NanoSwarm: CubeSats Enabling a Discovery Class Mission

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NanoSwarm Mission Objectives

- Detailed investigation of Particles and Magnetic Fields to characterize the surface of airless planetary bodies
  - Specific target: Lunar Swirls (surface magnetic anomalies)
- Goals
  - Understand mechanisms of space weathering
  - Understand near-surface water formation and distribution on airless bodies
  - Understand how small bodies have generated dynamos and magnetized their crusts
  - Investigate the physics of particle-field interactions at the smallest scales
- Measurements:
  - Near-surface solar wind flux measurements across swirls
  - Near-surface magnetic field structure at a diverse set of lunar magnetic anomalies
  - Polar neutrons

Lunar Prospector magnetic field contours from 0 to 30 nT
NanoSwarm Mission Challenges

- **Measurements at very low altitudes**
  - Below 5Km
- **High measurement density**
- **Multiple Locations**
  - Several near-surface swirls
  - Polar Areas for Neutrons
- **Different solar illumination conditions**
  - Lunar day (28 earth days)
Solution Concept

- **Large number of “disposable” Lunar impactors**
  - Multiple locations & multiple times
  - Very low altitude measurements
  - Low-cost CubeSat based
  - Direct data dump to Earth

- **Problems**
  - Large ΔV requirements to reach Moon and target impacts
  - Potential long duration mission to satisfy different illumination requirements
  - Launch opportunities
  - Volume and mass constraints

- **Solution:** Proven spacecraft to carry probes to the Moon
Space Vehicle Concept

• **LCROSS based carrier**
  – Low-Cost spacecraft
  – Flight Proven
  – Large ΔV Capability (>1km/s)
  – Standard ESPA accommodations
    • 32 3U CubeSats (2x16)

• **Carrier Roles**
  – Inject into Lunar orbit
  – Deploy CubeSats at appropriate times
  – Support CubeSats: Thermal, Trickle Charge, Diagnostics

• **Benefits to CubeSats**
  – Low ΔV requirements
    • Impactor 50m/s – Orbiter 100m/s
  – Short mission duration
    • Impactor 11days – Orbiter 3months
  – Single launch for all mission requirements
CubeSats

• Simple Design
  – VACCO Hybrid propulsion (ΔV & Attitude Control)
  – JPL IRIS deep space transponder (Navigation & Data Download)
  – Tyvak Endeavor based avionics (C&DH and Attitude determination)

• Instruments
  – Nano-Solar Wind Ion Sensor (NanoSWIS) – UC Berkley
  – Nano-Magnetometer (NanoMAG) - UCLA
  – Nano-neutron Spectrometer (NanoNS) – APL

• 3 CubeSat types
  – Day Impactor (Qty. 15 + 2 spares)
    • NanoSWIS + NanoMAG
  – Night Impactor (Qty. 10)
    • NanoMAG
  – Neutron Orbiter (Qty. 2 + 1 spare)
    • NanoNS
CubeSats Internal Configuration

• Day Impactor

- Tyvak Main Board
- Star Tracker
- IMU
- Batteries
- Propulsion Unit
- Structure
- Boom
- Wind Instrument
- Magnetometer Boards
- Magnetometer Sensors
- IRIS Radio

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Mission Concept Observations

• Collaboration Between Traditional Spacecraft & CubeSats
  – Key Enabler for Discovery class mission
  – Traditional spacecraft reliability is critical for carrier
• Carrier reduces CubeSats requirements & complexity
  – Shorter mission timeline
    • Environmental exposure
    • Propulsive Attitude control
  – Lower ΔV
    • Low complexity propulsion system
• Science measurements require extremely low altitude & multiple measurements
  – “Disposable” impactor is ideal sensor
  – Low-cost CubeSats provide measurement multiplicity & redundancy
• COTS based CubeSats provide low recurrent cost
  – Large numbers of identical CubeSats are “very affordable”
• Most required technologies available in CubeSat form factor
  – IRIS radio, Propulsion system, Avionics, Instruments, Deployers, . . .
Conclusions

- CubeSats can play at Discovery mission level
- Dangerous measurements ➔ low-cost disposable sensors
- Low-cost spacecraft can provide large measurement numbers
- Collaboration with traditional spacecraft creates new opportunities
- Science community must identify appropriate problems