

# INSPIRE

## Interplanetary NanoSpacecraft Pathfinder In a Relevant Environment

*Low-cost mission leadership with the world's first CubeSat beyond Earth-orbit*

*PI: Dr. Andrew Klesh, Jet Propulsion Laboratory, California Institute of Technology*

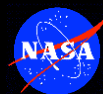
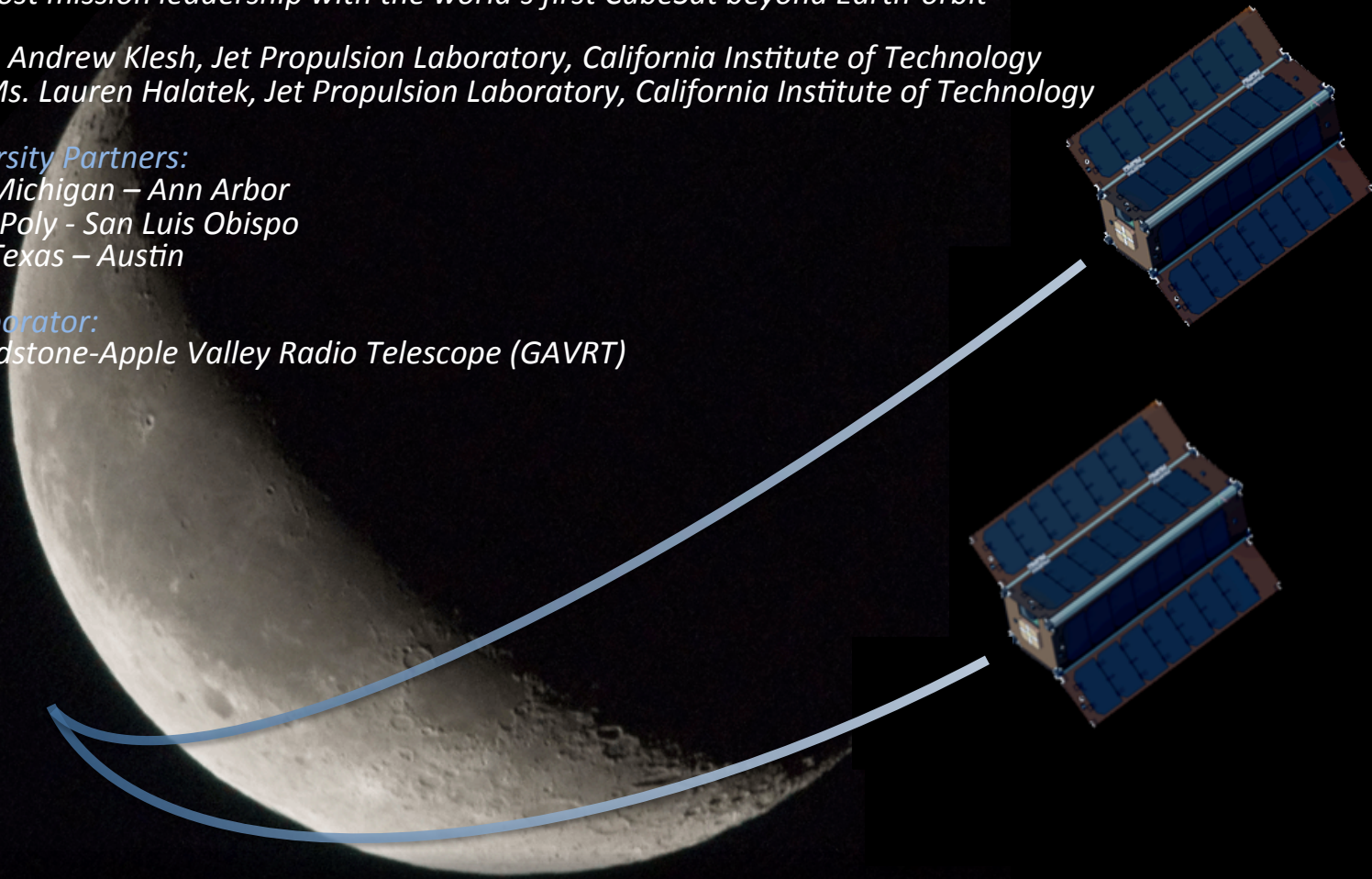
*PM: Ms. Lauren Halatek, Jet Propulsion Laboratory, California Institute of Technology*

### *University Partners:*

- *U. Michigan – Ann Arbor*
- *Cal Poly - San Luis Obispo*
- *U. Texas – Austin*

### *Collaborator:*

- *Goldstone-Apple Valley Radio Telescope (GAVRT)*



Jet Propulsion Laboratory  
California Institute of Technology

CALPOLY

GAVRT



THE UNIVERSITY OF  
TEXAS  
— AT AUSTIN —

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# What is a CubeSat?

- A CubeSat is an accepted standard to enable low-cost launch access at the price of higher risk – but not to the primary (**encapsulation of risk**)
- **A CubeSat is a flexible platform** without defined “innards”
- **A CubeSat is an instrument** – with a few spacecraft parts tacked on.
- **A CubeSat allows for low-cost** if the project accepts higher risk

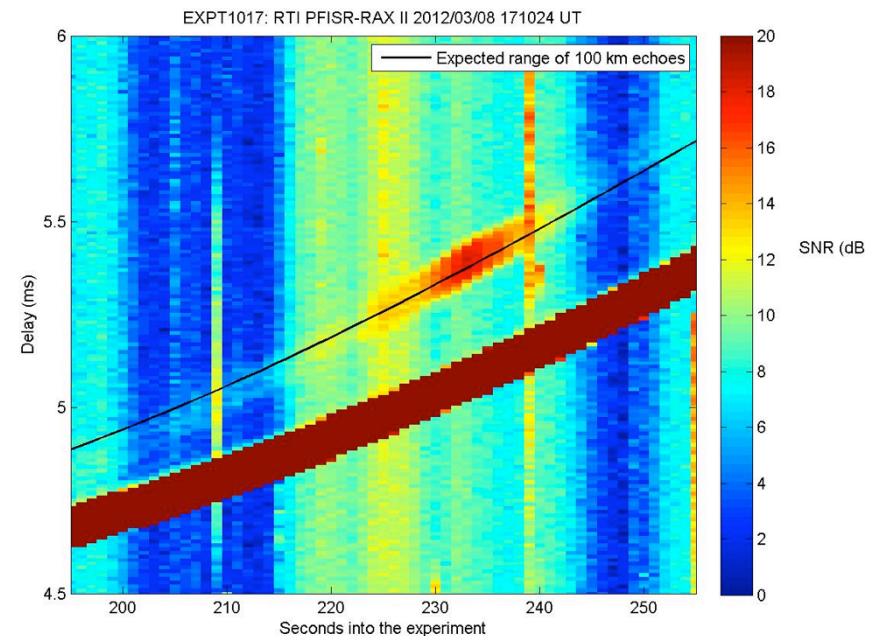
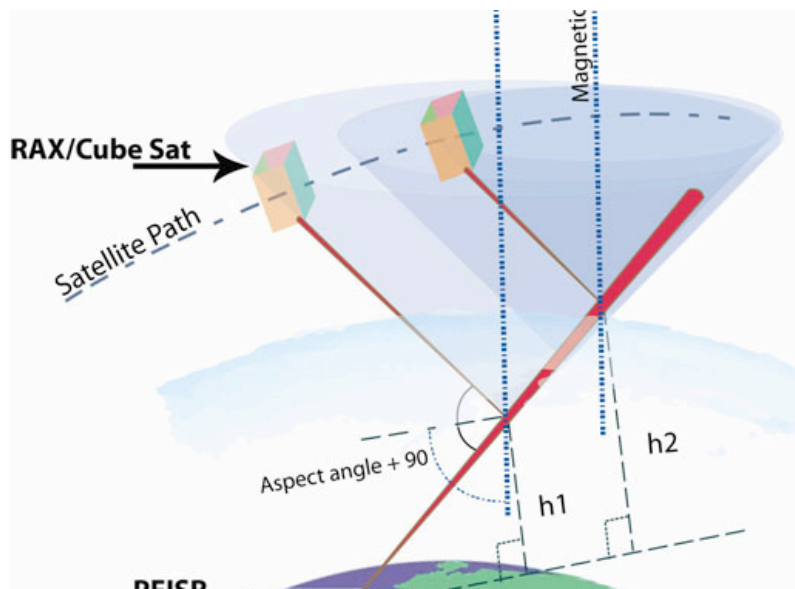


**A CubeSat is a focused tool**, trading capability for size, and maximizing utility through acceptance of risk.



# CubeSats – Inside the Box

- 10 years orbiting in LEO
- Currently >50 launches per year
- Have developed significant capability for science return



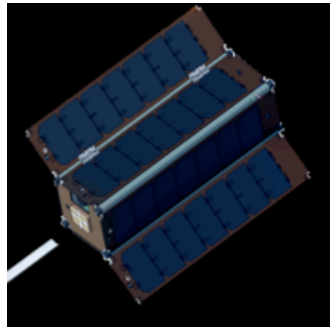
The RAX radar echo discovery has convincingly proved that miniature satellites, beyond their role as teaching tools, can provide high caliber measurements for fundamental space weather research.

**- Dr. Therese Moretto Jorgensen, Geospace program director, Division of Atmospheric and Geospace Sciences, NSF**

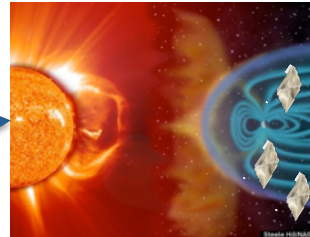


# Opportunities

**Why do this?** NASA and JPL have identified high-value science applications using Nano s/c



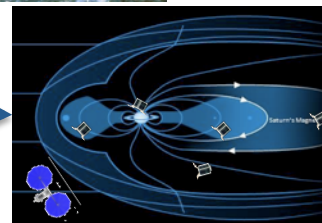
**INSPIRE Mission**



**Low-Cost Heliophysics:** Constellation of 50 standalone 10 kg spacecraft to monitor the solar wind 3D structure at Sun-Earth L1.



**Supplemental Science:** Sacrificial probes used to scout plume passage or descend into high magnetic fields.



**Enabling Novel Science:** Use multiple nano s/c to allow for distributed flybys, capturing multiple vantage points simultaneously.

These innovative science applications can only be enabled through the development and demonstration of critical gap-filling nano-s/c technologies.

*INSPIRE  
Telecom, C&DH, Nav,  
Magnetometer*

*Explorer  
Disco-13*

*InSight Launch  
NF-4*

*Mars '18*

*Mars '20  
Disco-14  
Clipper?*



2014

2015

2016

2017

2018

2020 and Beyond

Pre-Decisional -- For Planning and Discussion Purposes

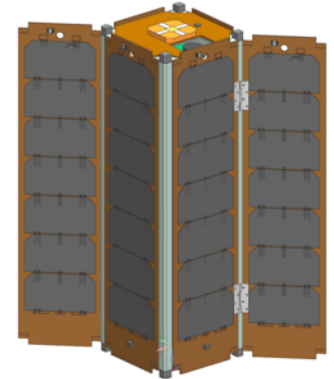


# INSPIRE

INSPIRE will enable a new class of interplanetary explorer, while providing components to reduce the size and cost of traditional missions

## Mission Objectives

- Demonstrate and characterize key nano-spacecraft telecommunications, navigation, command & data handling, and relay communications for mother-daughter
- Demonstrate science utility with compact science payload (1/2U Helium Vector Magnetometer and Imager)
- Demonstrate ability to monitor and power cycle COTS/university processing systems



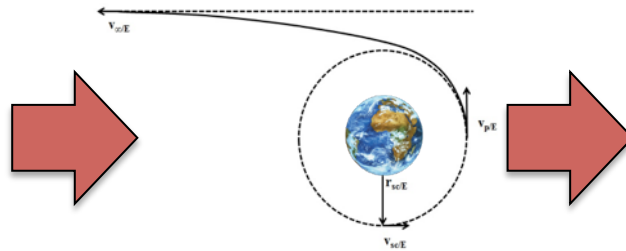
## Mission Concept

- JPL-built spacecraft; collaborative partnerships with Michigan, Texas, and CalPoly/Tyvak for COTS processing systems. Ground stations at U. Michigan and Goldstone with DSN compatibility



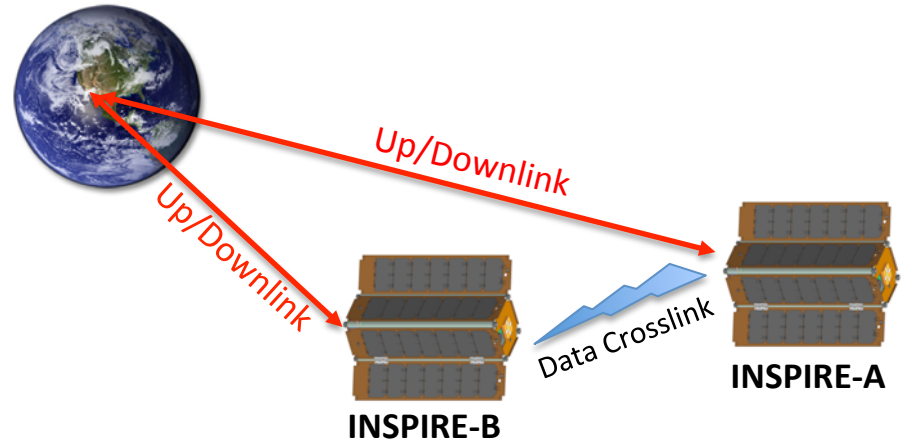
**Nominal:**

NASA CLI Launch:  
Ready by Summer 2014



**Nominal:**

Deploy to Escape





# Design Overview

## CubeSat Overview:

**Volume:** 3U (10x10x30cm)

**Mass:** 3.8 kg

**Power Generation:** 20 W

**Data Rate:** 62-256000 bps

## Software:

Developed in-house

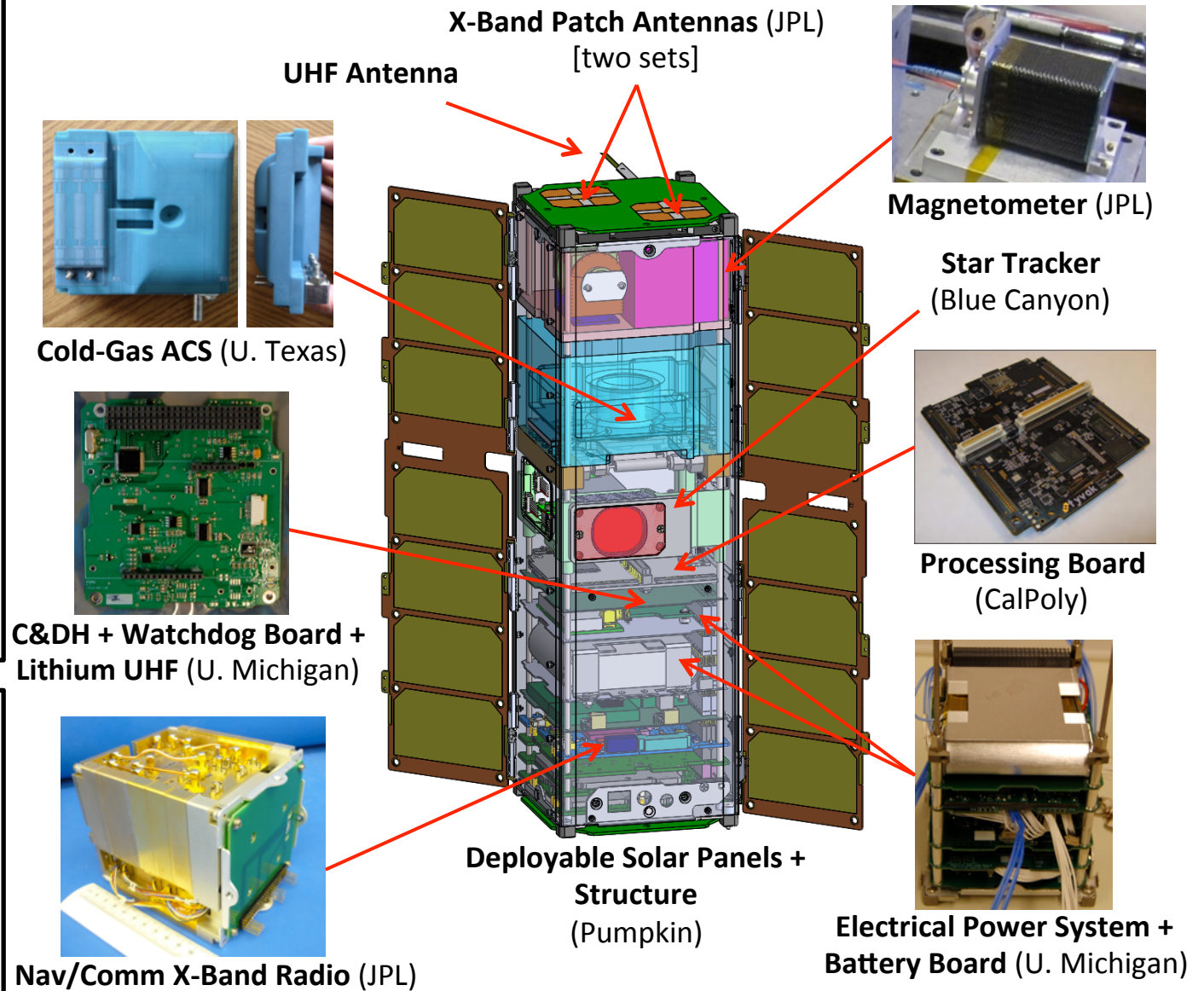
## I&T:

In-house S/C I&T, CalPoly  
P-Pod/Launch Integration

## Operations:

DSN, DSS-13 (JPL), & Peach  
Mountain (U. Michigan)

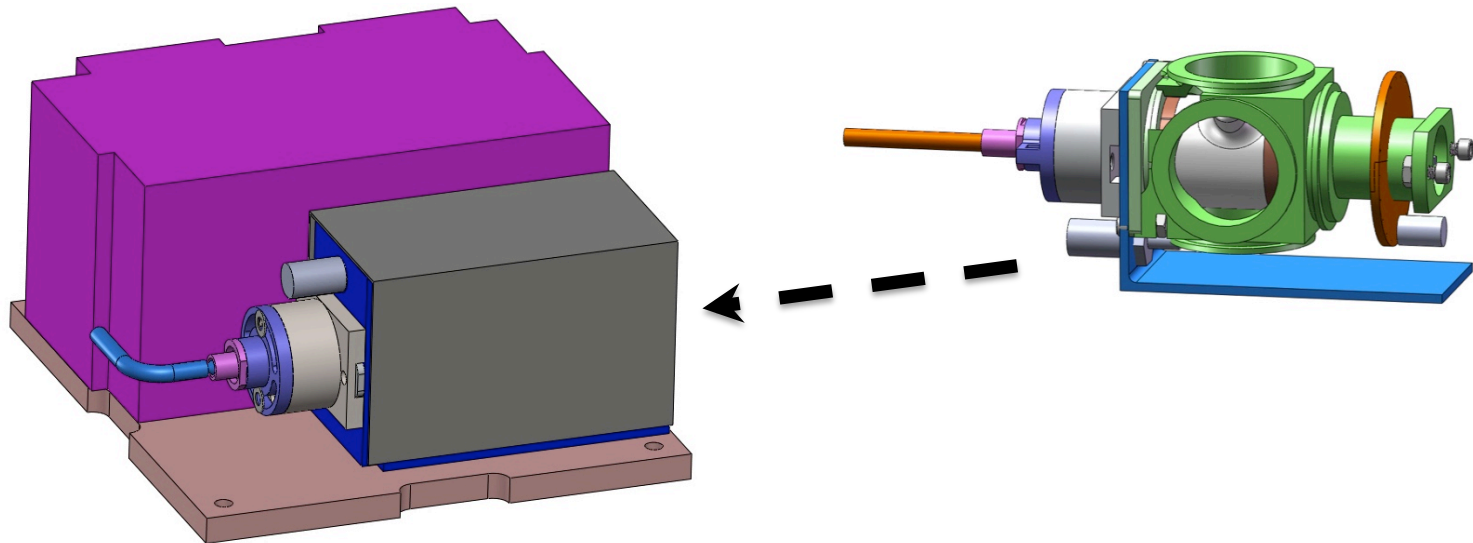
S/C components provide  
*the basis for future high-  
capability, lower-cost-risk  
missions* beyond Earth  
expanding and *provide  
NASA leadership in an  
emergent domain*





# Compact Vector Helium Magnetometer

- Built upon a scientific legacy stretching back to the early days of planetary exploration, from the Mariner missions through Cassini
- Stability of  $<10\text{pT}$  in approximately  $5\times 10\times 10\text{cm}$  at  $0.5\text{kg}$ !



- Tested on a suborbital flight in June, 2011, and again today. Will be flown on INSPIRE to measure fine-scale solar wind features and structure.

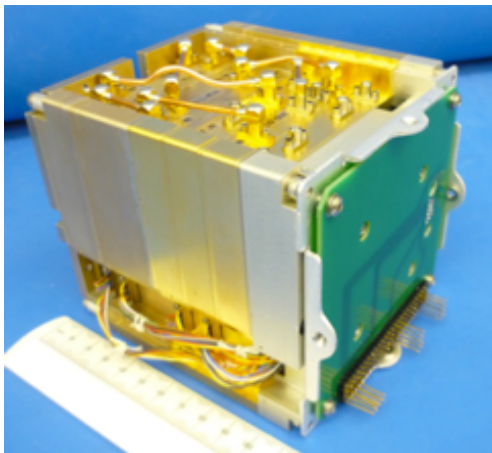
## Science Mission Example:

Supplement the 2014 Magnetospheric Multiscale Mission (MMS) objectives of large-scale 3D-structure solar wind measurements with fine-scale observations obtained from the two slowly separating INSPIRE spacecraft.

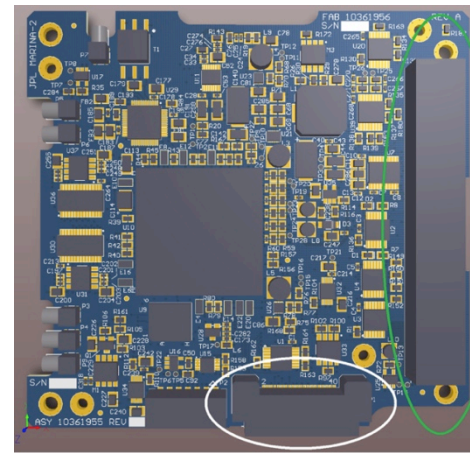


# Iris X-Band Communication / Navigation Radio

- **Heritage:** Derived from extensive radio heritage from Electra, SDST and the Low Mass Radio Science Transponder (LMRST)
- **Technical:** ~8 GHz radio with a 5 W amplifier, supporting 2 x Rx and 2 x Tx patch antennas – 4x10x10cm at less than 0.5kg.
  - 62.5 bps to 256kpbs and 1kbps from 1.5m km
- **Navigation:** Coherent uplink / downlink allowing for accurate ranging and Doppler measurements.



LMRST Prototype



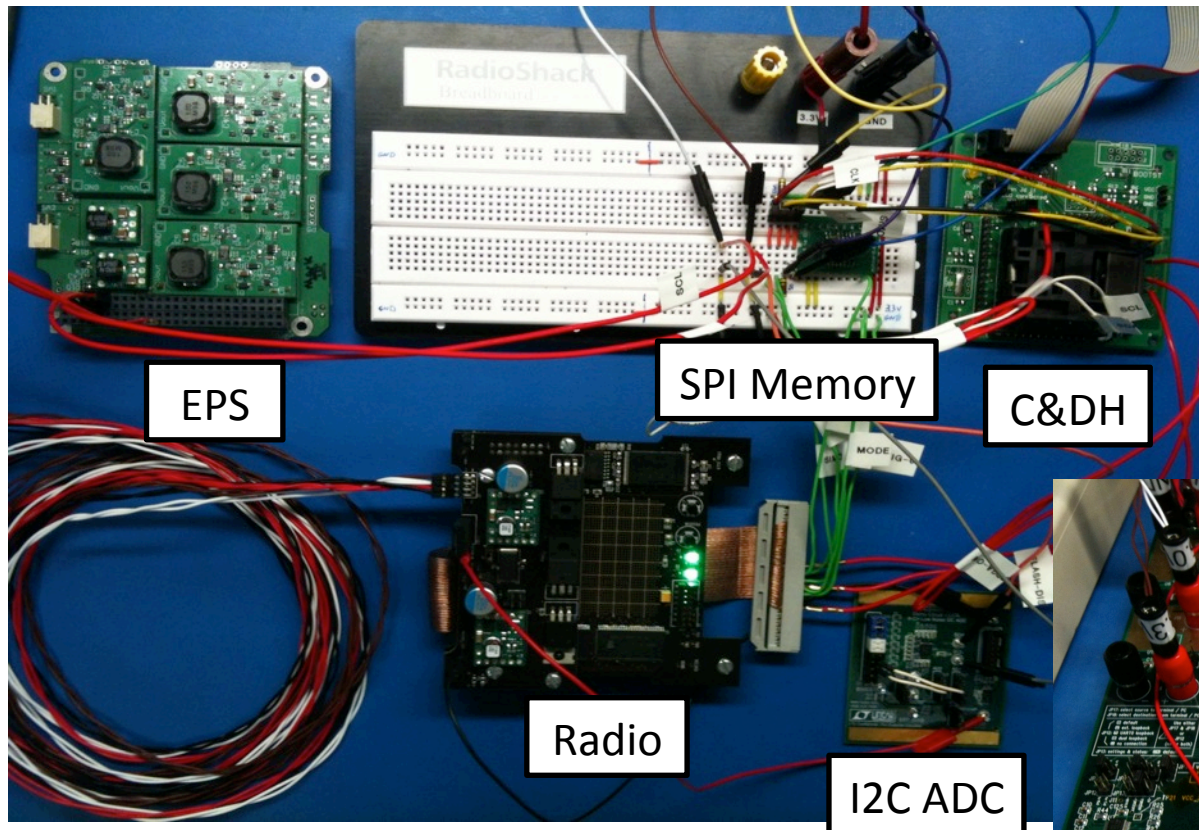
CubeSat Kit Compliant Iris Digital Board  
(Arrives next week)

- **Operations:** DSN / CCSDS Compliant – libraries built for NASA AMMOS mission operations / ground data systems software, but are flexible

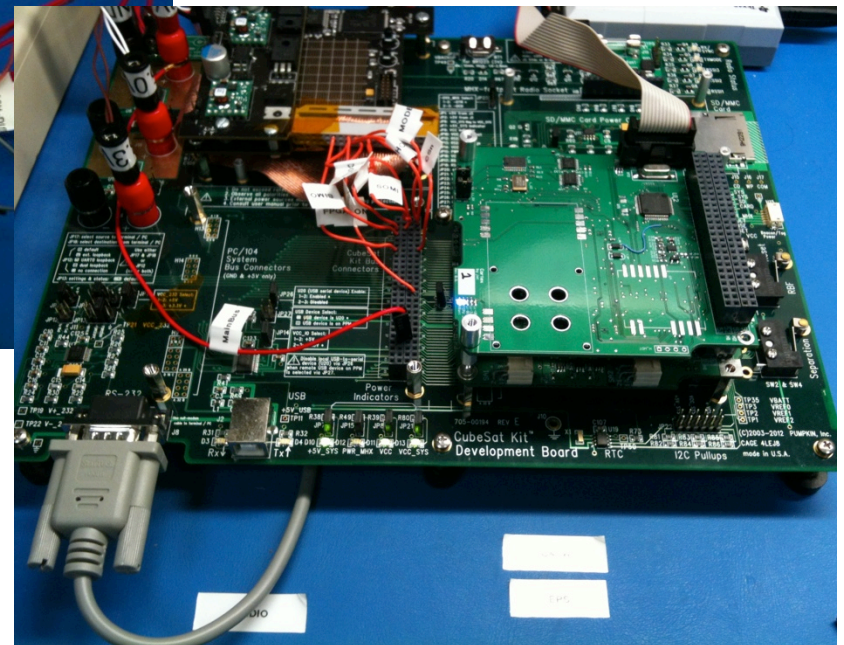




# Current INSPIRE Development



FlatSat in initial stack on development board



## Current Status:

- Selected by the CubeSat Launch Initiative – awaiting manifest
- Prototype units are arriving at JPL (with interns). Characterization and integration is ongoing.
- 3 operating “Flat-Sats” for development and testing
- Approximately 10 months until launch ready



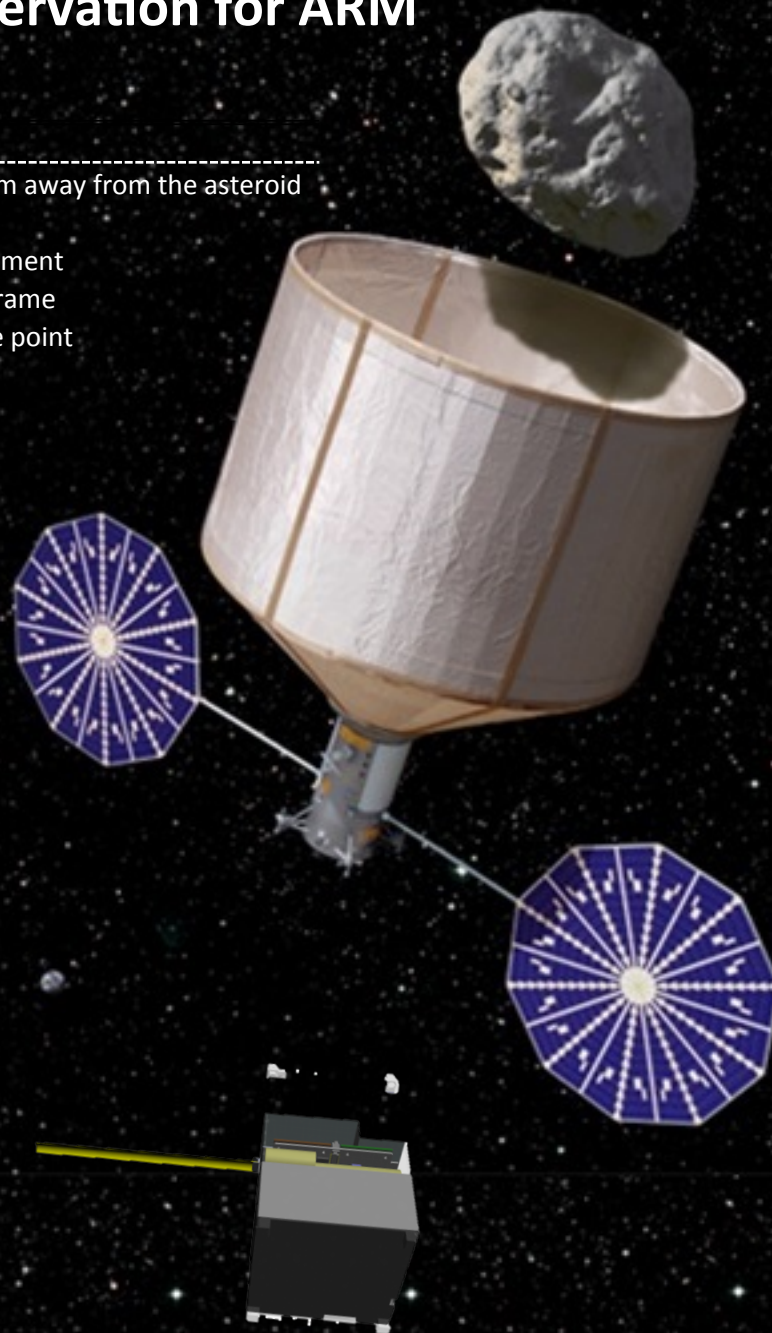
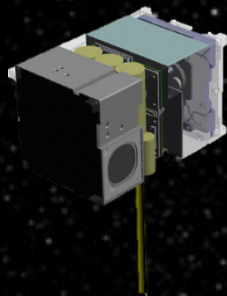
# Low-Cost Lessons Learned

Lessons learned from INSPIRE can help to improve the cadence of interplanetary missions, and supplement new concepts with novel science opportunities.

- NASA's Deep Space Network is interested in supporting NanoSpacecraft missions and the CubeSat community
  - Currently investing in a low-cost "CubeSat" version of NASA Advanced Multi-Mission Operations System.
- Everyone is learning in the CubeSat community
  - Collaboration is key. JPL has deep expertise in certain areas, but the CubeSat community has developed (and flown) incredible capability. INSPIRE is partnered with 5 universities and 4 small companies (along with 40,000 middle school students).
- Reliability can be improved through testing when analysis may be unaffordable – test early, test often.
- A small focused team can "know" the system, minimizing paperwork, and supporting multidisciplinary experts, able to tackle a broad set of challenges.
- Flexible capabilities provide margin for fixed objectives

# INSPIRE Follow-on: Witness Observation for ARM

Time	Activity
T0	ARV will begin at a station keeping position ~50m away from the asteroid
T0 (uncertain)	MIRAGE will get deployed
T0+30 minutes	MIRAGE will null spin rates arising from deployment
T0+90 minutes	MIRAGE will orient with respect to the inertial frame
T0+90 minutes	MIRAGE will maneuver to a pre-defined vantage point
T0+210 minutes	MIRAGE will orient the camera for imaging
T0+210 minutes	ARV begins bag deployment
T0+210 minutes	MIRAGE will record the bag deployment
T0+215 minutes	ARV will wait for ground telemetry analysis
T0+215 minutes	MIRAGE will go on idle mode for this duration
T0+395 minutes	ARV starts the capture process
T0+395 minutes	MIRAGE will record the capture process
T0+415 minutes	MIRAGE will stop recording the capture process
T0+435 minutes	MIRAGE will have completed the crosslink





# Conclusions

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INSPIRE will enable a new class of interplanetary explorer, while providing components to reduce the size and cost of traditional missions

- Deep space NanoSpacecraft are scientifically compelling – but they must be proven before PI / reviewer acceptance
- INSPIRE would demonstrate survivability, navigation and communication utilizing the CubeSat platform, and in partnership with the CubeSat community
- INSPIRE is partnering with the CubeSat community to extend capabilities to deep space
  - Peach Mountain and DSS-13 receive stations
  - Robust low-power C&DH
  - Monitored high-power processing
  - 3-axis cold-gas system
- JPL is developing novel technologies to support these and future missions
  - X-band Nav/Comm radio
  - Vector-Helium Magnetometer
  - DSN Compatible Ground Data System and Flight Software