INSPIRE

Interplanetary NanoSpacecraft Pathfinder In a Relevant Environment

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

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University Partners:
• Cal Poly - San Luis Obispo
• U. California – Los Angeles
• U. Michigan – Ann Arbor
• U. Texas – Austin

Collaborator:
• Goldstone-Apple Valley Radio Telescope (GAVRT)

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Why do this? NASA and JPL have identified high-value science applications using nano-s/c technologies.

**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.

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**INSPIRE Mission**

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

**Exploder**
- Disco-13

**InSight**
- Launch

**NF-4**

**SLS EM-1**

**BioSentinel**

**NEA Scout**

**Lunar Flashlight**

**Mars '18**

**Mars 20 Disco-14**

**Clipper?**

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2014
2015
2016
2017
2018
2020 and Beyond

Pre-Decisional -- For Planning and Discussion Purposes
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 Compact Helium Vector Magnetometer & Imager w/ Agile Science Processing)
- Demonstrate ability to monitor and power cycle COTS/university processing systems

Mission Concept

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

Nominal:
- NASA CLI Launch: Ready Summer 2014
- Deploy to Escape
- Up/Downlink
- Data Crosslink
Design Overview

**CubeSat Overview:**
- Volume: 3U (10x10x30cm)
- Mass: 4.0 kg
- Power Generation:
  - 3 Axis Stabilized: 20 W
  - Tumbling: 13 W
- Data Rate: 62-256000 bps

**Software:**
Developed in-house (protos)

**I&T:**
In-house S/C I&T, external environmental testing, NASA CLI P-Pod/Launch Integration

**Operations:**
- Primary: DSN
- Secondary (Receive only): DSS-28 (GAVRT), & Secondary Stations, ex: Peach Mountain

**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**

*Model is from Mechanical Fit Check on Feb 3, 2014*
Rapid Hardware Evolution

Prototype Mechanical Fit Check
Feb 2014

Functional Engineering Model – TVAC Fixture
Apr 2014
Dark Sky StarTracker Validation
Table Mountain, Feb 2014

JPL American Flag Imaged by Star Tracker

Blue Canyon Technology Thin-Slice StarTracker
End-to-End Detumble Demonstration
Formation Flight Lab - JPL, Apr 2014
Detumble Algorithm, Gyro, and Attitude Control Demonstration

AstroDev CDH System with onboard MEMS gyro
JPL Flight Software – Joshua Schoolcraft and Thomas Werne
JPL ACS Algorithm – Dr. Eric Gustafson
U.Texas Cold-Gas Thruster System – Travis Imken and Dr. Glenn Lightsey
Thermal-Vacuum Functional Testing & Deployment Verification
JPL, Apr 2014

ISIS UHF Antenna
Pumpkin Deployable Solar Arrays
JPL CVH Magnetometer – Dr. Carol Raymond and Dr. Neil Murphy
TVAC led by Allen Kummer, with Lauren Halatek and John Leichty
• X-Band Radiating / Receiving
• Uplink / Downlink Ground SW
• Telemetry “Backbone”
• Electrical / Hardware Integration
• Flight Software Functionality w/ Subsystem Power Control
We are here!
Software has multiple (competing) objectives:
- Design Robust SW for Flight
- Design Enough SW for Immediate Test

Present Day
- ACS DeTumble
- UHF Relay
- DSN Compatibility
- System Mag
- Board Functional Testing
- System Thermal-Vac Testing / Balance
- HW Iteration

End-to-End Testing / ORTs
- Test Pod Vibe
- System TVAC / Bakeout
- COFR / Pre-Ship Review
- Ready for Flight
- End of June 2014
- Awaiting NASA CLI Manifest

Selected Subsystem TVAC
Iterate

Iterate and Re-Deliver

Thermal-Re-Design

Ambient, Hot, Cold-Vac Deploy

DSN Compatability

Sw Check

Dark Sky

Mag Improvements

Mag/EMI/EMC

Parallel Configurations are Critical

Iterate and Re-Deliver

COFR / Pre-Ship Review

System Mag

Prototype DSN Compatability

Mag/EMI/EMC

End of June 2014

Waiting NASA CLI Manifest

Antenna Tuning

DSN Compatibility
Conclusions & Lessons

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 technological challenges are not simple.

• INSPIRE would demonstrate survivability, navigation and communication utilizing the CubeSat platform, and in partnership with the CubeSat community

• Integration is never easy, and some problems are exacerbated in deep space. Thermal (no eclipse!); ACS (no magnetic fields!); Communications (need big dishes!); Tracking (no space command!)

• Iterate early, with several version of boards in the lab for parallel software development and testing. Interfaces amongst a large team are challenging, and generally limited documentation exists for CubeSats.

• Exploit existing capabilities (eg, NASA AMMOS ground software); adapt processes to meet needs and risk posture; adopt standards that make sense (CCSDS enables DSN coverage); and, sometimes, create when it “can’t be done”.

• DSN has NO fees for aperture time and RF compatibility testing. There is a setup/ configuration fee during mission development that all missions pay.