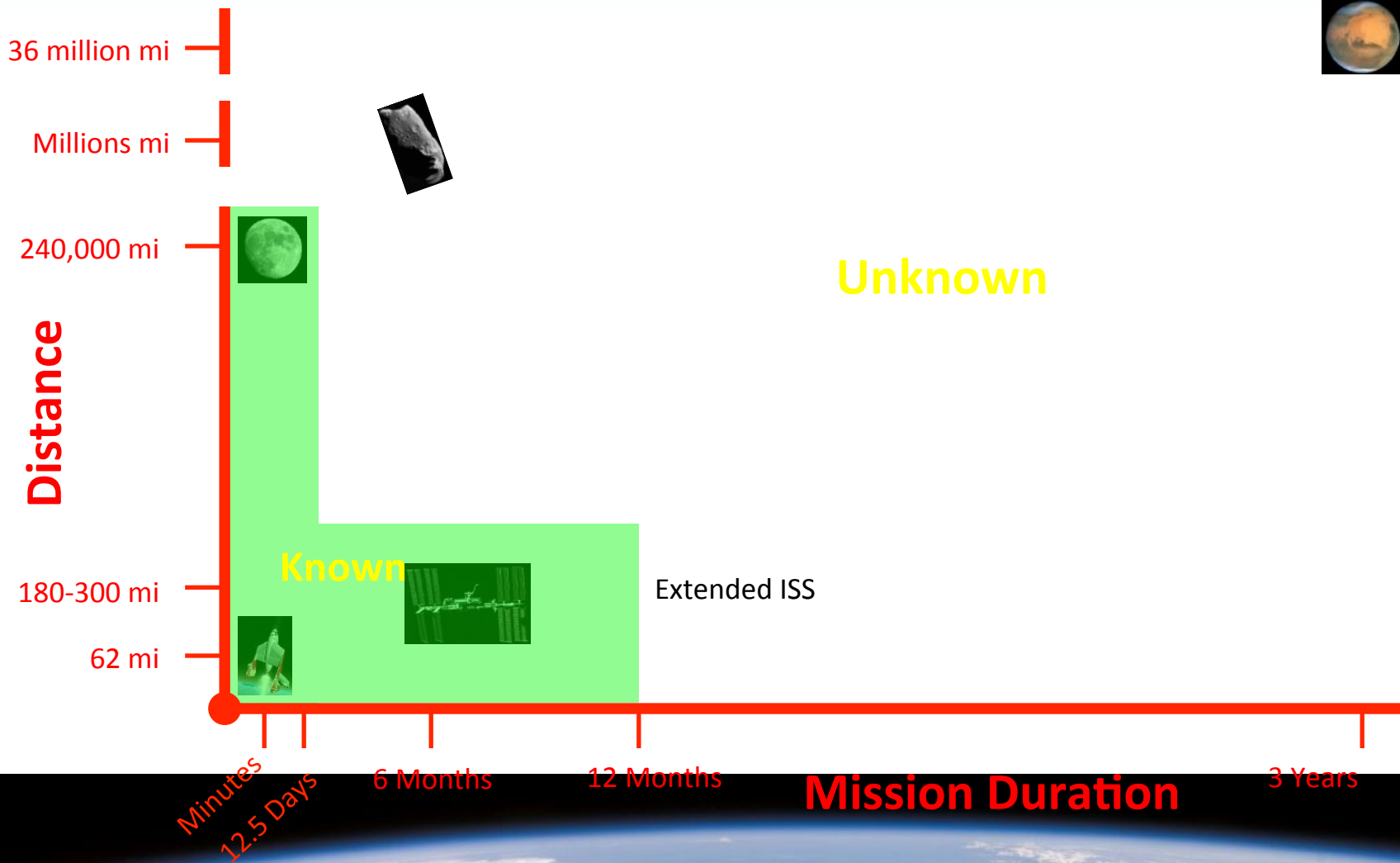
The project was recently kicked off and is working towards MCR. Level 1 requirements are signed and Level 2 requirements are underway. System trades are being conducted and programmatics (cost estimates, schedule, and risk) are being defined. Procurement strategies are being defined for the candidate propulsion systems.

Critical Milestones

ATP	MCR	SRR/PDR	CDR	FHR	FRR/ORR	Launch	Mission Ops	Mission Duration	Project Closure
1/14/15									

Why Study Space Biology?

The limit of life in space, as we know it, is 12.5 days on a lunar round trip and 1 year in LEO. As we send people further into space, we have to use other





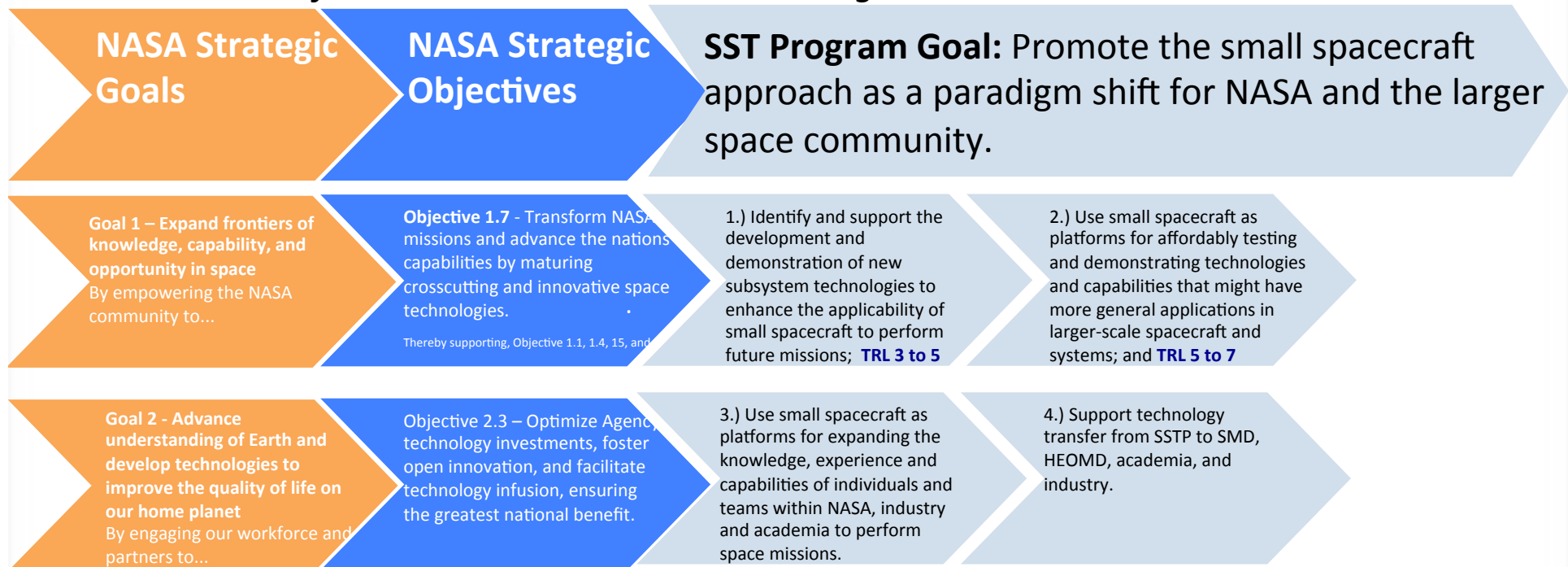
- Overview
 - vision and projections
 - Where NASA is, and where it is going re smallsats existing programs
 - Highlight Technologies Tech Needs
 - DRM examples
 - Win-Win is leveraging
 - What WE can do to go forward TOGETHER
 - to meet OUR mutual challenges
 - for NASA comes first

Program Relevance, Goals, Objectives, & Customers



Relevance: *Contributes to 2 of 3 NASA Strategic Goals*

Goals and Objectives: *as related to NASA Strategic Goals*



Customers: *Future NASA missions in NASA Mission Directorates, other USA government agencies, academia, the aerospace industry.*



National Aeronautics and
Space Administration



Actual photo of
TechEdSat-1 deployed
from ISS, Oct 4 2012



- Deorbit Requirements
- DRM
 - Planetary Defense
 - Asteroid Detection, Characterization and Impact Mitigation
 - Sample Return
 - NEA Observation
- Improved Deep Space Networks for communications and GNC