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NanoSwarm: CubeSats Enabling a Discovery Class Mission

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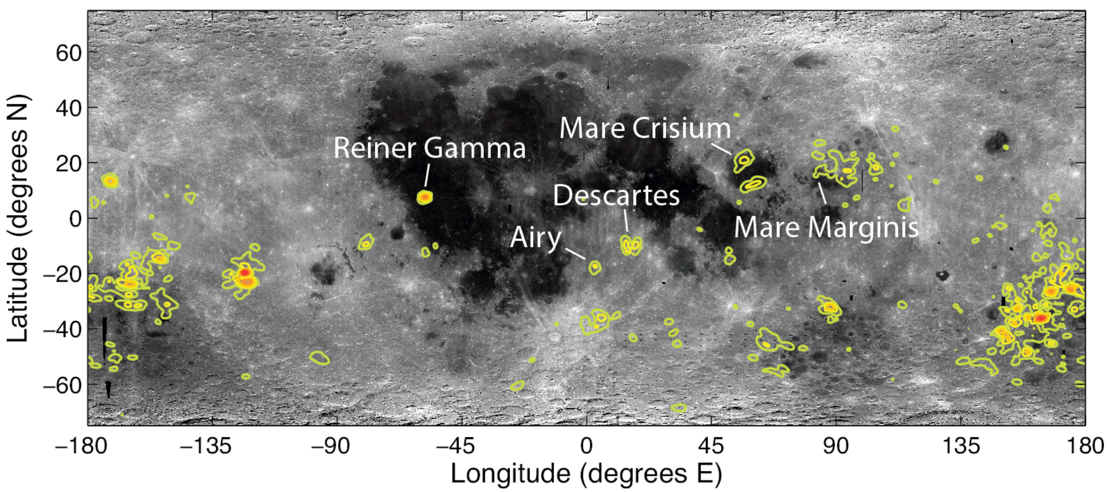
NanoSwarm Mission Objectives

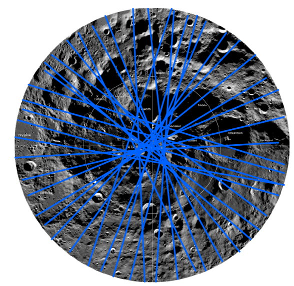
- **Detailed investigation of Particles and Magnetic Fields to characterize the surface of airless planetary bodies**
  - **Specific target: Lunar Swirls (surface magnetic anomalies)**
- **Goals**
  - **Understand mechanisms of space weathering**
  - **Understand near-surface water formation and distribution 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**

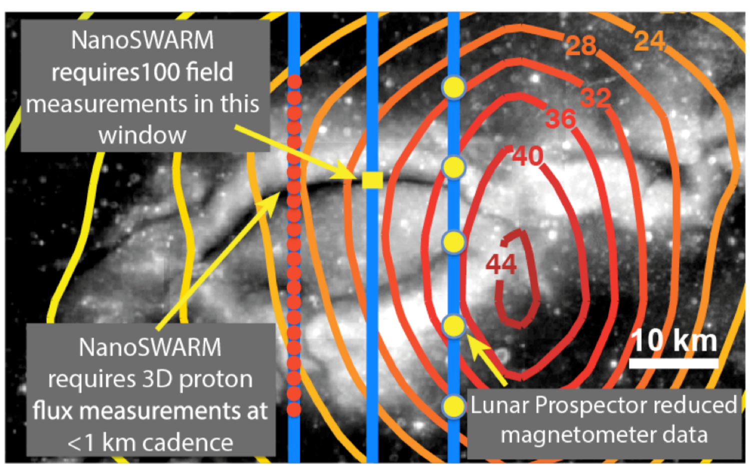


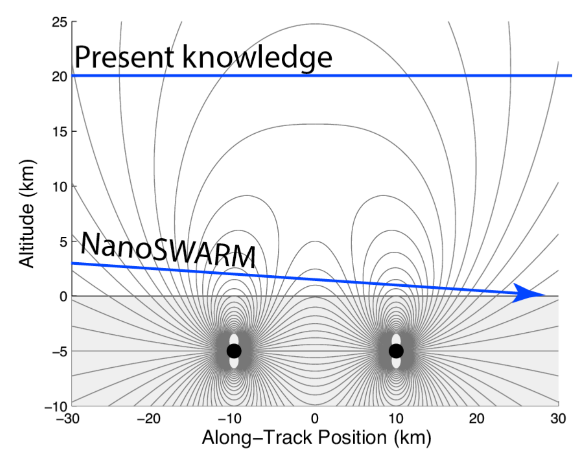
Lunar Prospector magnetic field contours from 0 to 30 nT

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)**

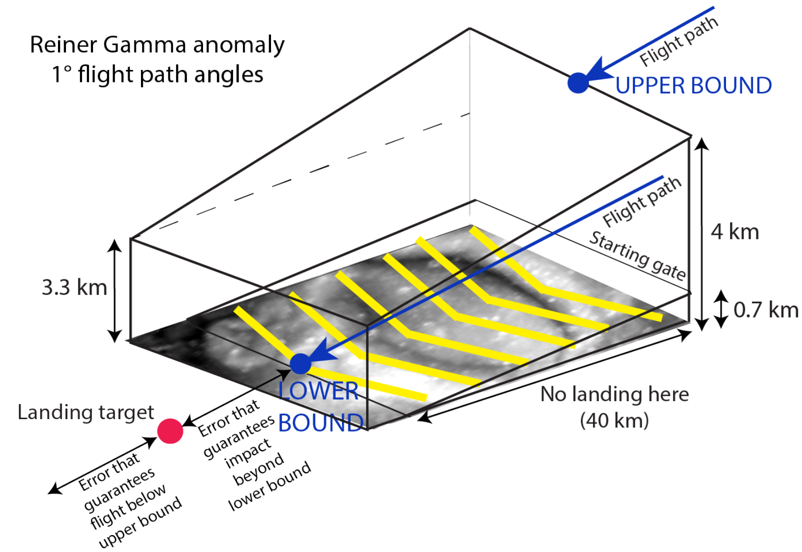






Solution Concept

- **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**

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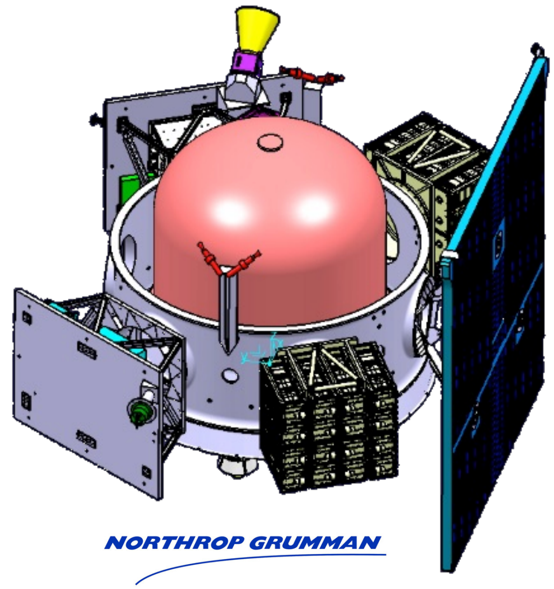
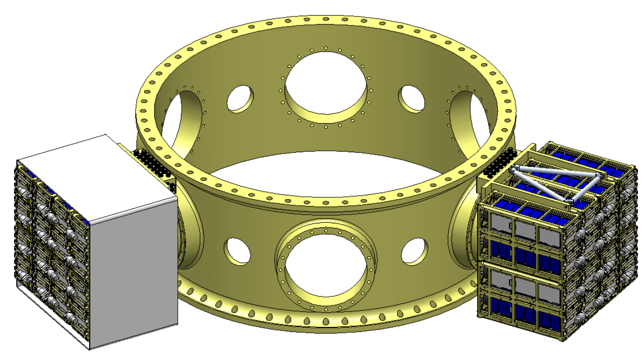
Space Vehicle Concept

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

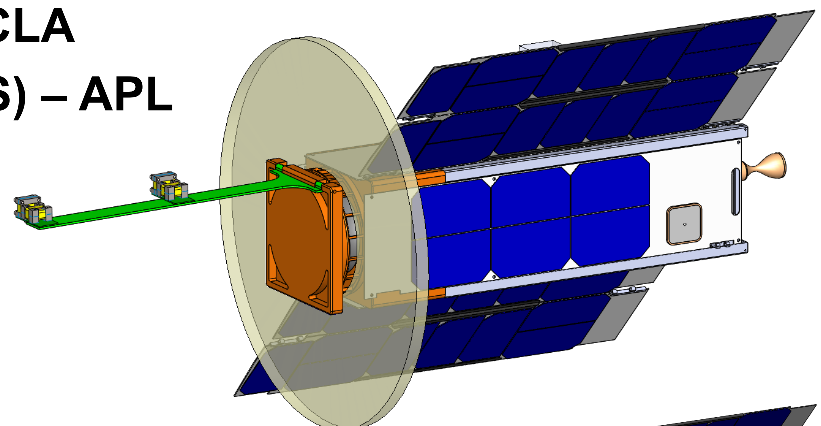


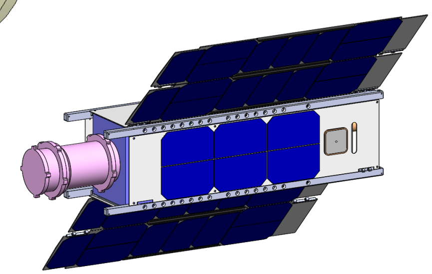
- **Carrier Roles**
  - Inject into Lunar orbit
  - Deploy CubeSats at appropriate times
  - Support CubeSats: Thermal, Trickle Charge, Diagnostics
- **Benefits to CubeSats**
  - Low ΔV requirements
    - Impactor 50m/s – Orbiter 100m/s
  - Short mission duration
    - Impactor 11days – Orbiter 3months
  - 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





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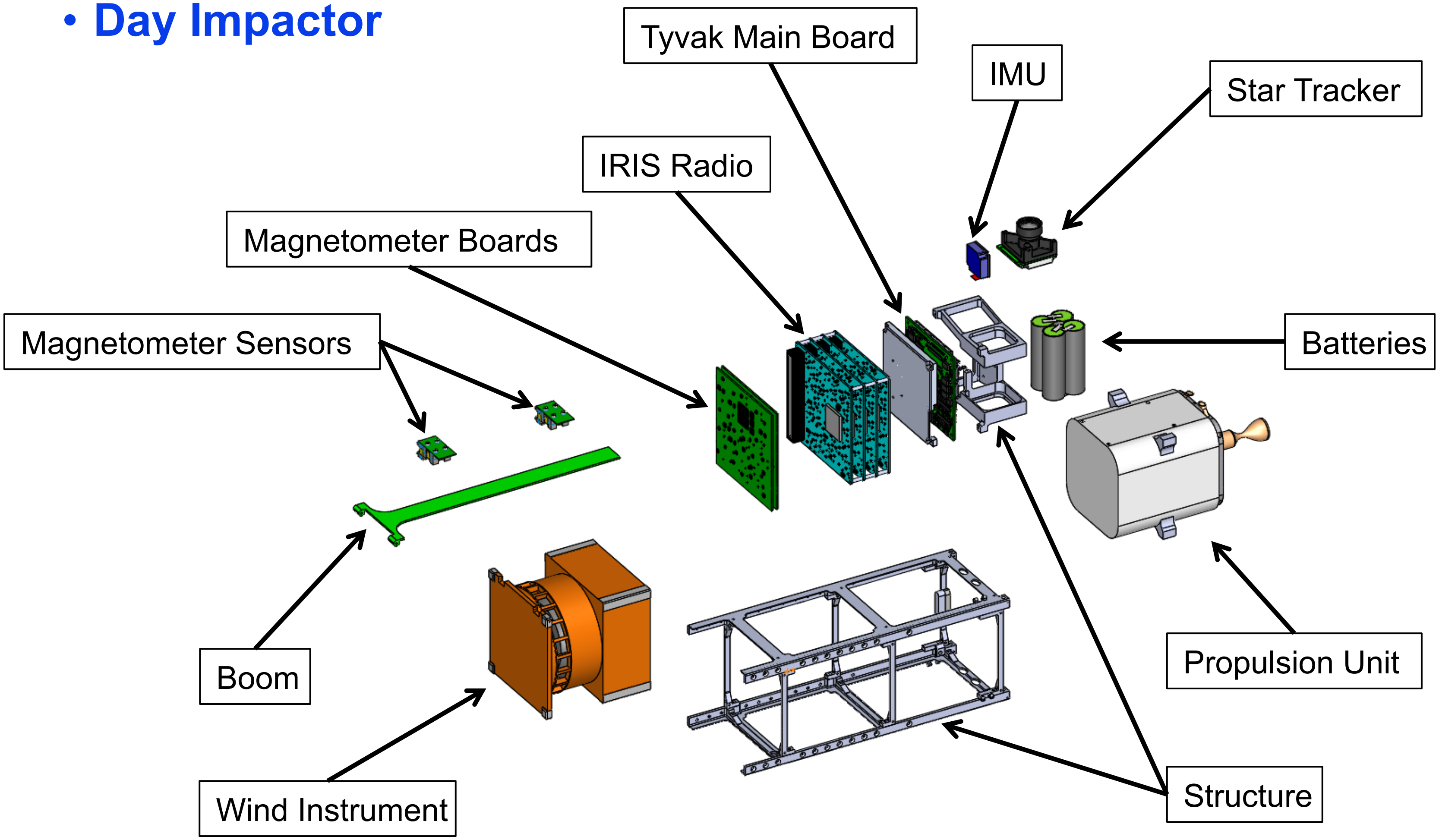
CubeSats Internal Configuration

- **Day Impactor**

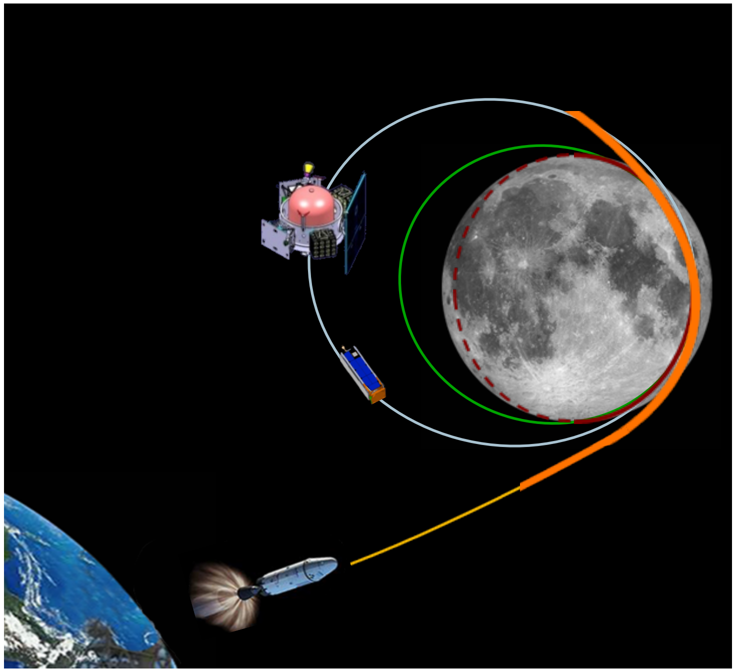


Mission Concept Observations

- 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



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