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Nano-Satellite Systems Inc.

NanoSwarm: CubeSats Enabling a Discovery Class Mission

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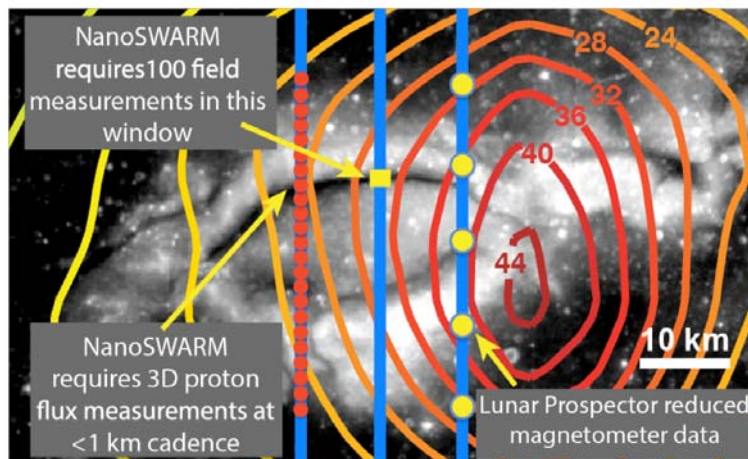
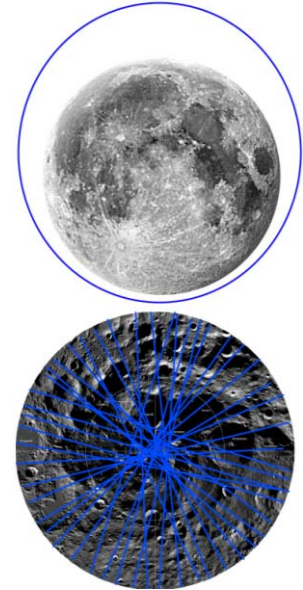
NanoSwarm Mission Objectives

- **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

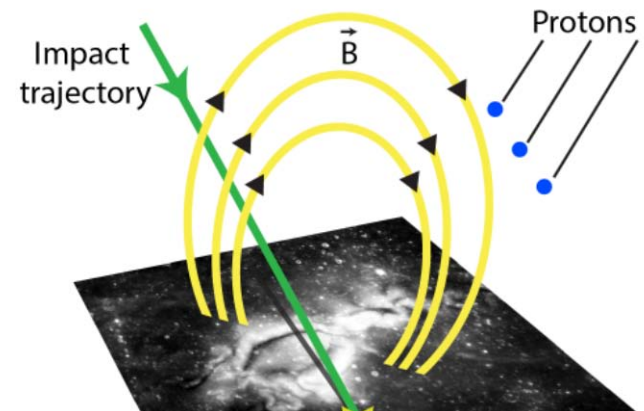
Lunar Prospector
magnetic field contours
from 0 to 30 nT

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)



Magnetic anomaly measurements



Solution Concept

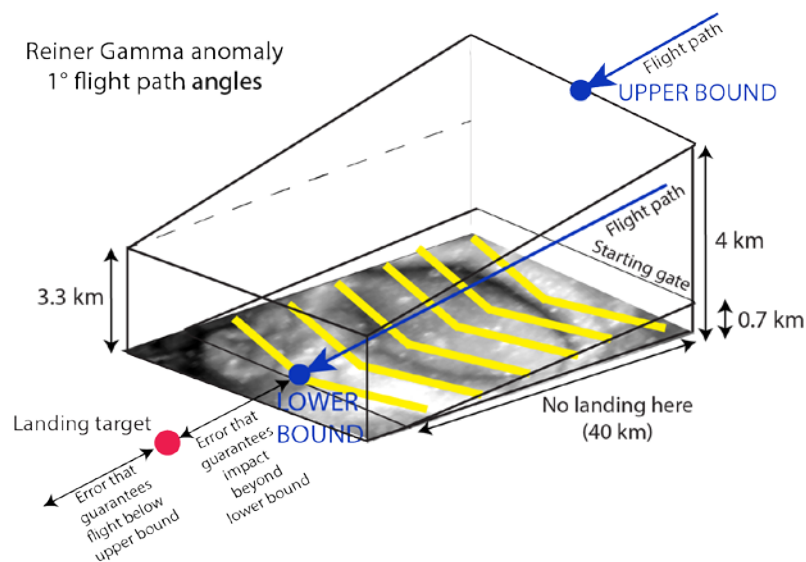
- **Large number of “disposable” Lunar impactors**

- 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 constrains

- **Solution: Proven spacecraft to carry probes to the Moon**



Space Vehicle Concept

- **LCROSS based carrier**

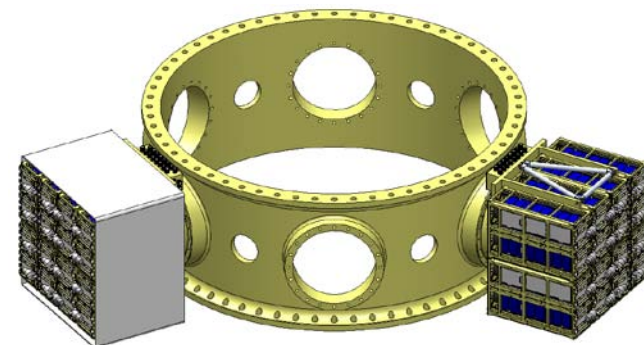
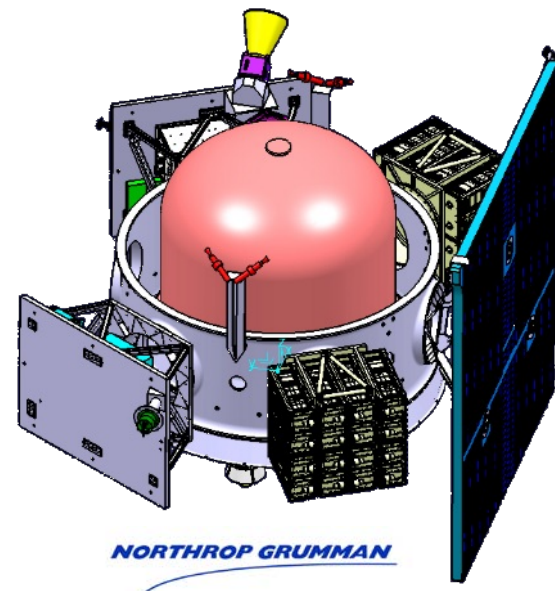
- Low-Cost spacecraft
- Flight Proven
- Large ΔV Capability ($>1\text{km/s}$)
- Standard ESPA accommodations
 - 32 3U CubeSats (2x16)

- **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**

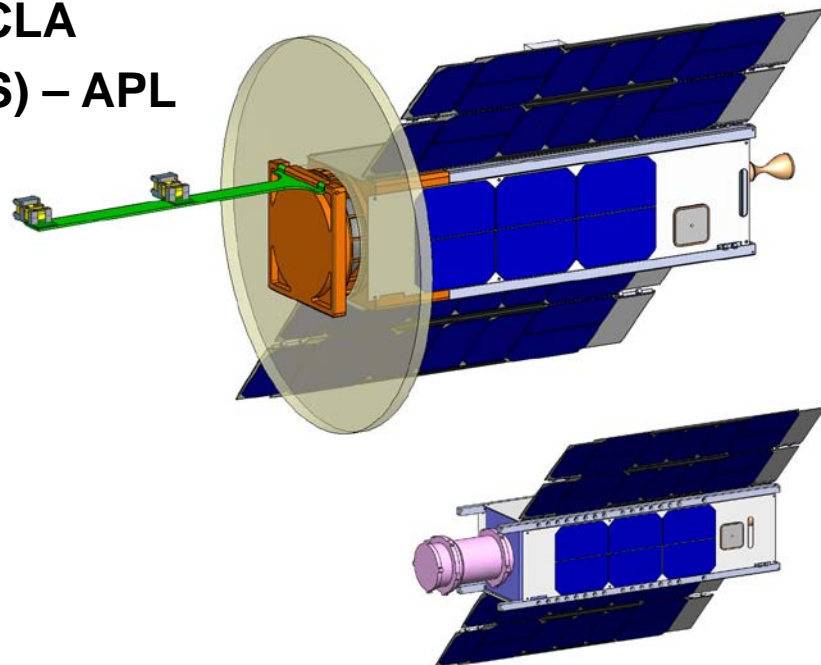
- VACCO Hybrid propulsion (ΔV & Attitude Control)
- JPL IRIS deep space transponder (Navigation & Data Download)
- Tyvak Endeavor based avionics (C&DH and Attitude determination)

- **Instruments**

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

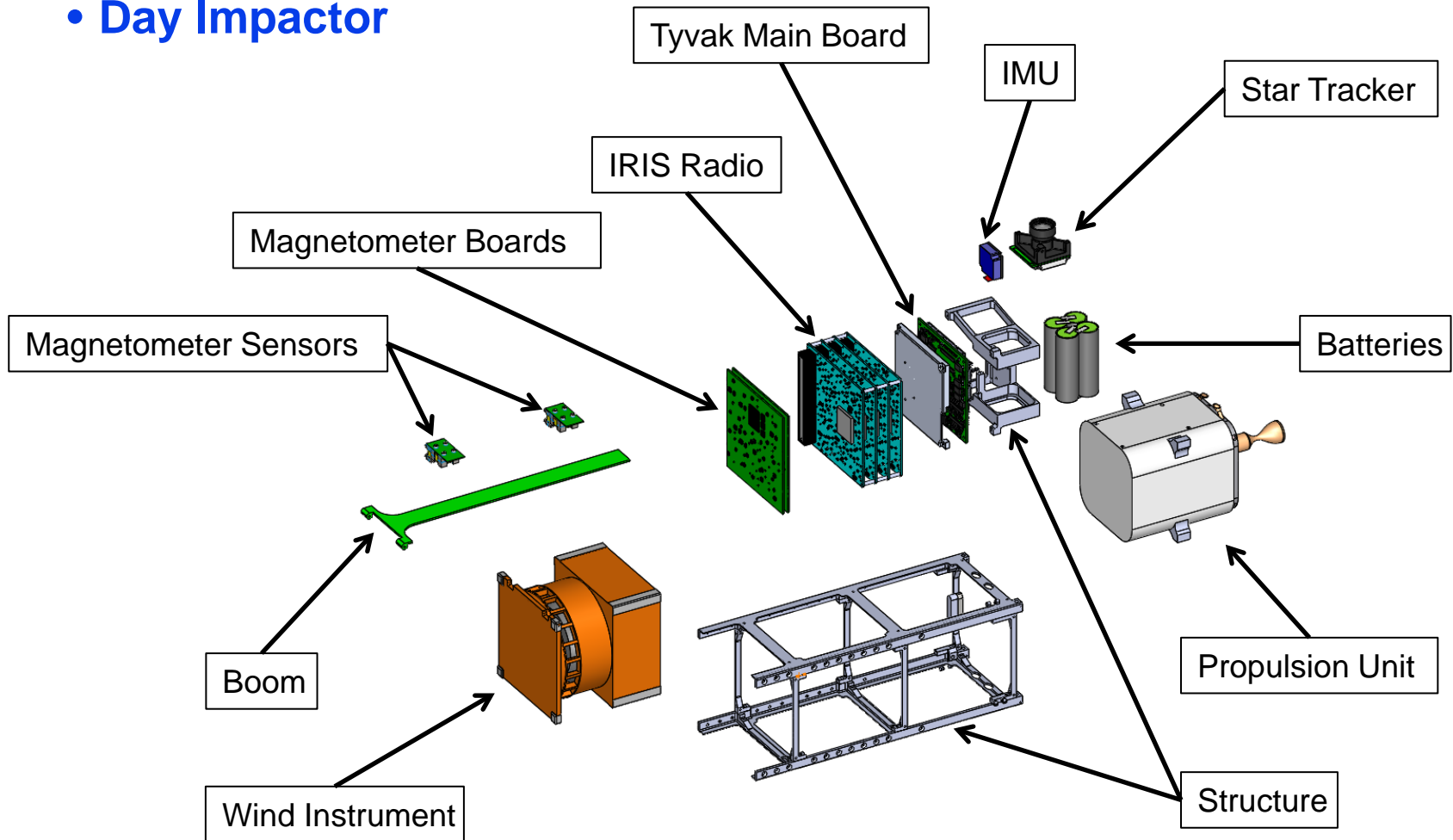
- **3 CubeSat types**

- 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



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**

