

A photograph taken from space showing three small, dark, rectangular spacecraft orbiting Earth. The Earth's surface is visible at the bottom, showing a blue horizon and white clouds. The background is a deep blue sky with wispy white clouds.

Space Technology Mission Directorate

***Small Spacecraft
Technology***

Andrew Petro

**Briefing to the NASA Advisory Committee
April 15, 2014**



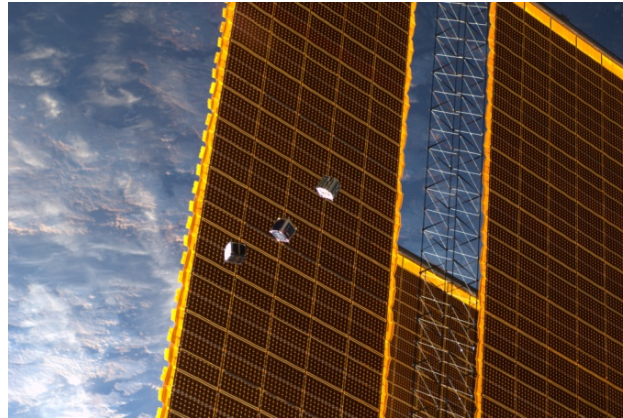
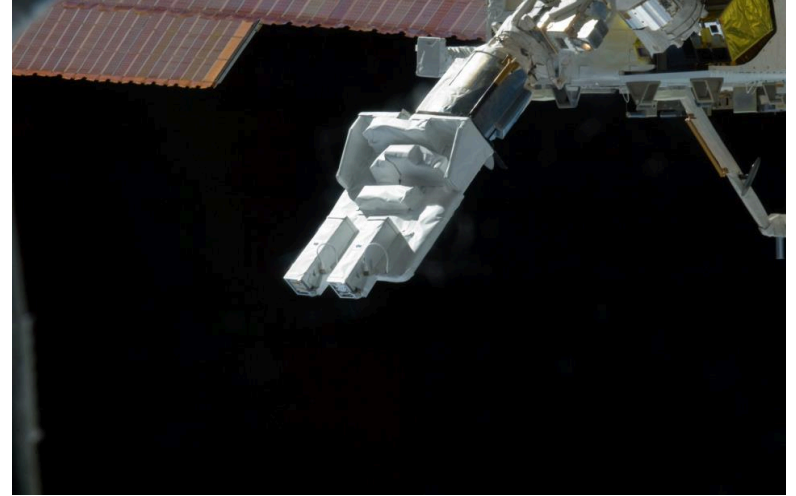
In the beginning all spacecraft were small...

but this is about more than miniaturization

- **Standardized interfaces for rideshare launches (i.e. ESPA rings)**
- **Standard form (i.e. cubesats)**
- **Containerization (i.e. P-PODS)**
- **“Build and test” versus extensive analysis of design**
- **Greater use of off-the-shelf components**
- **Lower cost**
- **Rapid development**
- **Higher risk tolerance**
- **Lower barrier-to-entry for space missions (university and small business researchers, etc.)**
- **Possibility for unique applications**



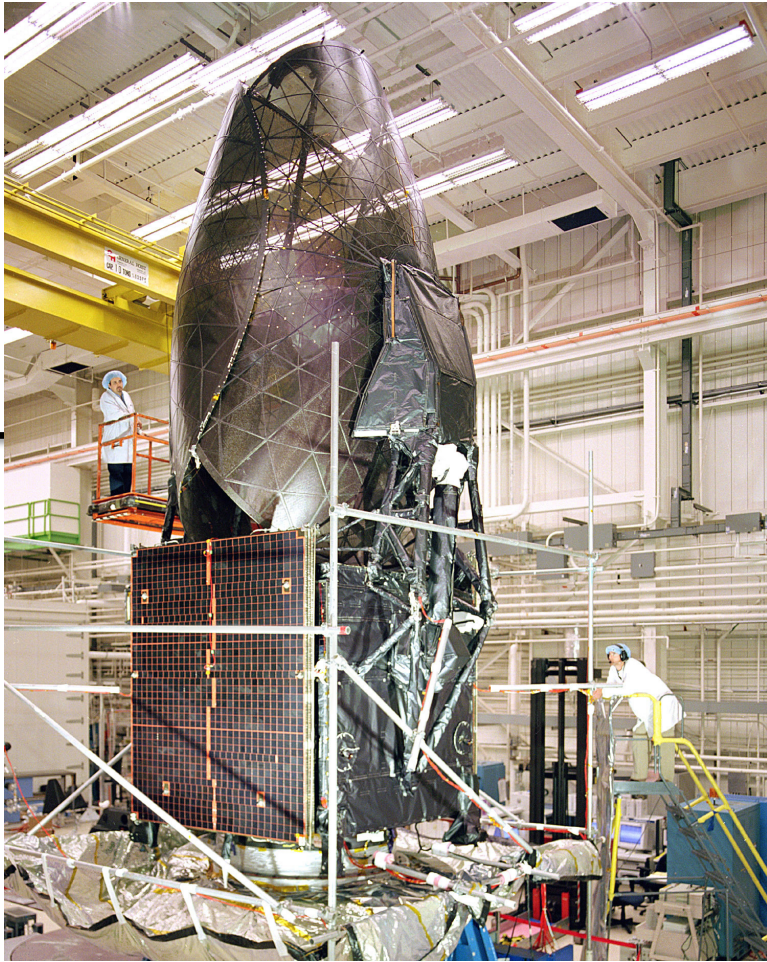
Rideshares



and ISS Deployments

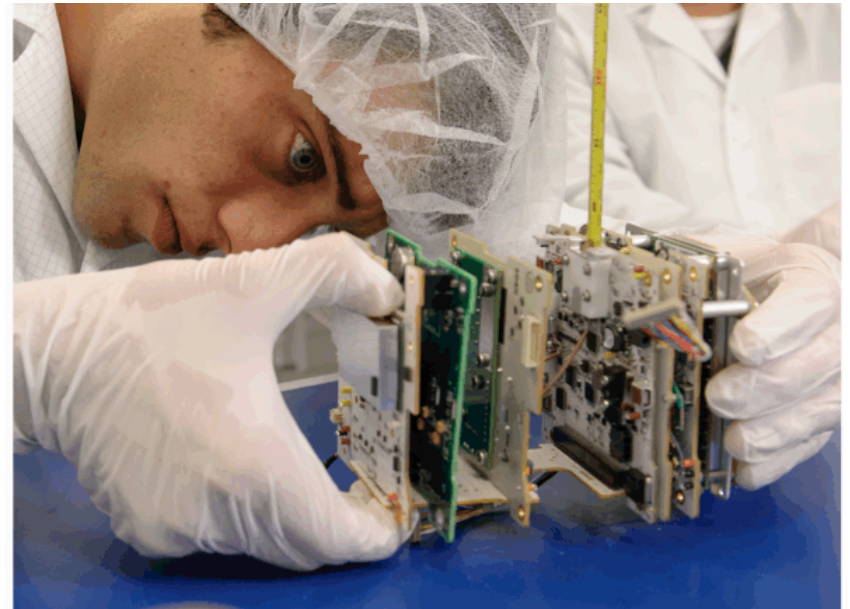
Cubesats & P-PODS





TDRSS

Spacecraft development on a Human Scale



EDSN

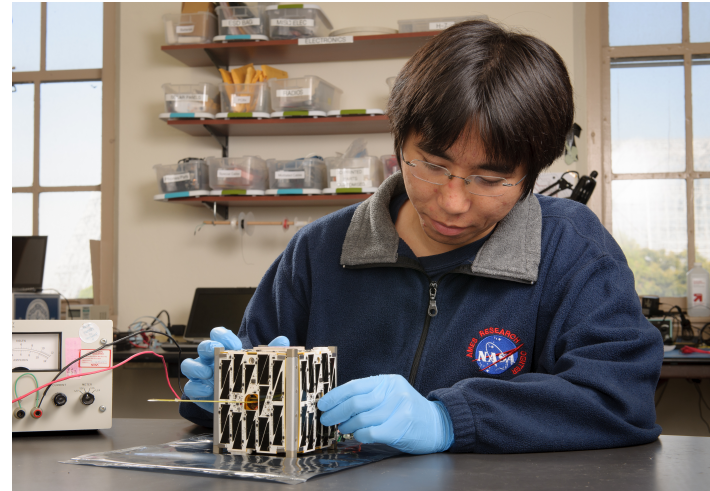
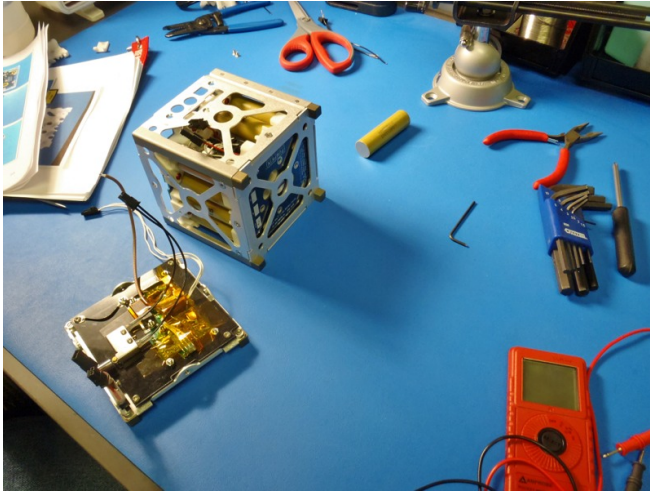
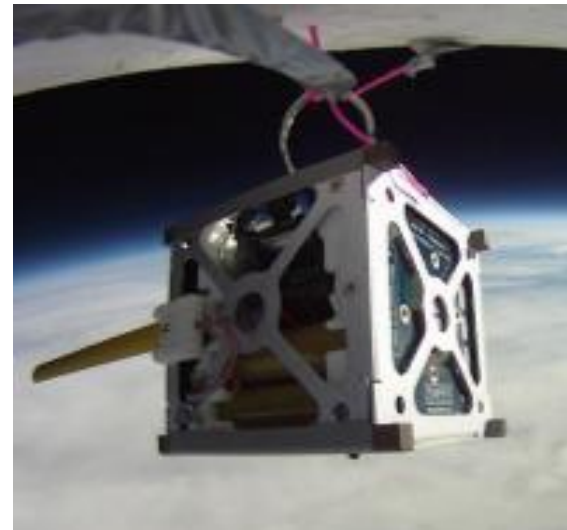


Table top assembly and testing



Zero-g tests



Balloon tests

Small Spacecraft Technology Program

Small, Affordable, Rapid, & Transformative Development and Demonstration



Combines previous Franklin and Edison Programs
Program Executive: Andrew Petro (HQ)
Level 2 Program Office at Ames Research Center
Program Manager: Bruce Yost

Objectives:

- Identify and develop new subsystem technologies to enhance or expand the capabilities of small spacecraft. **TRL 3 to 5**
- Demonstrate new technologies, capabilities, and applications for small spacecraft. **TRL 5 to 7**
- Use small spacecraft as low-cost platforms for testing technologies and capabilities with applications for spacecraft and systems of any size.
- Promote the small spacecraft approach as a paradigm shift for NASA and the larger space community.

Small Spacecraft Technology Program

Small, Affordable, Rapid, & Transformative Development and Demonstration

Focused Technology Development Projects in:

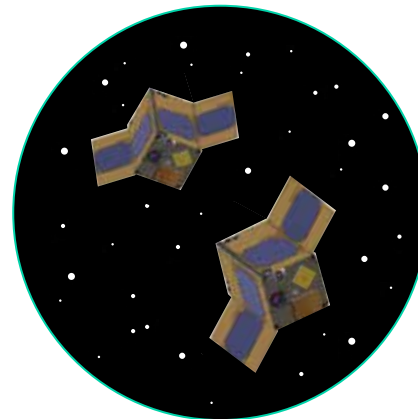
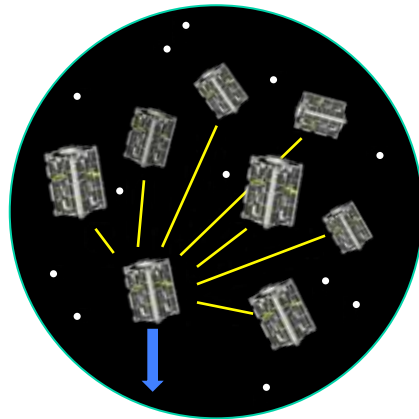
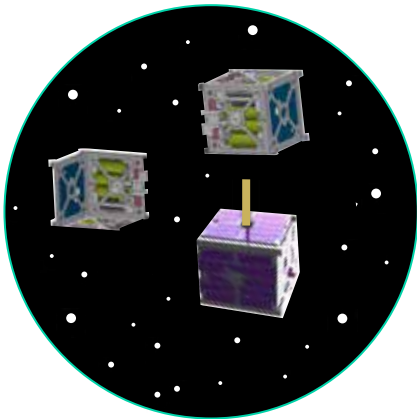
- Communications
- Avionics
- Propulsion
- Power
- Instruments
- Manufacturing
- Small Earth Return Vehicle

Flight Demonstration Projects in:

- Radio and Laser Communications
- Formation Flight and Docking
- Low cost satellite buses
- Smallsat swarms for space science missions

Implemented through:

- Directed NASA projects
- Contracts with private industry
- University-NASA partnerships
- Collaboration with SBIR and other programs



Program Highlights

Strategic Analysis

State of the Art: Small Spacecraft Technology

Focused Technology Development

- Smallsat Technology Partnerships – 2013 Cooperative Agreement Notice
- Technology Development Projects – 2013 NRA with Flight Opportunities and Game Changing Development Programs
- Collaboration with Game Changing Development on Miniature Electro spray Propulsion
- SBIR Topic on Deep Space Cubesats

Flight Demonstrations

- Phonesat 1.0 and 2.0 β – Launched April 21, 2013
- Phonesat 2.4 launched November 19, 2013
- Phonesat 2.5 scheduled for April 14
- EDSN later in 2014
- Suborbital flight later in 2014
- 3 flight demonstrations in 2015

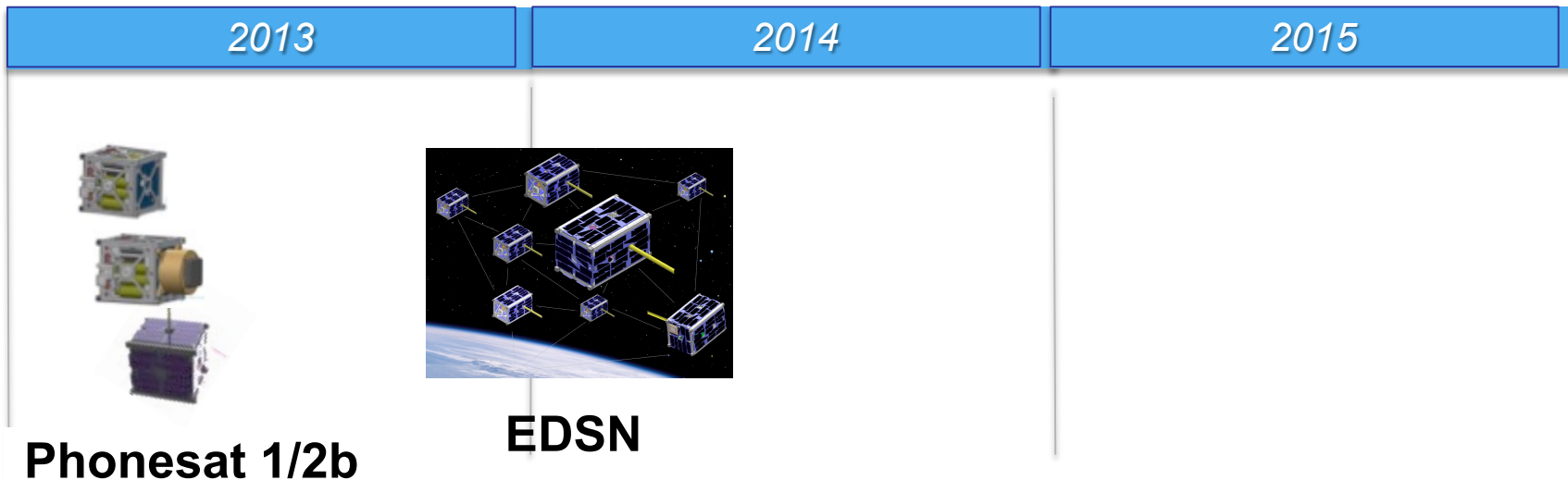
Leveraged Investments

- New SBIR Select Subtopic: Deep Space Cubesat Technology

Cross-agency Collaboration

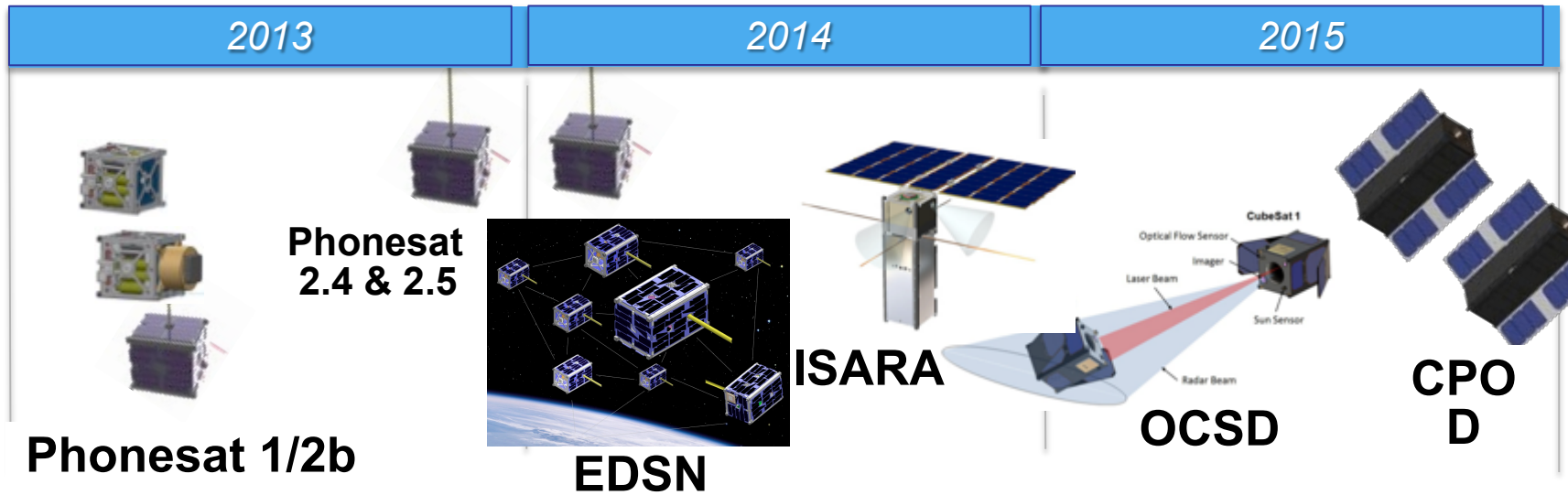
- Community of Practice
- Secondary Payloads for Asteroid Redirect Mission

SST PROJECTS - 2012



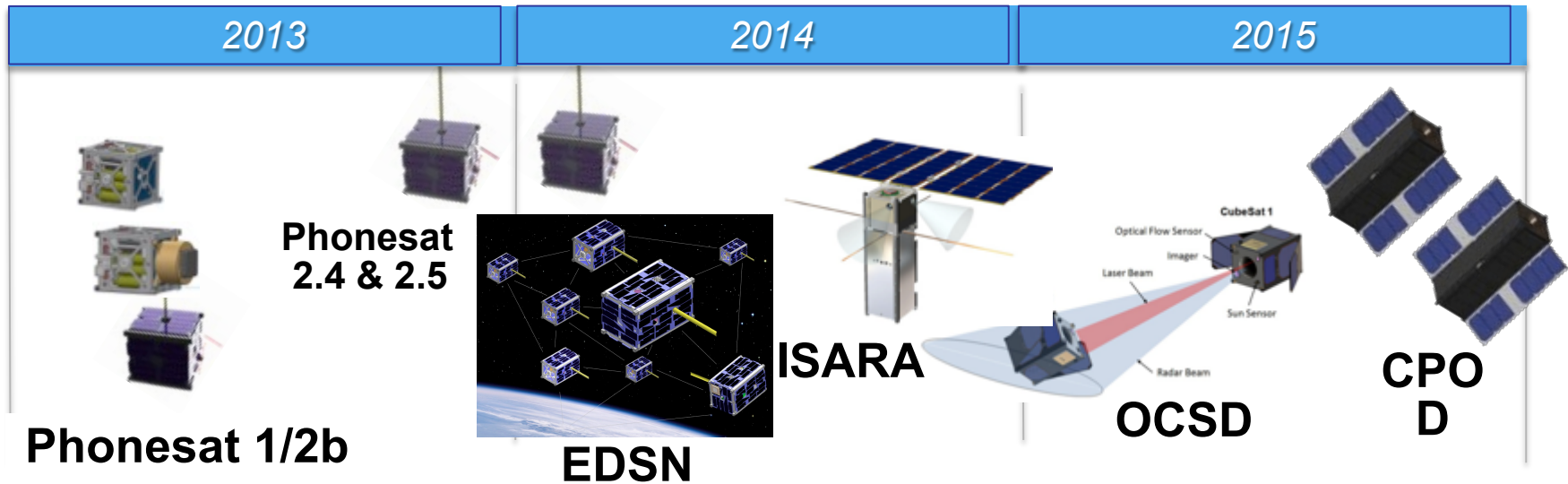
EDSN: Edison Demonstration of Smallsat Networks

SST PROJECTS - 2013



EDSN: Edison Demonstration of Smallsat Networks
ISARA: Integrated Solar Array and Reflectarray Antenna
OCSD: Optical Communications and Sensor Demonstration
CPOD: Cubesat Proximity Operations Demonstration

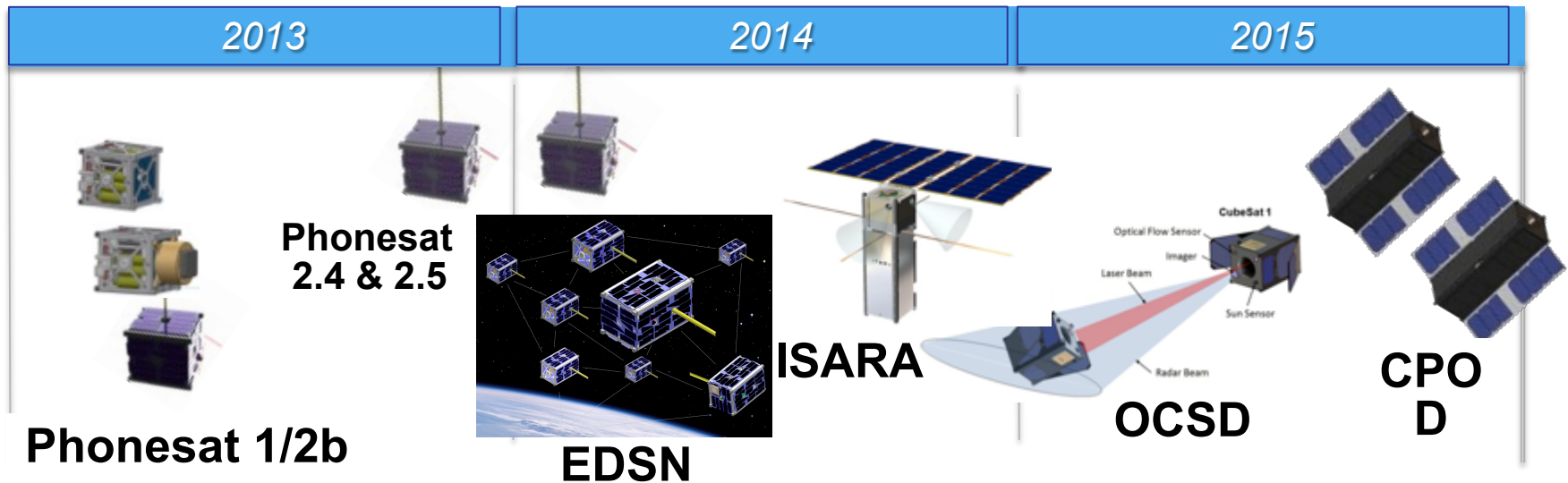
SST PROJECTS - 2014



**Smallsat Technology Partnerships
13 New Projects**

- EDSN:** Edison Demonstration of Smallsat Networks
- ISARA:** Integrated Solar Array and Reflectarray Antenna
- OCSD:** Optical Communications and Sensor Demonstration
- CPOD:** Cubesat Proximity Operations Demonstration

SST PROJECTS - 2014

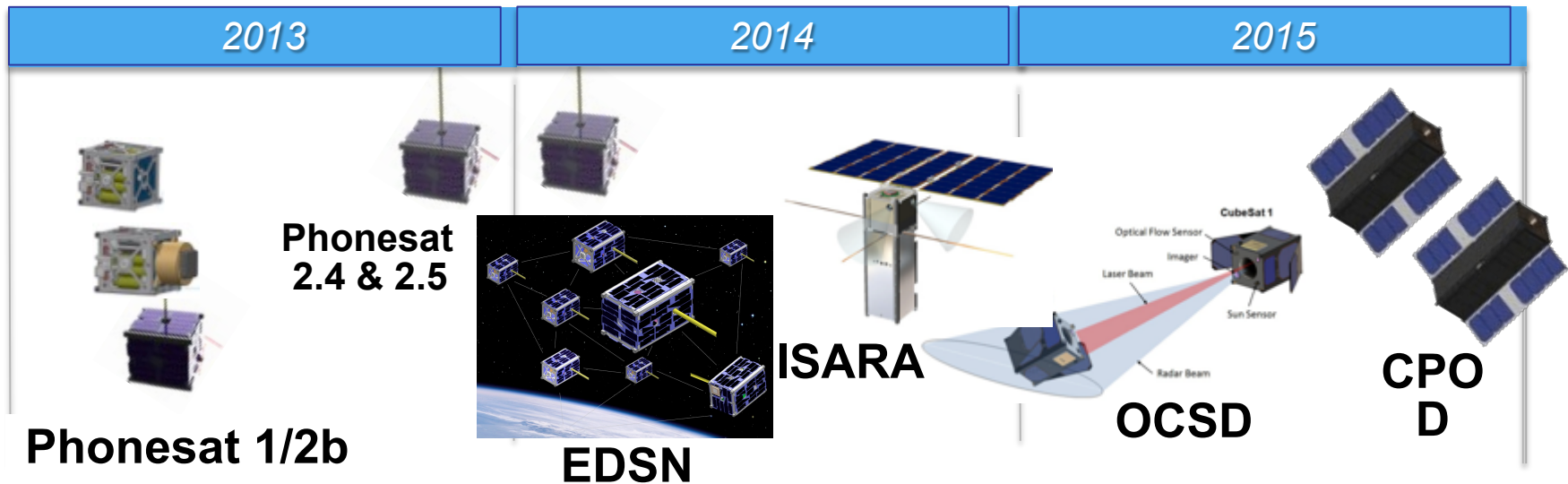


Smallsat Technology Partnerships
13 New Projects

Propulsion & Small Entry
Vehicle Projects

EDSN: Edison Demonstration of Smallsat Networks
ISARA: Integrated Solar Array and Reflectarray Antenna
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SST PROJECTS - 2014 AND BEYOND



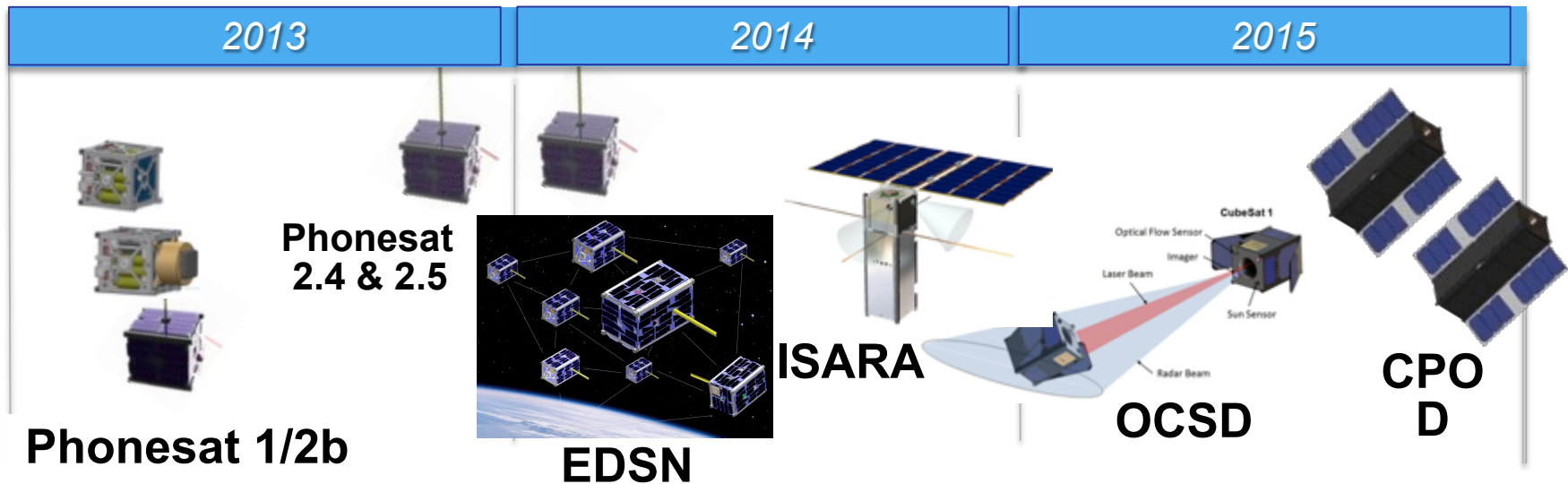
**Smallsat Technology Partnerships
13 New Projects**

**Propulsion & Small Entry
Vehicle Projects**

MEP Demo

EDSN: Edison Demonstration of Smallsat Networks
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SST PROJECTS - 2014 AND BEYOND



**Smallsat Technology Partnerships
13 New Projects**

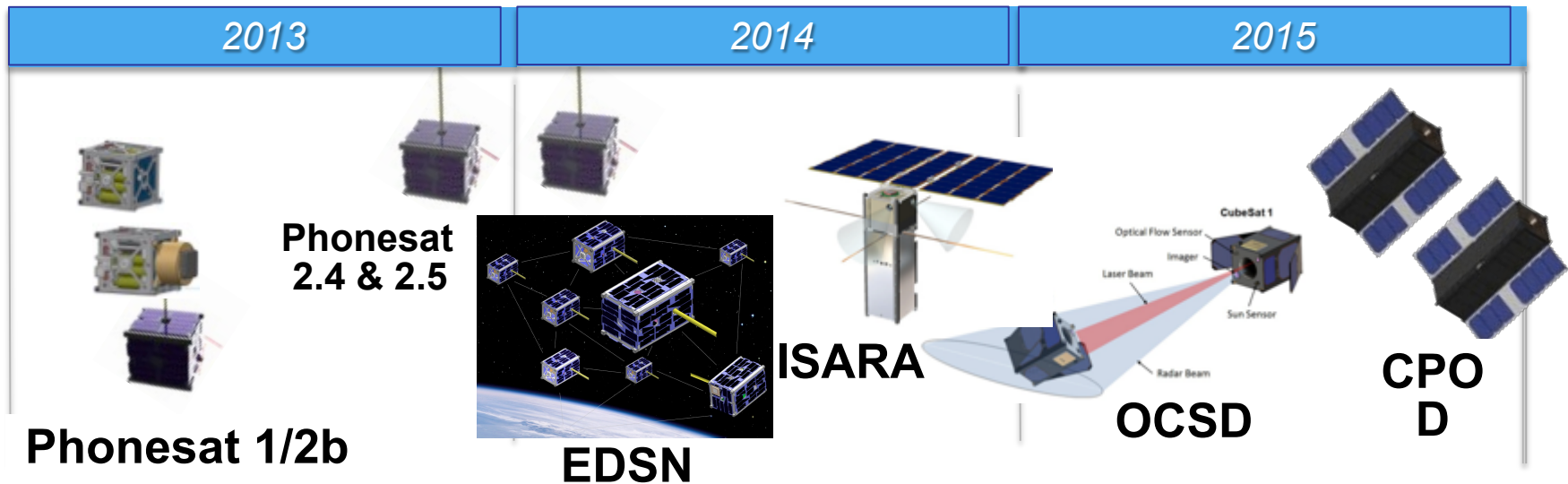
**Propulsion & Small Entry
Vehicle Projects**

MEP Demo

**Advanced Manufacturing
Demo**

EDSN: Edison Demonstration of Smallsat Networks
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SST PROJECTS - 2014 AND BEYOND



**Smallsat Technology Partnerships
13 New Projects**

**Propulsion & Small Entry
Vehicle Projects**

MEP Demo

**Advanced Manufacturing
Demo**

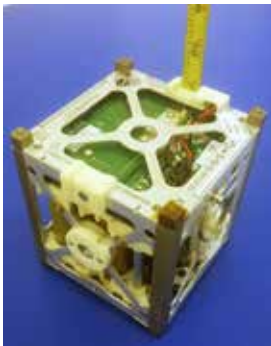
SBIR - Deep Space Cubesats

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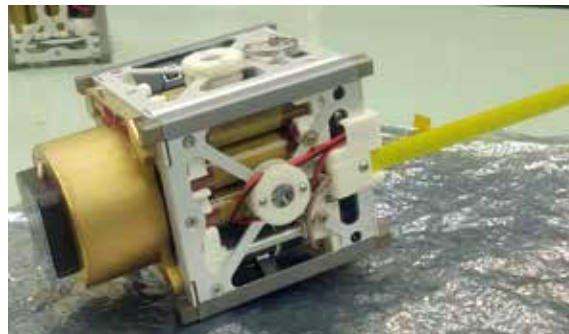
Phonesat



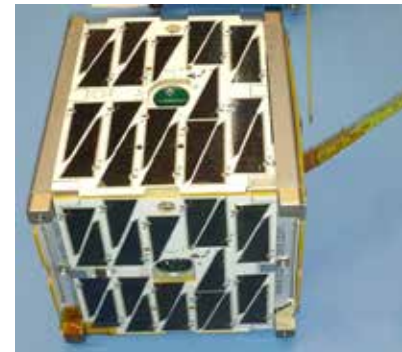
Phonesat Team – NASA Ames Research Center



“Graham” Phonesat 1.0



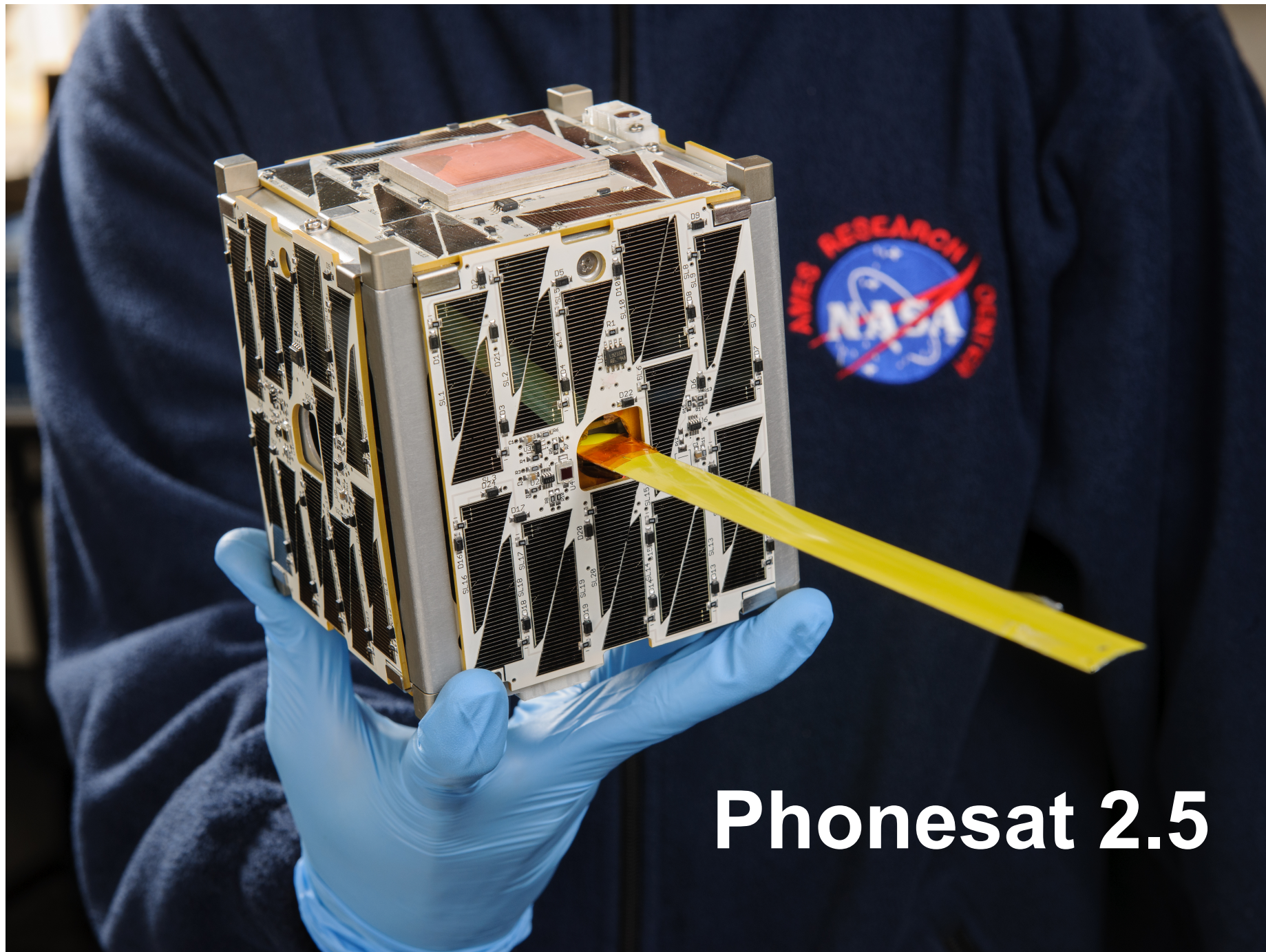
**“Bell” Phonesat 1.0 with
Iridium experiment**



**“Alexander”
Phonesat 2.0b**



Photo of Earth from Phonesat 1.0



Phonesat 2.5

EDSN

Edison Demonstration of Smallsat Networks

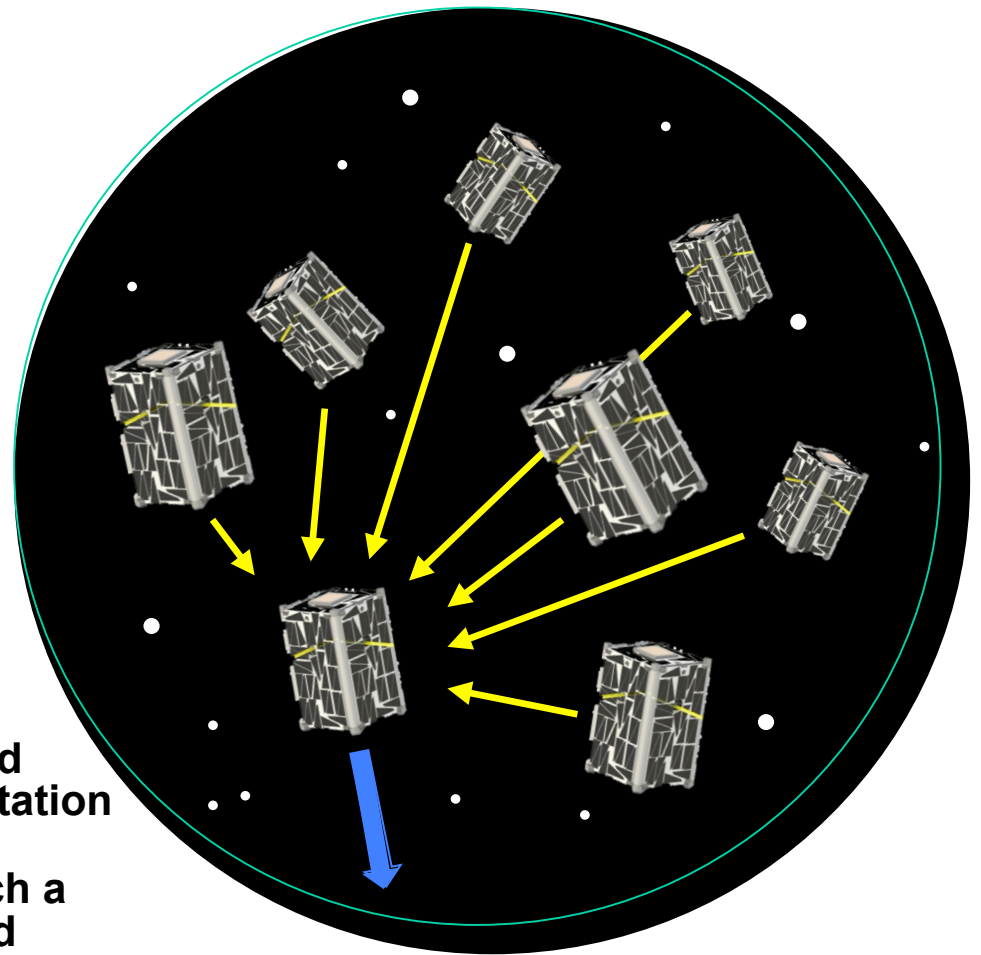
Ames Engineering Directorate,
with support from MSFC

Partners:

Montana State University – Payload
Santa Clara University – Ground Station

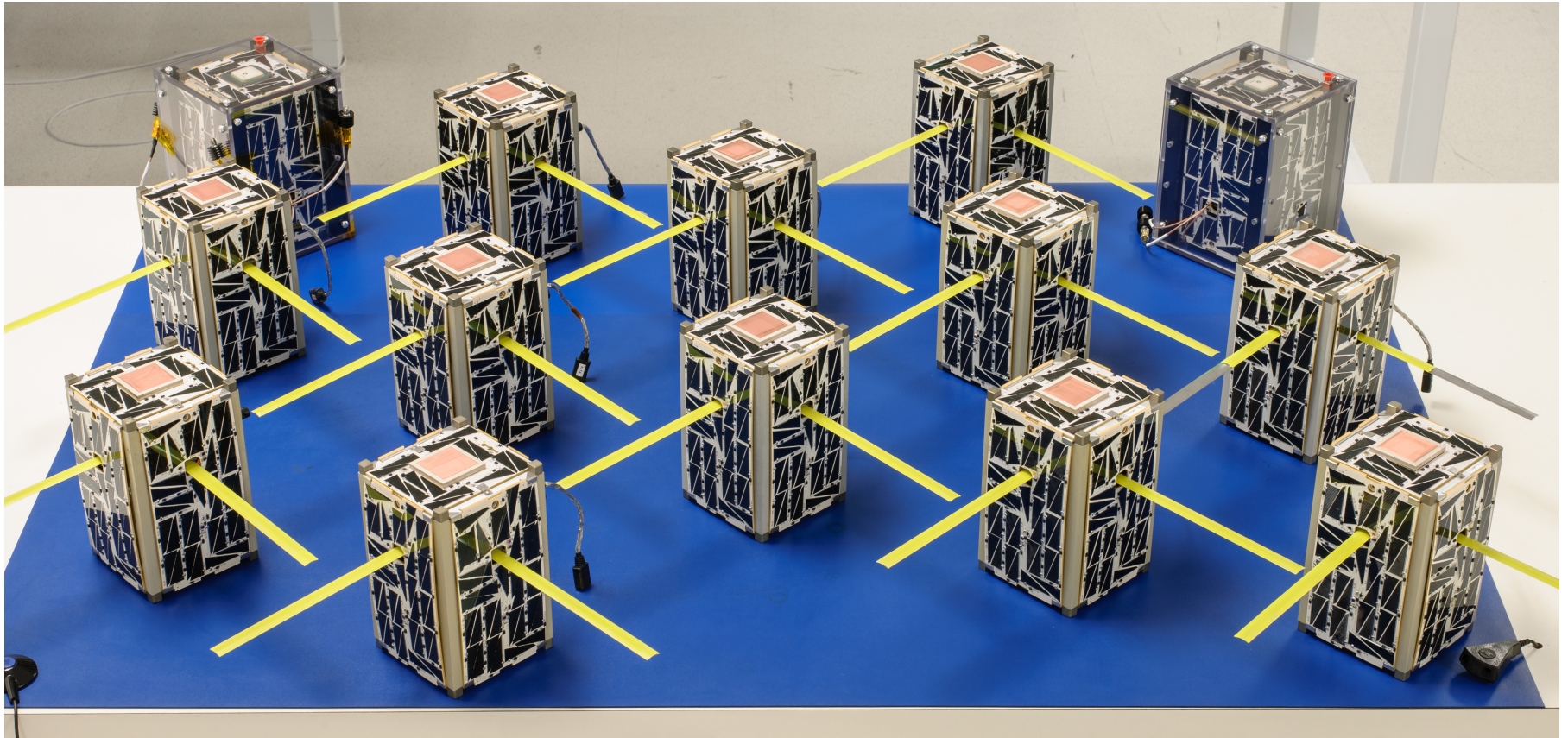
Objective: The EDSN Mission will launch a swarm of 8 low-cost small satellites and demonstrate the operation of an intra-swarm communication link and multi-point sensing measurement.

Satellite bus based on Phonesat heritage.



EDSN Spacecraft

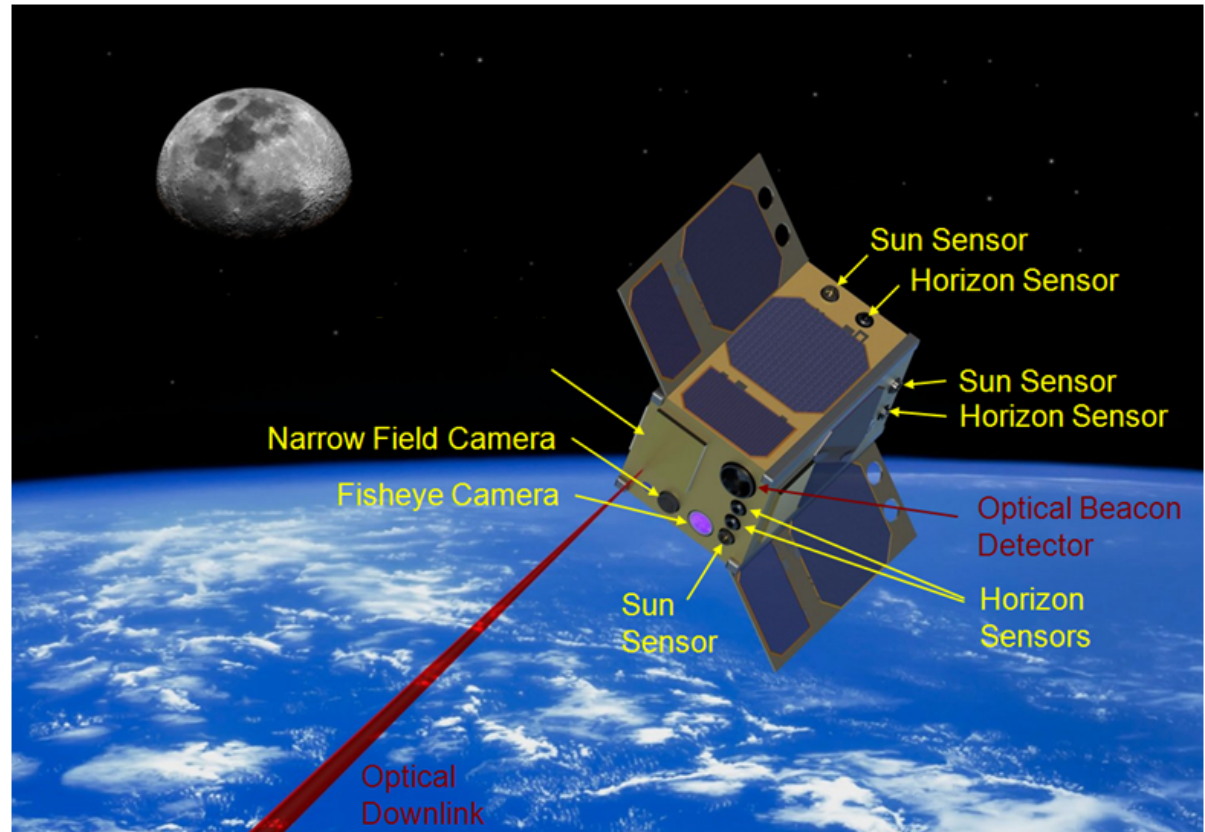
8 Flight Units, 2 Spares, 4 Engineering Development Units



OCS D Optical Communication and Sensor Demonstration

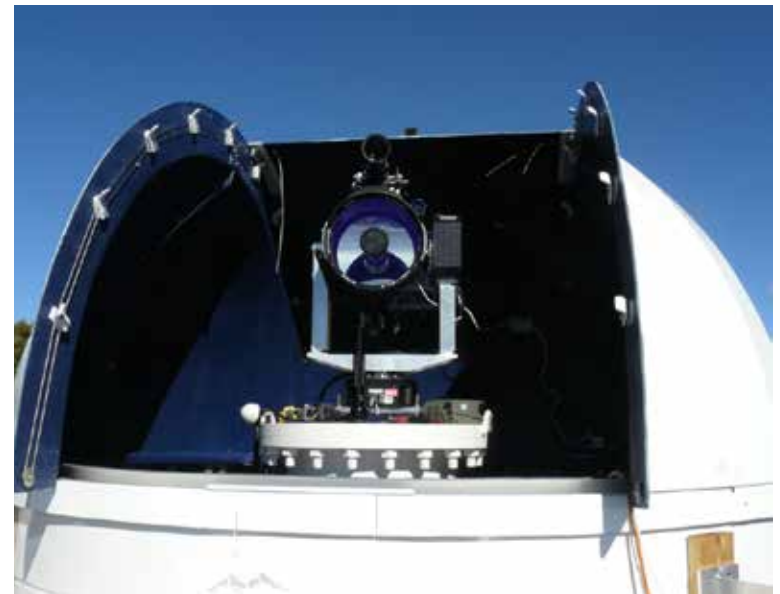
The Aerospace Corporation: Dr. Siegfried Janson, Dr. Richard Welle

Objective: Demonstrate ranging, optical downlink, cold gas propulsion, and cross-track motion sensing technologies on a cubesat proximity operations mission with two 1.5 U cubesats.



OCSD Optical Ground Station

MOCAM: Mt. Wilson Optical Communications and Atmospheric Measurements System



The optical ground station already exists and is used on other projects.

ISARA Integrated Solar Array and Reflect array Antenna

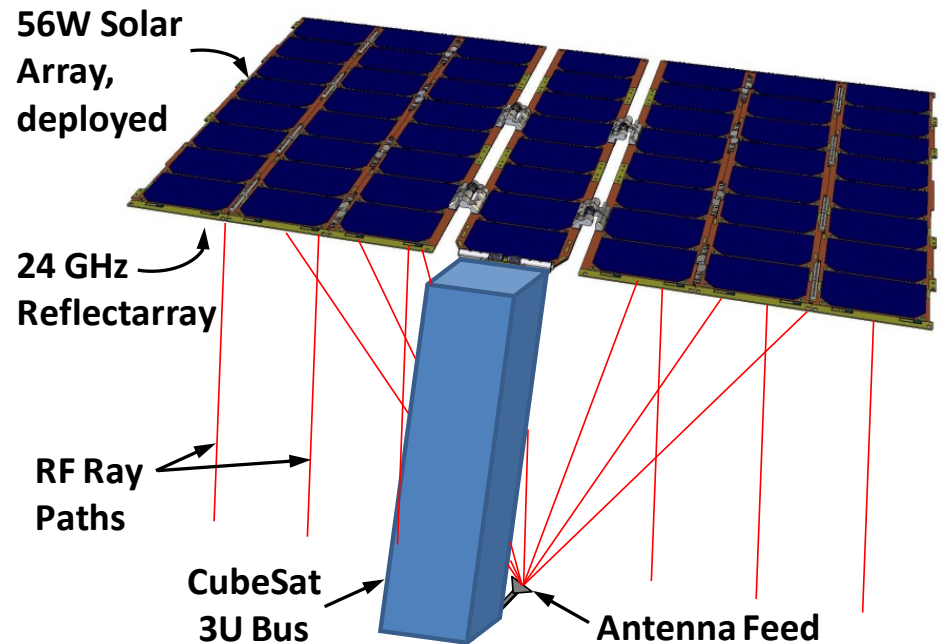
Jet Propulsion Laboratory

Partners:

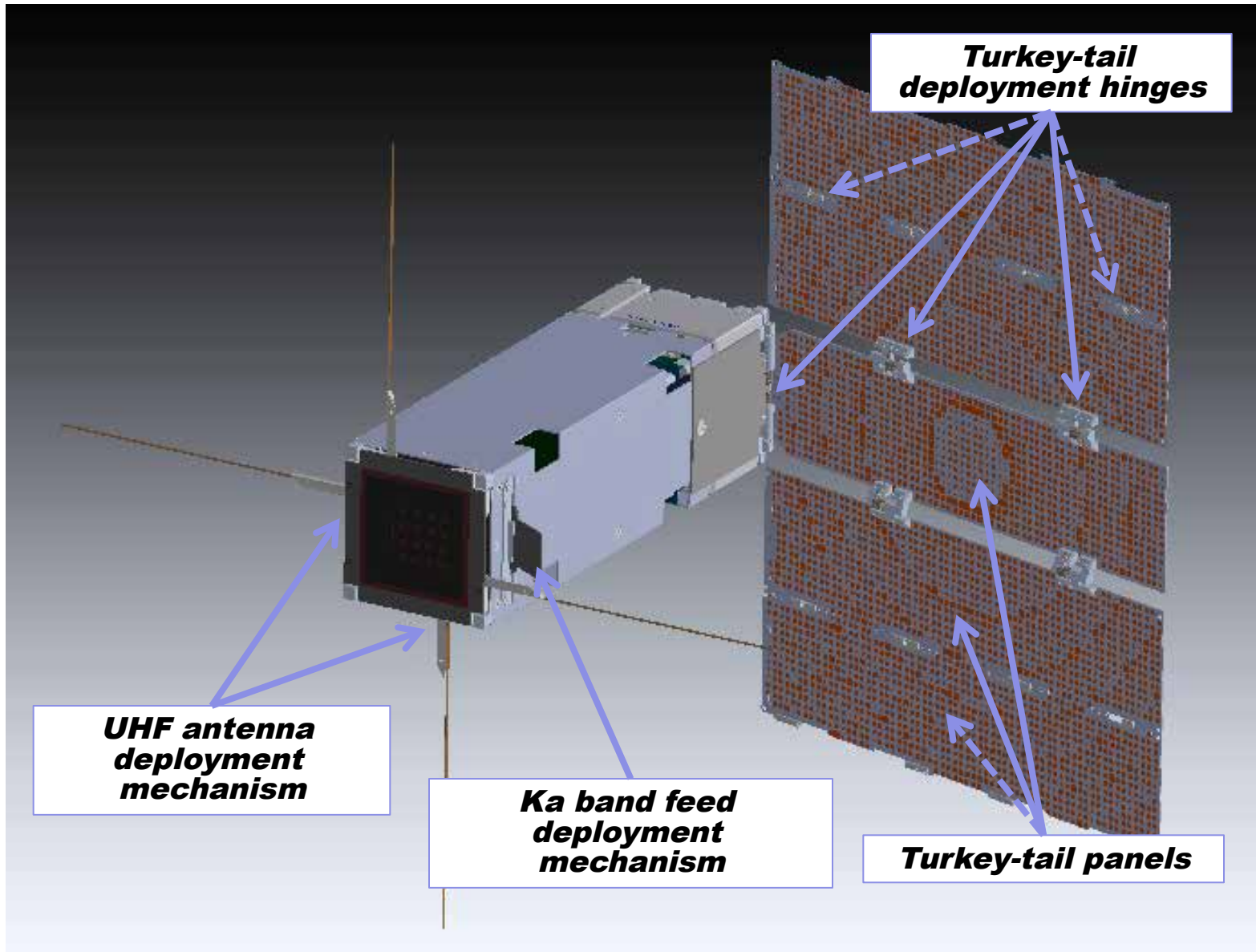
Aerospace Corporation - Cubesat bus and operations

Pumpkin, Inc. - Solar Panel

Objective: ISARA will demonstrate a high gain antenna (HGA) integrated into a commercially available solar array that enables 100 Mbps Ka-band cubesat communications capability at very low cost and minimal payload mass and volume impact.



ISARA Mechanical Design Overview



CPOD Cubesat Proximity Operations Demonstration

Tyvak Nano-Satellite Systems LLC

Partners:

406 Aerospace

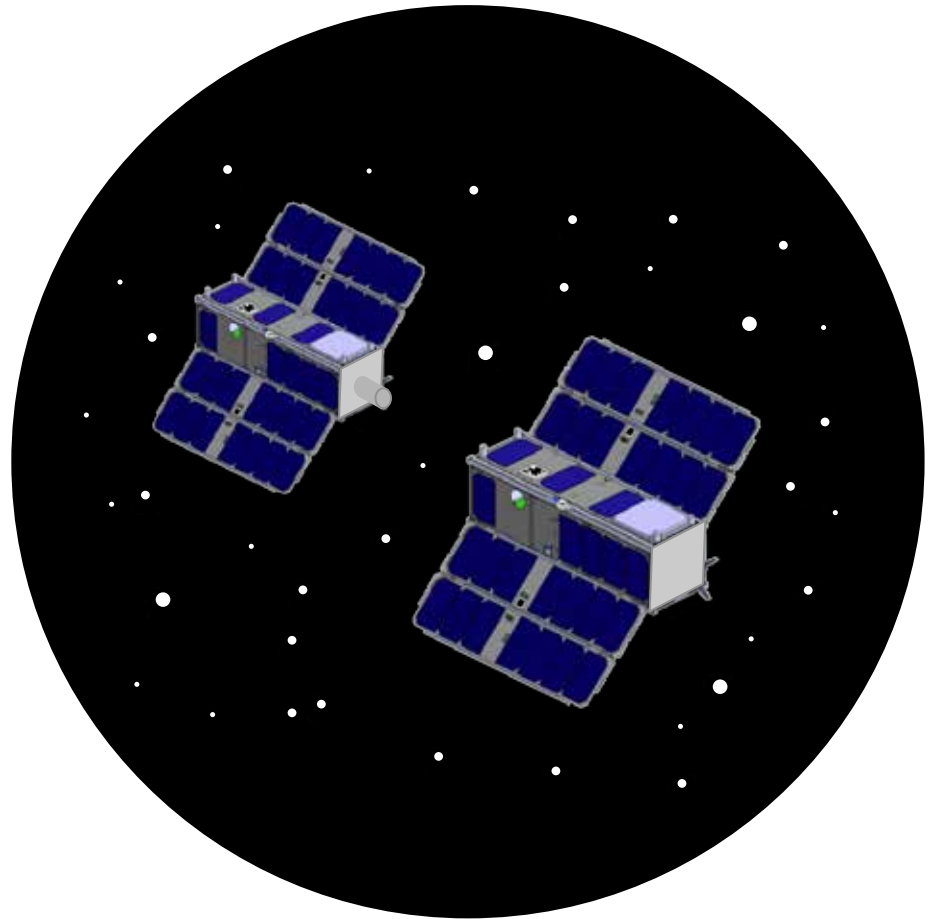
Applied Defense Solutions

Analytical Graphics Inc.

California Polytechnic State University

External Contribution: \$300K from AFRL

Objective: Demonstrate close proximity operations and docking of two 3U cubesat spacecraft in LEO.



Smallsat Technology Partnerships

Cooperative agreements with US colleges and universities to develop and/or demonstrate new technologies and capabilities for small spacecraft in collaboration with NASA.

One to two year projects

Up to \$100,000 per year, per university (up to \$150,000 if more than one university)

Up to 1.0 FTE in NASA labor per year, per project

13 Projects selected on August 8, 2013

17 universities

7 NASA Center partners



Smallsat Technology Partnerships 2013 Awards

COMMUNICATIONS

High Rate Cubesat X-band/S-band Communication System

PI: Scott Palo

University Of Colorado

NASA Partners: Goddard Space Flight Center, Marshall Space Flight Center

Space Optical Communications Using Laser Beam Amplification

PI: Govind Agrawal

University Of Rochester

NASA Partner: Ames Research Center

Development of Novel Integrated Antennas for Cubesats

PI: David Jackson

University Of Houston

NASA Partner: Johnson Space Center

Smallsat Technology Partnerships 2013 Awards

GUIDANCE, NAVIGATION & CONTROL

Smallsat Precision Navigation With Low-Cost MEMS IMU Swarms

PI: John Christian

West Virginia University

Partner: Marquette University

NASA Partner: Johnson Space Center

Cubesat Autonomous Rendezvous & Docking Software

PI: Glenn Lightsey

University Of Texas

NASA Partner: Johnson Space Center

Radiation Tolerant, FPGA-based Smallsat Computer System

PI: Brock LaMeres

Montana State University

NASA Partners: Goddard Space Flight Center, Marshall Space Flight Center

An Integrated Precision Attitude Determination and Control System

PI: Norman FitzCoy

University Of Florida

NASA Partner: Langley Research Center

Smallsat Technology Partnerships 2013 Awards

PROPULSION

Propulsion System and Orbit Maneuver Integration in Cubesats

PI: Jennifer Hudson

Western Michigan University

NASA Partner: Jet Propulsion Lab

Film-Evaporation MEMS Tunable Array for Picosat Propulsion and Thermal Control

PI: Alina Alexeenko

Purdue University

NASA Partner: Goddard Space Flight Center

POWER

Smallsat Low Mass, Extreme Low Temperature Energy Storage

PI: Sharlene Katz

California State University - Northridge

NASA Partner: Jet Propulsion Lab

Smallsat Technology Partnerships 2013 Awards

SCIENCE INSTRUMENT CAPABILITIES

Compressive Sensing for Advanced Imaging and Navigation

PI: Richard Kurwitz

Texas A&M University

NASA Partner: Langley Research Center

Mini Fourier-Transform Spectrometer for Cubesat-Based Remote Sensing

PI: John Allen

Appalachian State University

Partner: University of Maryland - Baltimore County

NASA Partner: Goddard Space Flight Center

ADVANCED MANUFACTURING

Printing the Complete Cubesat

PI: Craig Kief

University Of New Mexico

Partners: University of Texas - El Paso and Drake State Technical College

NASA Partner: Glenn Research Center

Technology Development Projects

2013 NRA Awards

SMALL SPACECRAFT PROPULSION

MPS-120 Cubesat High-impulse Adaptable Modular Propulsion System

PI: Christian Carpenter, Aerojet General Corporation, Redmond, WA

Advanced Hybrid Rocket Motor for Cubesats

PI: John DeSain, The Aerospace Corporation, El Segundo, CA

Partner: Pennsylvania State University, University Park, PA

1U Cubesat Green Propulsion System with Post-Launch Pressurization

PI: Michael Tsay, Busek Company. Inc., Natick, MA

Partner: NASA Goddard Space Flight Center

Iodine RF Ion Thruster Development

PI: Kurt Hohman, Busek Company. Inc., Natick, MA

Inductively Coupled Electromagnetic Thruster System Development for Small Spacecraft Propulsion

PI: John Slough, MSNW LLC, Redmond, WA

SMALL EARTH RETURN VEHICLES

Technology Development for the Maraia Earth Return Capsule

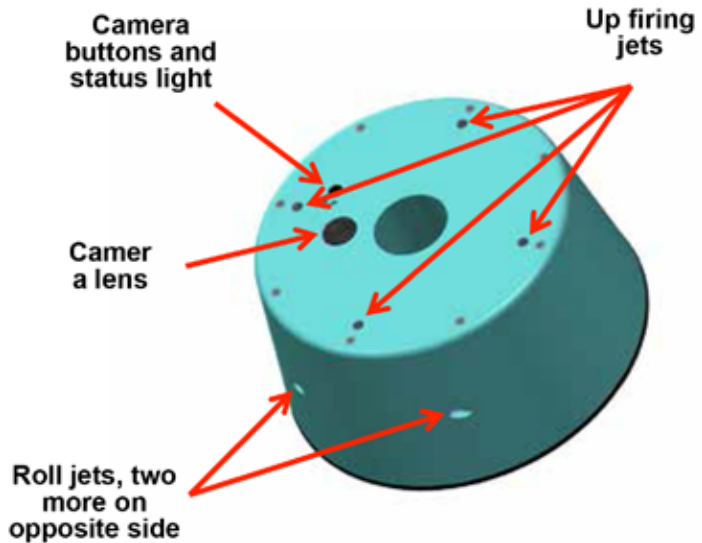
PI: Alan Strahan, NASA Johnson Space Center

Maraia - Small Earth Return Capsule Suborbital Flight Demonstration

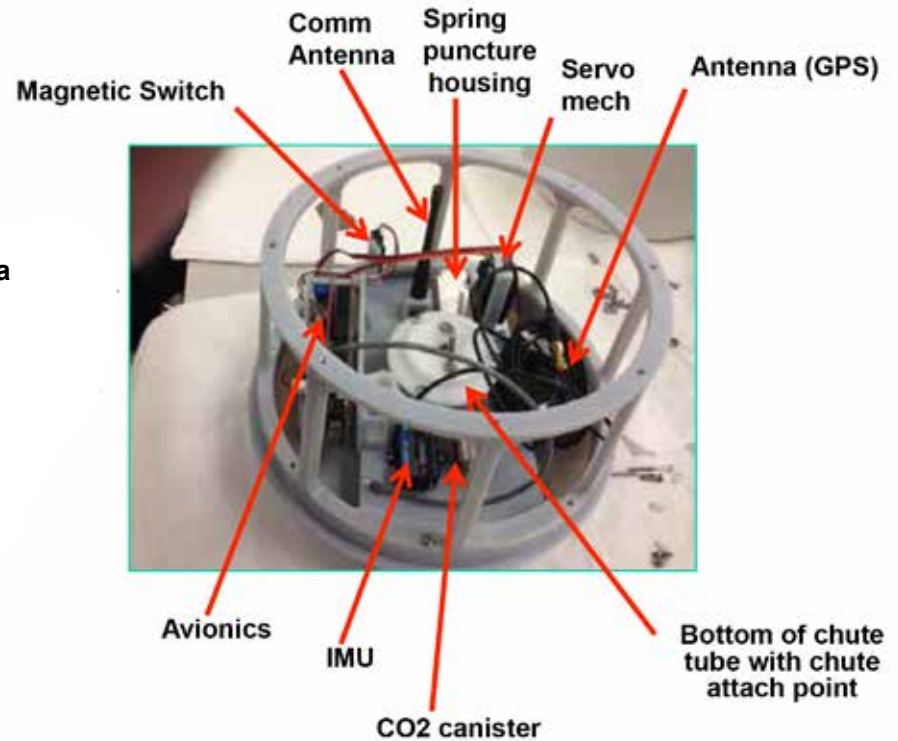
Partnership between Small Spacecraft Technology and Flight Opportunities (2013 NRA)

Being developed by engineers at JSC and KSC

Suborbital flight test planned for Fall 2014 – Launch from Spaceport America, land at White Sands



Interior Maraia
KSC
Sub-Scale
Balloon Drop
Capsule –
April 2013



Up Aerospace Launch Facility
at Spaceport America, New Mexico



Investment Opportunities for FY15 and Beyond

Technology Development Projects

- Follow-on to FY14 one-year propulsion projects
- New technology focus area (i.e., power)
- New round (or expansion) of Smallsat Tech Partnerships

New Flight Demonstrations

- Propulsion technology demonstrations
- Follow-on projects to ISARA, OCSD, CPOD, EDSN, Phonesat
- EM-1 Secondary Payload development
- Others

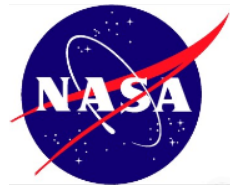
Leveraged Investments (i.e., GCD, SBIR, CIF, STP follow-on projects)

- MEP Flight Demo (from GCD)
- Earth Return Vehicle
- Deep Space Cubesat Technology (2013 SBIR Select Topic)
- Other SBIR Phase 2E/3 or CIF follow-on projects

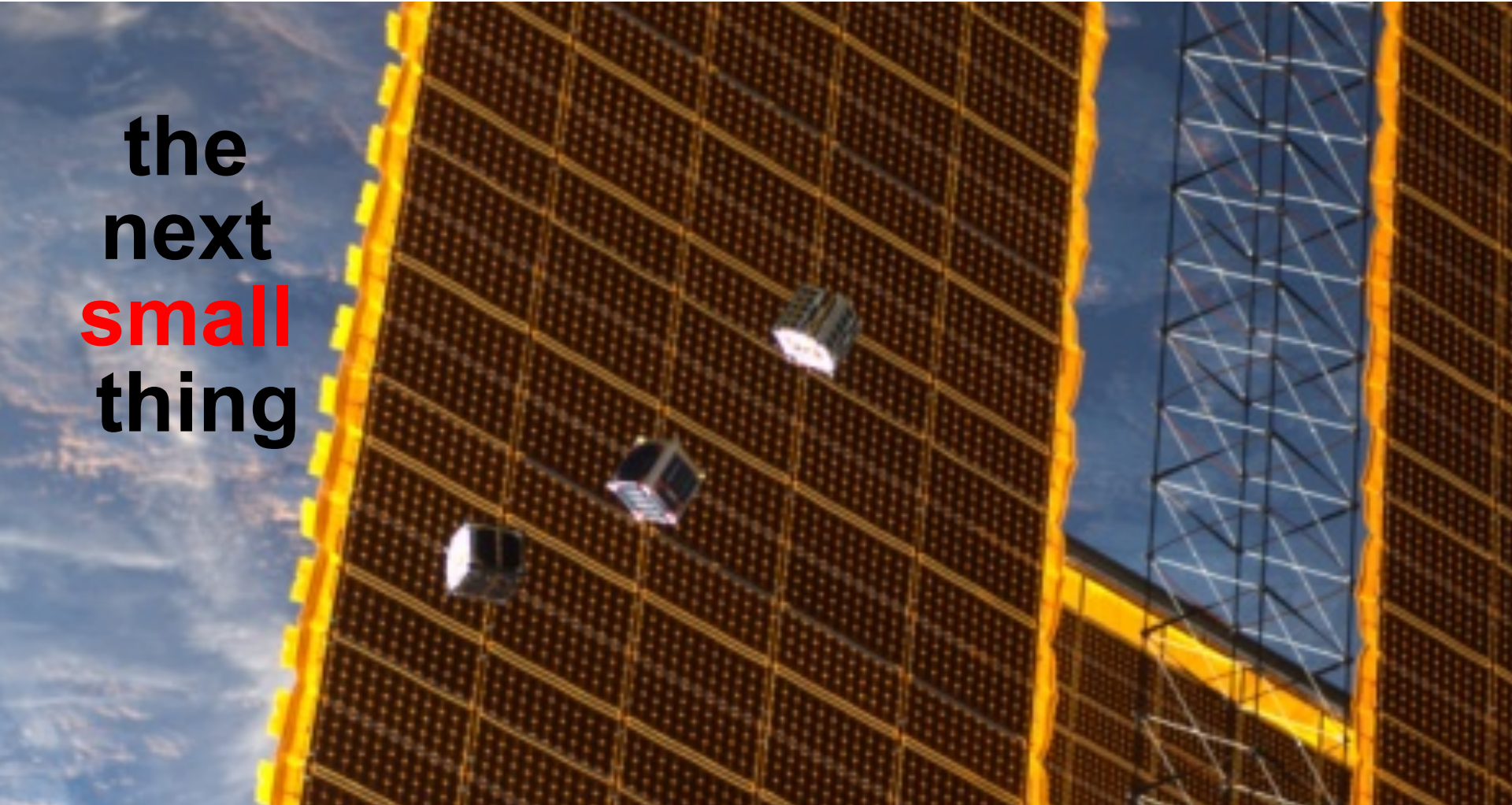
Strategic Initiatives

- Update to State of the Art Assessment
- Flight Software Development Concepts
- Ground System Collaboration

Small Spacecraft Technology



the
next
small
thing



www.nasa.gov/smallsats