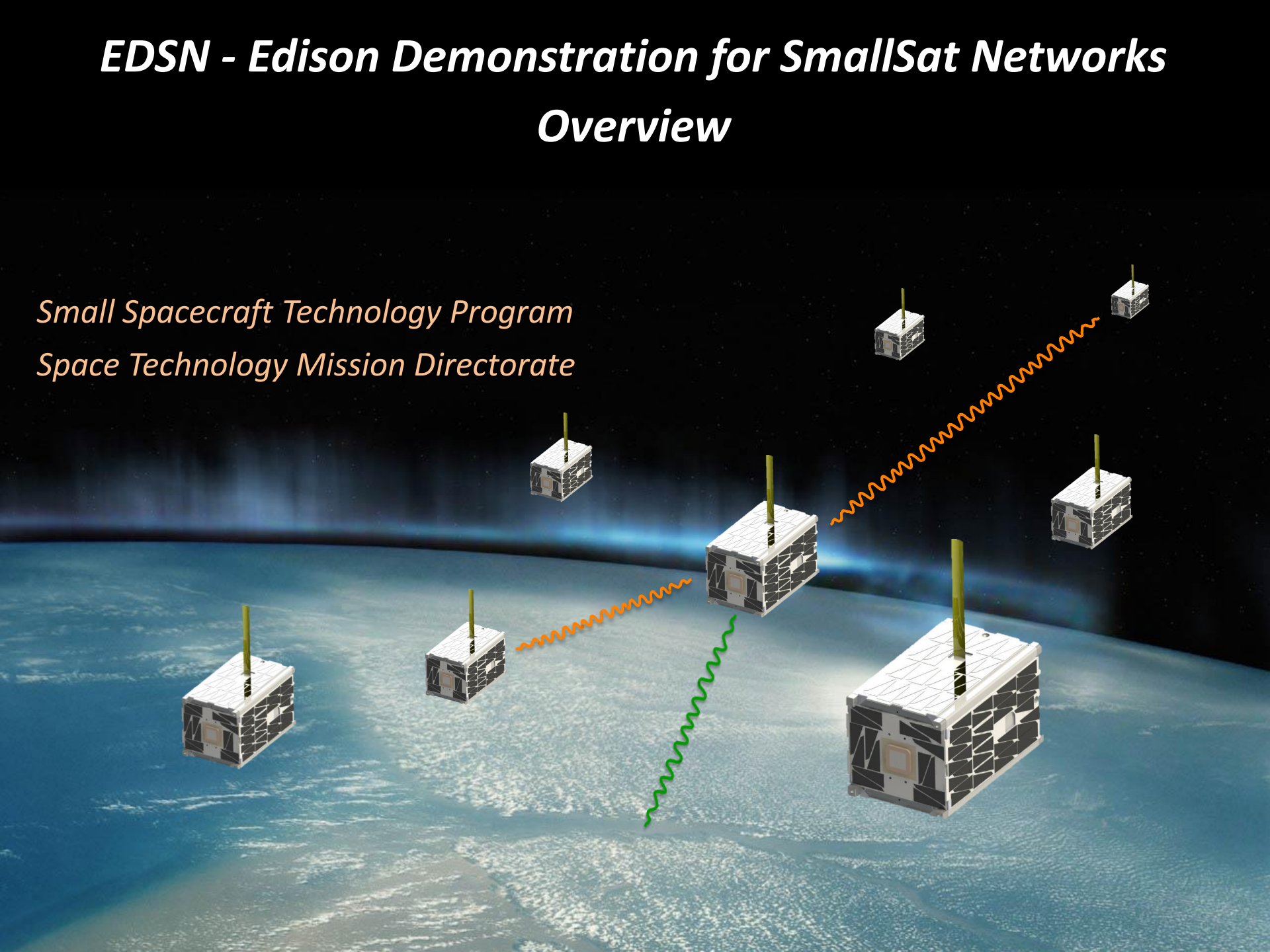
# *EDSN - Edison Demonstration for SmallSat Networks*

## *Overview*

*Small Spacecraft Technology Program*

*Space Technology Mission Directorate*



# Swarm & Constellation Utility

*Current monolithic mission architectures enable high quality science data but only provide single point time repeated measurements. New science discoveries require improvements in mission architectures to include time varying, multi-point and time correlated measurements to fully understand complex, fluctuating and interactive phenomenon.*

NASA

DOD

NOAA

NRC

**Astrophysics**
- Distributed arrays
- Time correlated measurements
- Co-ordinated assets

**Planetary**
- Distributed measurements
- Time correlated measurements
- Deep space operation

**Heliophysics**
- Global coverage
- Multiple measurements
- Time varying measurements

**Earth Science**
- Global coverage
- Time coordinated measurements
- High data throughput

**Space Warfighter**
- Global coverage
- Rapid response
- Reliability

**Single Spacecraft Disadvantage**
- Reliability must be integrated
- Limited coverage
- Time unvarying measurements
- Time varying measurements
- Single system
- Limited upgradability
- Limited coverage
- High unit cost

**Swarm / Constellations**
- Redundant reliability
- Distributed assets
- Time correlated measurements
- Time varying measurements
- Scalable system
- Upgradable system
- Scalable coverage
- Low unit cost

# Swarm Technology Infusion Avenues

- Independent, cooperative mission elements
  - Survey/inspection
  - Sample return (future potential)
  - Autonomous Deep Space missions
  - Hybrid architectures; mothership + probes (Asteroid “Fighter Escorts”)

- Heliophysics & Astrophysics
  - Multipoint measurements – (Heliophysics)
  - Distributed space elements – arrays (Astrophysics)

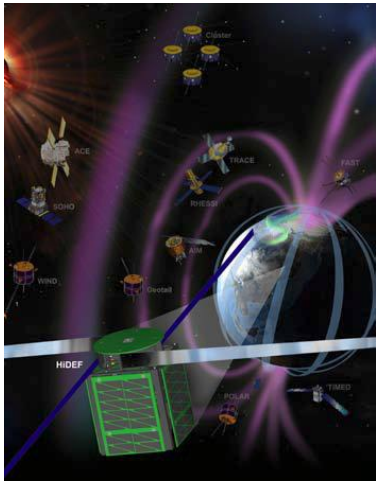
- Earth Sciences & DoD
  - Persistence
  - Wide geographical area coverage
  - Resiliency and robustness
  - Flexibility
  - “A Swarm” vs “A Train”

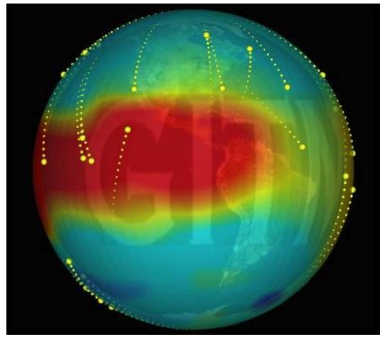
# Heliophysics – Near Term Swarm Applications

*"The study of the heliophysics system requires **multipoint observations** to develop understanding of the coupling between disparate regions: solar-wind, magnetosphere, ionosphere, and thermosphere, and mesosphere on a planetary scale and to resolve temporal and spatial ambiguities that limit scientific understanding…To enable future missions it would be wise to accelerate the development of **spacecraft technologies for supporting small satellites**, including **constellation** operations and **inter-spacecraft coordination**. …A constellation mission utilizing small satellites would radically improve our understanding of the dynamics of the coupled thermosphere/ionosphere system."*

NRC - Solar and Space Physics: A Science for a Technological Society – 2012

- HiDEF (NASA SMD - Heliophysics Roadmap 2009)
  - 90 spacecraft in swarm in range of low earth, polar orbits
  - Globally monitor electric field and thermosphere density
- ARMADA (NASA SMD - Heliophysics Roadmap 2009)
  - Swarm of 25 to 100 spacecraft in pseudo-random orbits
  - GPS Receivers with Radio Occultation and TEC capabilities
  - Drag model inferred from GPS
- COSMIC-II (NRC - Earth Science Decadal Survey 2007)
  - GPS Receivers with Radio Occultation and TEC capabilities
  - Persistent, real-time GPS monitoring in L1/L2 with 6 – 10 spacecraft



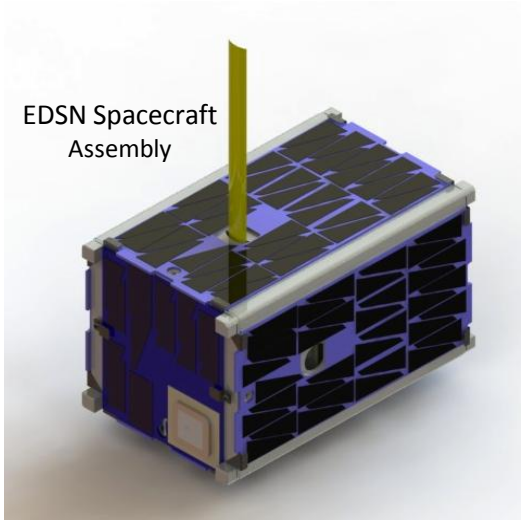
# Edison Demonstration of SmallSat Networks (EDSN) Project

## Project Summary

- **HQ Directorate:** Space Technology Mission Directorate
- **Governing PMC:** NASA Class D Category III Project
- **Project Manager:** Deborah Westley
- **Performing Organization(s):** ARC, MSFC
- **Partners:**
  - Montana State University – Payload provider
  - Santa Clara University – Ground Station operator

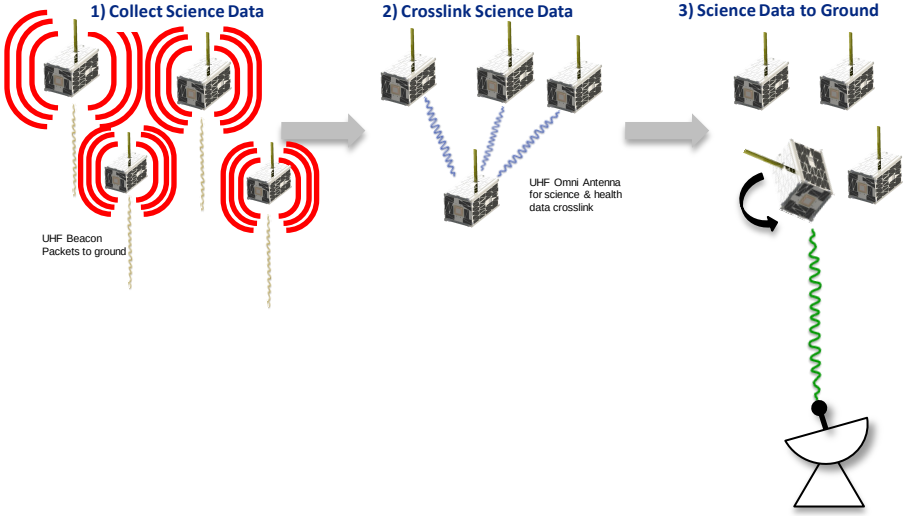
- **Description:** The EDSN Mission will launch a swarm of 8 low-cost small satellites and demonstrate the operation of an intra-swarm communication link and multi-point sensing measurements.

## Description




Montana State University
EPISEM Payload

## ConOps




## Schedule (CY)

| | 2012 | 2013 | 2014 |
|---|---|---|---|

△ ATP
PDR △
CDR △
FRR △
ORS Launch △ △
Mission Ops

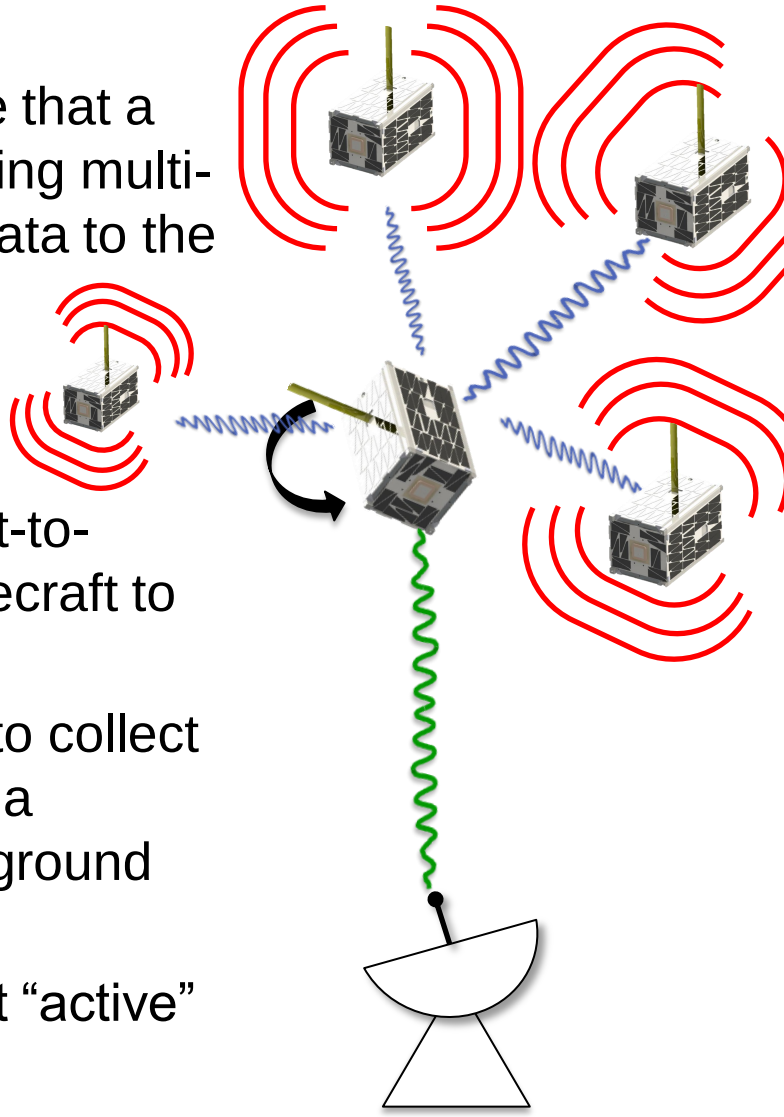
## Launch

**ORS Super Strypi (ORS-4)**
Launched from PMRF

# EDSN Mission Goal & Objectives

## Mission Goal

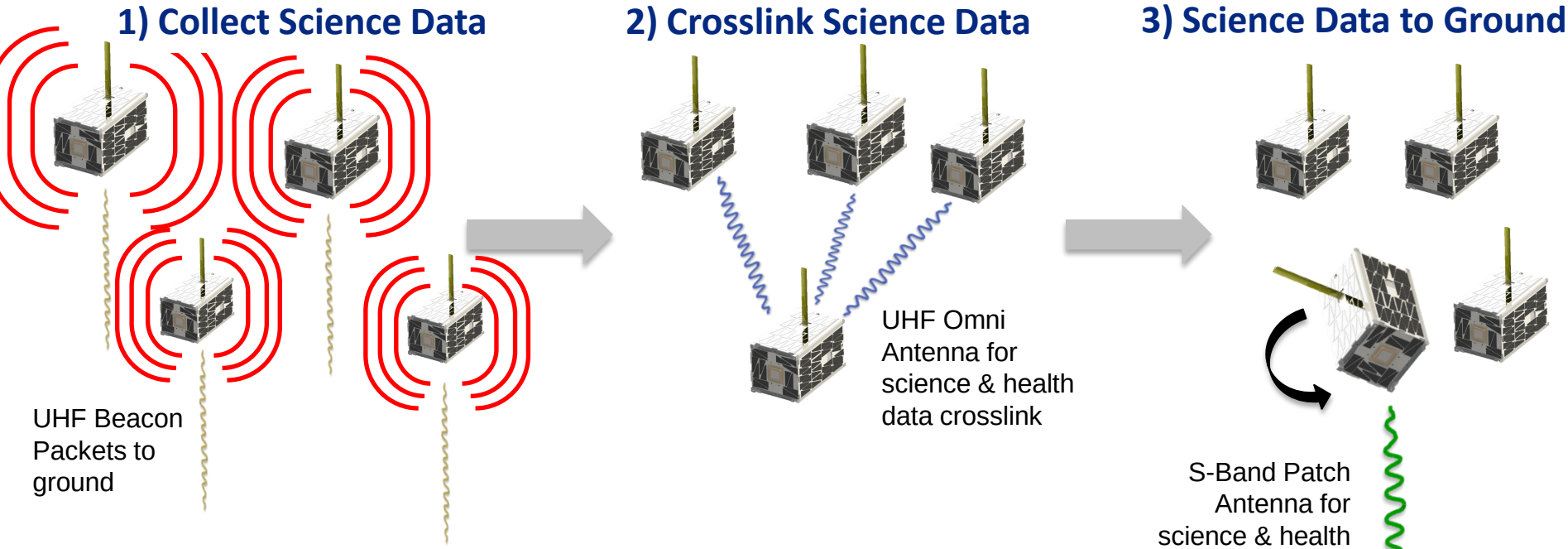
- The EDSN project goal is to demonstrate that a swarm of spacecraft is capable of collecting multi-point science data and transmitting the data to the ground



## Mission Objectives

- Deliver and flight demonstrate spacecraft-to-spacecraft communications link for spacecraft to transfer data to another spacecraft
- Deliver and flight demonstrate a system to collect multi-point science measurements and via Objective 1 transmit science data to the ground station
- Deliver and flight demonstrate spacecraft “active” pointing system

# Concept of Operations




- Each spacecraft (8) takes space weather data measurements (via EPISEM dosimeter)
- Crosslink data transmission demonstrated on multiple spacecraft
- Single spacecraft (“Mothership”) demonstrates a pointing capability and sends science data to the ground station
  - Any spacecraft can be the “Mothership” ground relay
  - Stretch goal to demonstrate upload during mission as swarm disperses
- Beacon packets provide back-up science data

# SSTP Portfolio Technology Matrix

"C3PO"

| *SSTP Projects* | EDSN | CPOD | ISARA | OCSD | Phonesat | Comment |
|---|---|---|---|---|---|---|
| **C**omm<br>Up-link<br>Down-link<br>Cross-link | □ | | □ | □ | | EDSN unique |
| **P**ropulsion | | □ | | □ | | |
| **P**ointing (ADCS/GNC) | □ | □ | □ | □ | □ | |
| **P**ower (EPS) | | | | | | Future topic? |
| **O**perations (autonomy) | | *Limited* | | | | Future topic? |
| Structures/deployables | | *Limited* | □ | | | |
| Science architectures | □ | | | | | EDSN unique |
| Swarms/Constellations | □ | | | | | EDSN unique |
| C&DH (processors) | | | | | □ | |

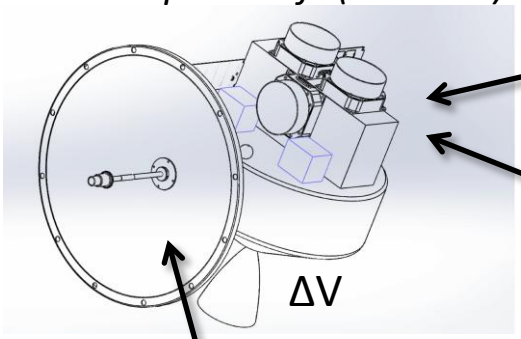
# Mission Extensibility

*Conceptual Mission: NEO investigation*

EDSN

EDSN

*Future Spacecraft (notional)*



ΔV

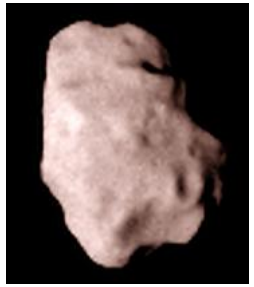
X-link Comm

ΔV

RPO

ΔV

X-link Comm



ISARA, OCSD

Comm

CPOD, OCSD

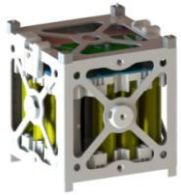
*SSTP portfolio addresses a number of key technologies*
*Not shown: Phonesat*
*Other future: Autonomy, Structures, Power*
*RPO = Rendezvous and Prox Ops*

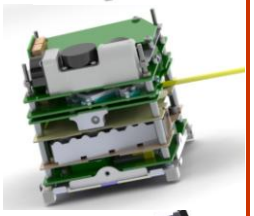
# Back up Charts

# PhoneSat: The Android App Plug&Play Satellite

## CURRENT STATUS OF THE PROJECT

- **PhoneSat 1.0**
  - Google Nexus One, StenSat radio, watchdog, 12 Li-Ion batteries and 4 retro-reflectors
  - Passed FRR on November 2012
  - 2 units successfully flown on Antares I launch (April 2013)
  - $3,500 per satellite (components)
- **PhoneSat 2.0.β**
  - Google Nexus S, StenSat radio, torque coils, solar cells, watchdog, router, sensor interface and 4 Li-Ion batteries
  - Passed FRR on November 2012
  - 1 unit successfully flown on the Antares I launch (April 2013)
  - $7,300 per satellite (components)
- **PhoneSat 2.0**
  - PhoneSat 2.0.β + Reaction wheels and Microhard radio
  - FRR: April 2013
  - ELaNa IV launch: September 2013
  - $7,800 per satellite (components)





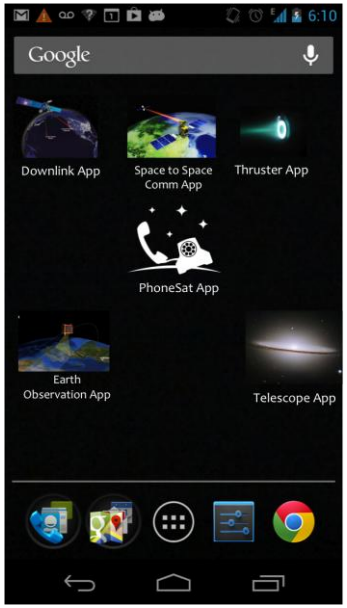
## MILESTONES FOR 2013

*PhoneSat 2+ versions will develop new sub-systems to increase the capabilities of the ultra cheap easy-to-program PhoneSat bus*

- **PhoneSat 2.0** Android App development
- ELaNa IV or V launch: **PhoneSat 2.0** (Sept 2013)
- **PhoneSat 2.x**: ELaNa V and future opportunities
- New concepts for **PhoneSat 3.0** development:
  - Engage the **Android development community** to provide satellite Android Apps
- **Upload an Android App** through the radio
  - Star tracker using the **smartphone camera**
  - GPS transceiver
- **Modulating Retro Reflector** for Optical Communication test
  - Test piezo-electric components for high accuracy ADCS
  - IOIO board phone interface
  - Deployable solar panels

## THE ANDROID APP SATELLITE

- The PhoneSat platform, based on the Android open source operating system, will open the space industry to **more than a million Android programmers** around the world
- The PhoneSat project plans to leverage the continual development of the billion-dollar Smartphone industry
- Shifting the space paradigm from a hardware problem to **a software problem**
- New flight software and updates will be coded by anyone with Android programming skills
- **Universities and Research groups** will have access to the PhoneSat platform through **international competitions**

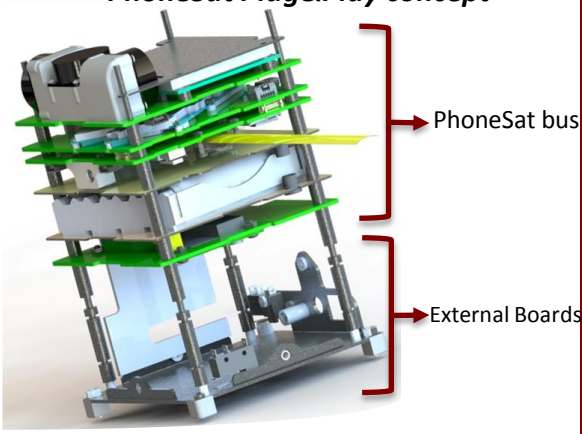



## ULTIMATE GOAL: THE ANDROID APP PLUG&PLAY SATELLITE

The Plug&Play nature of the PhoneSat bus, together with the open-source Android platform, will enable rapid hardware and software satellite development

- The project has already demonstrated the capability of adding new sub-systems to the bus: **EDSN , KickSat projects**
- Hardware modularity will allow **Plug&Play** for many different payloads
- The Android platform will enable rapid, cheap and adaptable software development

***PhoneSat Plug&Play concept***



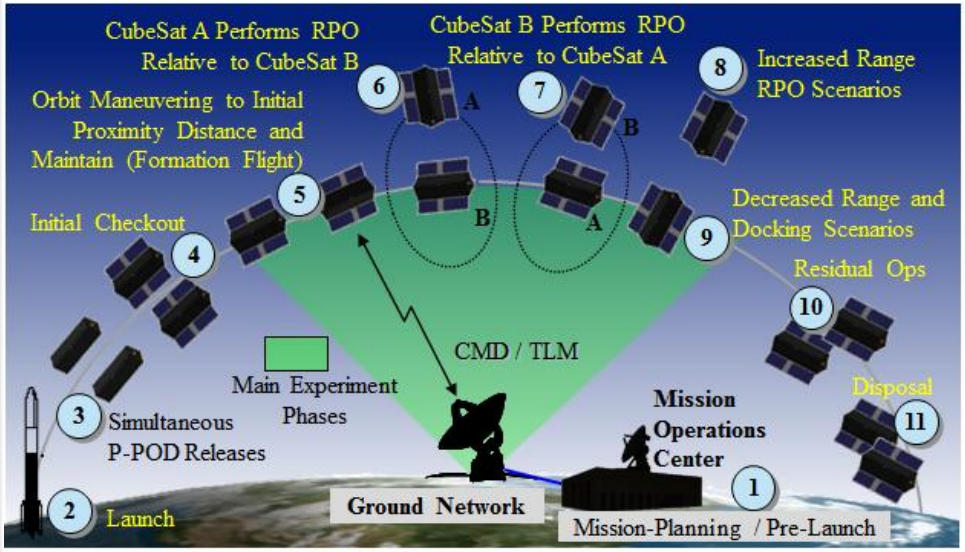
# Proximity Operations Nano-Satellite Flight Demonstration

## Project Summary

**Contractor:** Tyvak Nano-Satellite Systems LLC
**PI:** Scott MacGillivray/Tyvak
**Subcontractors:**

- 406 Aerospace
- Applied Defense Solutions
- Analytical Graphics Inc.
- California Polytechnic State University, San Luis Obispo

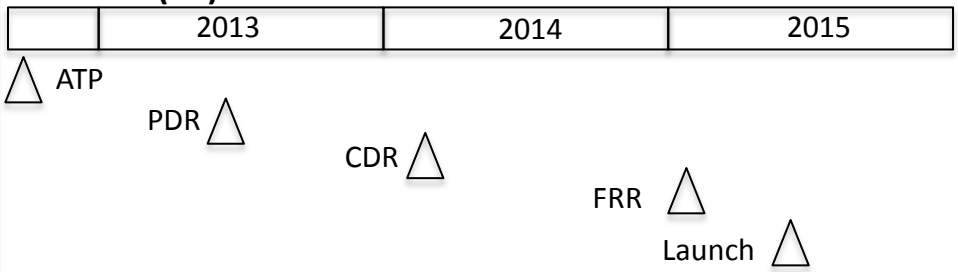
## Description/ConOps




## Concept of Operations

- Two 3U CubeSats will demonstrate rendezvous, proximity operations, docking and servicing, and formation flight over a 1-year nominal mission.

## Schedule (CY)




## Launch

- Launch is planned for second quarter of CY2015 (selected by CSLI).
- Orbit inclination > 30° for ground coverage considerations and altitude should nominally support 1 year of on-orbit operations.

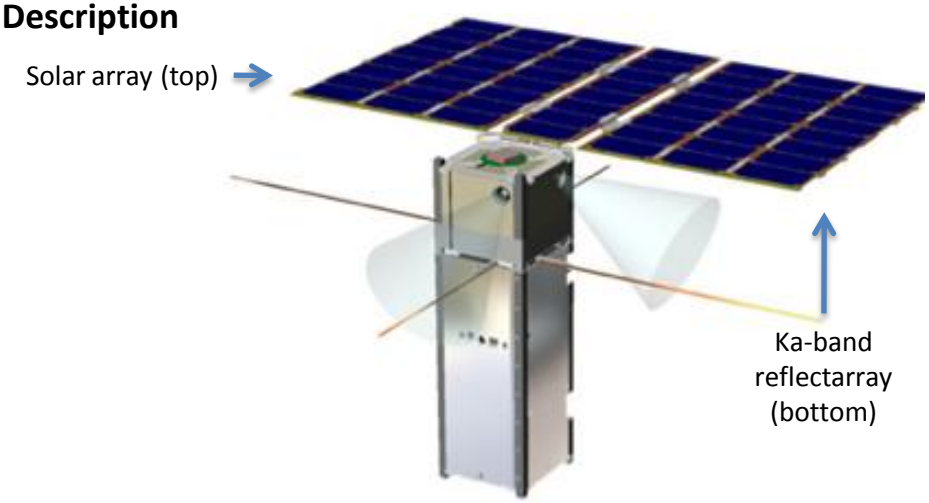
# ISARA –Integrated Solar Array and Reflectarray Antenna for High Bandwidth CubeSat

## Project Summary

**Center:** Jet Propulsion Laboratory
**PI:** Richard Hodges
**PM:** Biren Shah
**Subcontractors:**
- Pumpkin, Inc. (spacecraft bus)

**Objective:**
- Demonstrate a high bandwidth Ka-band data downlink system for cubesats

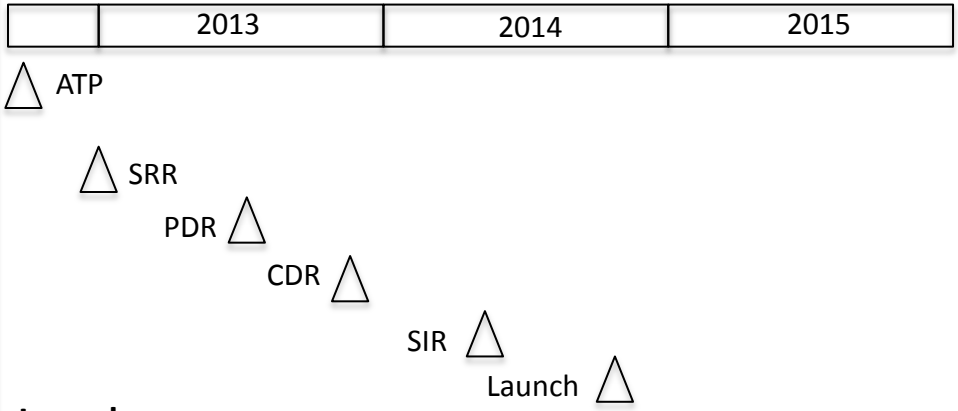
## Description




## Concept of Operations

- One 3U cubesat employs a large, deployable solar array that doubles as a Ka-band reflectenna providing up to 100 Mps of data downlink capability.

## Schedule (CY)




## Launch

- Launch planned for CY2014 (selected by CSLI)
- LEO from 300km to 700km at 51.7° is acceptable.
- GTO orbit would also be considered.

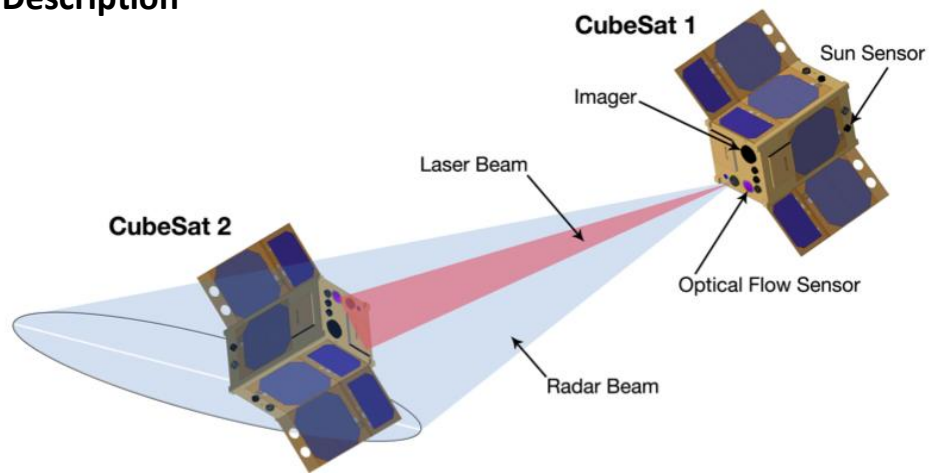
# Integrated Optical Communications and Proximity Sensors Demonstration (OCSD)

## Summary

**Contractor:** Aerospace Corp.
**PI:** Siegfried Janson
**Subcontractors:**
- N/A

**Objective:**
- Demonstrate radar ranging, optical downlink, cold gas propulsion, and cross-track motion sensing technologies on a cubesat proximity operations mission.

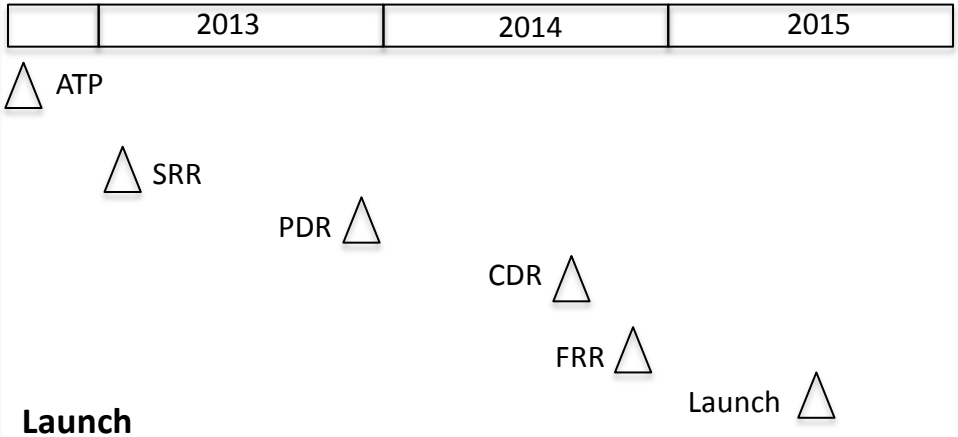
## Description




## Concept of Operations

- Two 1.5U cubesats execute formation flying and rendezvous operations using radar, optical flow sensor and cold gas propulsion.
- Demonstrate laser-comm downlink.

## Schedule (CY)




## Launch

- Launch is planned for mid CY2015 (selected by CLSI)
- LEO at 500km is sufficient.