Near Earth Asteroid Scout Mission

AIAA Space 2014
7 August 2014

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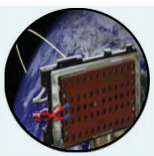
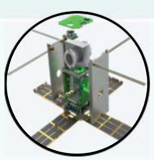
SLS EM-1 Secondary Payload Overview

- **HEOMD's Advanced Exploration Systems (AES) selected 3 concepts for further refinement toward a combined Mission Concept Review (MCR) and System Requirements Review (SRR) planned for August 2014**
- **Primary selection criteria:**
  - Relevance to Space Exploration Strategic Knowledge Gaps (SKGs)
  - Life cycle cost
  - Synergistic use of previously demonstrated technologies
  - Optimal use of available civil servant workforce
- **Project in Pre-formulation**
- **Completed a Non-Advocate Review of the Science Plan**

Payload *NASA Centers*	**Strategic Knowledge Gaps Addressed**	**Mission Concept**
BioSentinel ***ARC***/*JSC* 	**Human health/performance in high-radiation space environments** • Fundamental effects on biological systems of ionizing radiation in space environments	Study radiation-induced DNA damage of live organisms in cis-lunar space; correlate with measurements on ISS and Earth
Lunar Flashlight ***JPL***/*MSFC* 	**Lunar resource potential** • Quantity and distribution of water and other volatiles in lunar cold traps	Locate ice deposits in the Moon's permanently shadowed craters
Near Earth Asteroid (NEA) Scout ***MSFC***/*JPL* 	**Human NEA mission target identification** • NEA size, rotation state (rate/pole position) **How to work on and interact with NEA surface** • NEA surface mechanical properties	Flyby/rendezvous and characterize one NEA that is candidate for a human mission

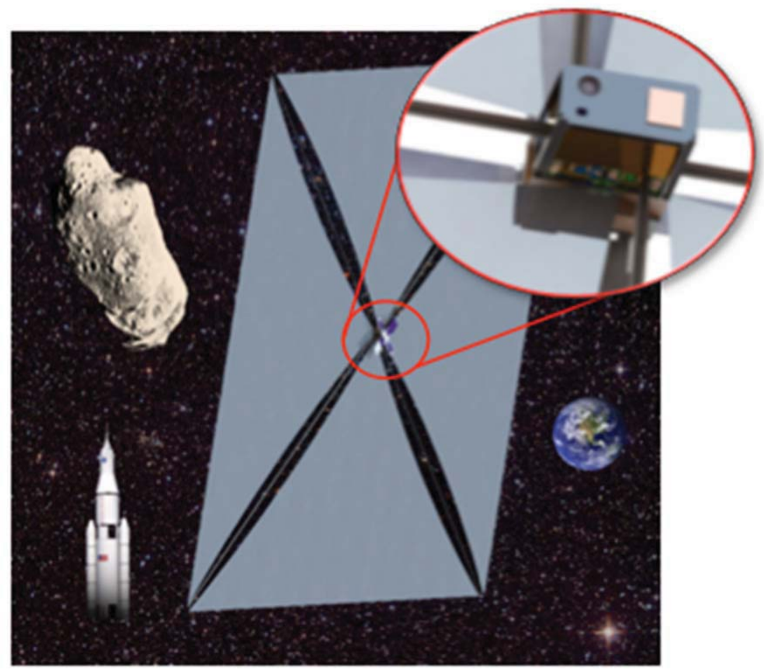
NEA Scout Overview

Why NEA Scout?

- Characterize a NEA with an imager to address key Strategic Knowledge Gaps (SKGs)
- Demonstrates low cost reconnaissance capability for HEOMD (6U CubeSat)

Leverages:

- Solar sail development expertise (NanoSail-D, Sunjammer, LightSail-1)
- CubeSat developments and standards (INSPIRE, University & Industry experience)
- Synergies with Lunar Flashlight are in review (Cubesat bus, solar sail, communication system, integration & test, operations)



Measurements: *NEA volume, spectral type, spin mode and orbital properties, address key physical and regolith mechanical SKG*

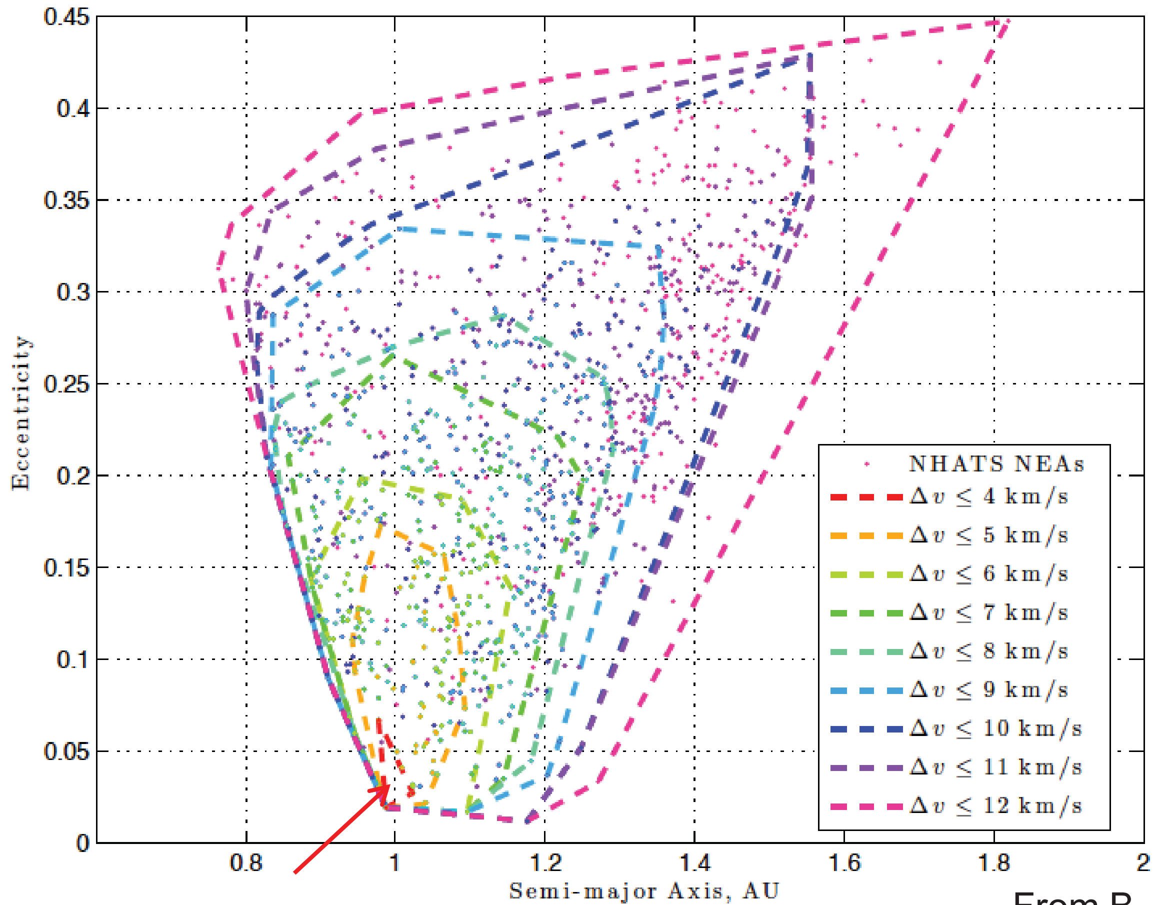
- ≥80% surface coverage imaging at ≤50 cm/px
- Spectral range: 400-900 nm (incl. 4 color channels)
- ≥30% surface coverage imaging at ≤10 cm/px

Key Technical Constraints:

- 6U Cubesat and ~80 m^2 sail to leverage commonalities with Lunar Flashlight, expected deployer compatibility and optimize cost
- Target must be within 1 AU distance from Earth due to telecom limitations
- Slow flyby with target-relative navigation on close approach

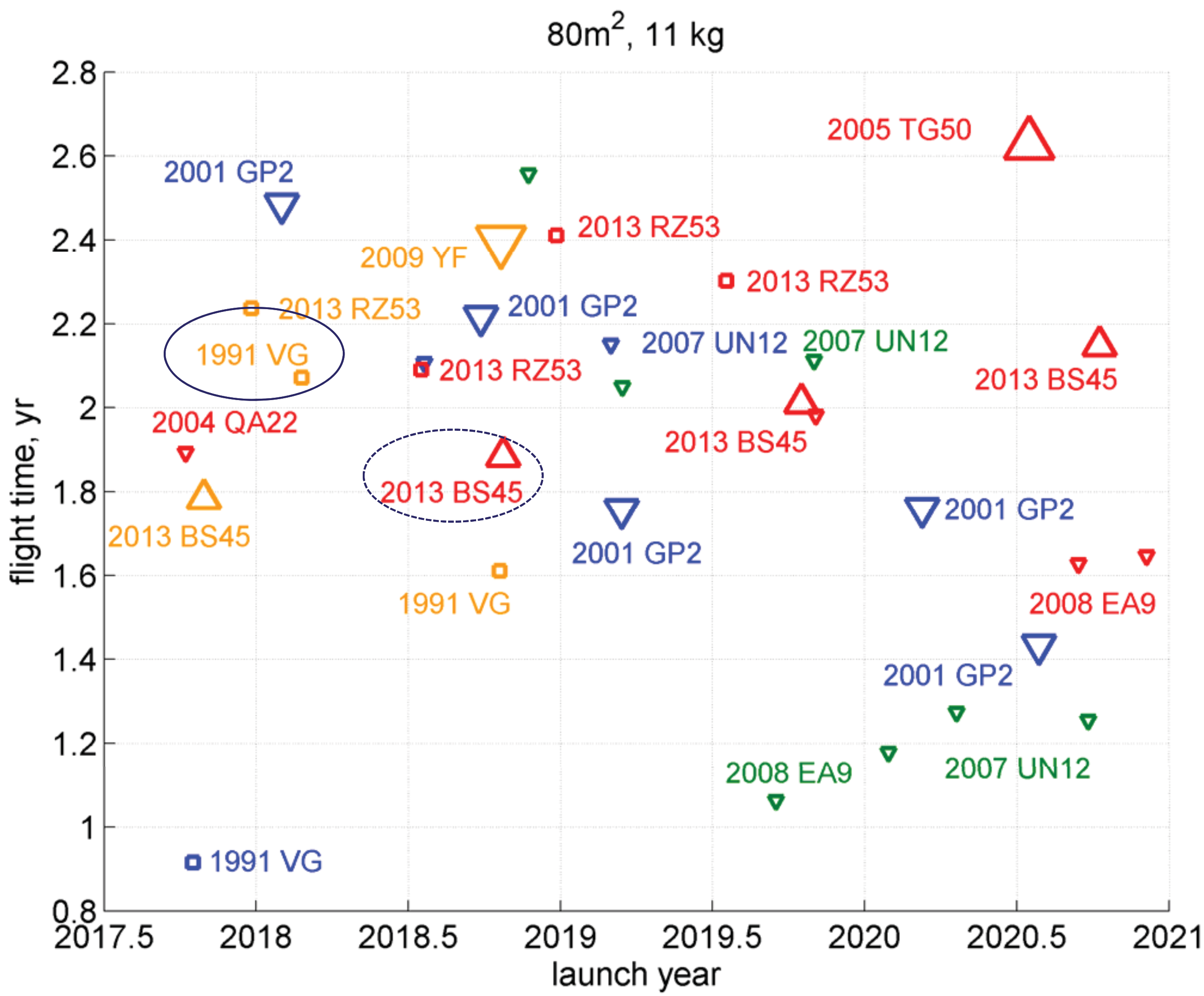
NEA Scout Targets an NHAT

- NHATS database contains targets from 1 m to >1 km
  - Do not all carry same value: low orbit condition code, >10 m, synodic period < 10 yr are of high priority
- Targets accessible to NEA Scout are < 50m



From B. Barbee (2013)

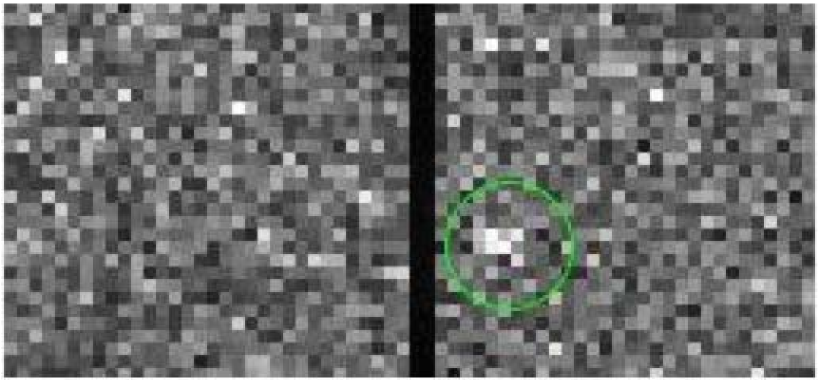
Rendezvous Target Search



- **Telecom Distance (AU)**
  - blue < .25
  - green < .5
  - orange < .75
  - red < 1
- **OCC**
  - △ under 2
  - □ under 4
  - ▽ under 7
- **Size (appx dia.)**
  - small < ~15 m
  - med. < ~30 m
  - large < ~50 m

Local minima for flight time. Flight time increases linearly with pre-escape loiter time
Flight time increases non-linearly with delayed escapes

What Do We Know About 1991 VG and Backups



2013 BS45 (radar, courtesy of Lance Benner):

- H=28.4±0.7
- Diameter ~ 5-12 meters
- Albedo is unknown
- Rotation period between a few minutes and less than 1 hr
- Unlikely to have a companion
- Likely did not retain an exosphere or dust cloud
  - Solar radiation pressure sweeps dust on timescales of hours or day

NEA	Absolute magnitude	30% albedo Diameter (m)	5% albedo Diameter (m)	Orbit Condition Code	Observation Opportunity prior to launch
1991 VG	28.5	5	12	2	2017-07 (Optical)
2001 GP_2	26.9	10	25	6	Depends on launch date 2020-10 (Optical)
2013 BS45	25.9	11	51	0	2015-01 (Optical)
2008 EA_9	27.7	7	17	5	none
2012 UV_{136}	25.5	19	47	1	2014-08 (Optical) 2020-05 (RADAR)

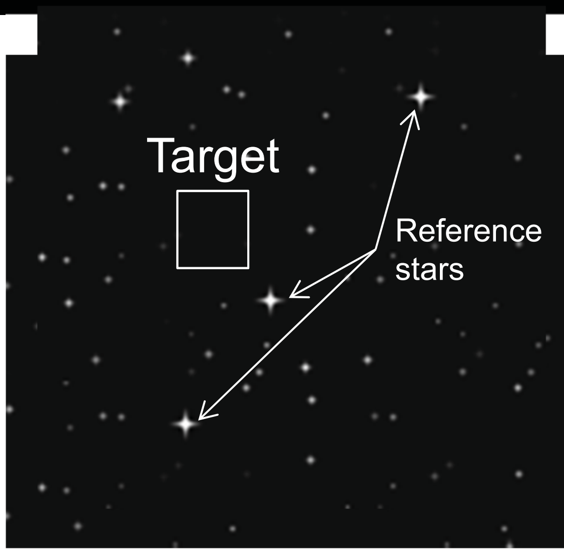
Prioritized Strategic Knowledge Gaps

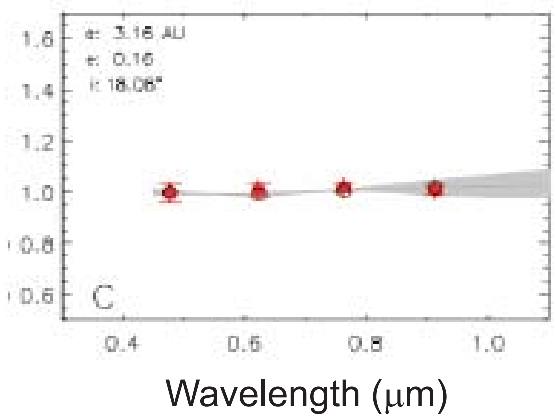
HEO-Defined Strategic Knowledge Gaps	Expected Performance	Risk Reduction or Benefit
Location (position prediction/orbit)	OCC decrease to 0	Crew/Mission, Operations, Cost
Size (existence of binary/ternary)	High accuracy on size, detection of satellites	Crew/Mission, Operations, Cost, Performance
Rotation rate & pole orientation	High accuracy on pole and velocity	Crew/Mission, Operations, Cost, Performance
Particulate environment/Debris field	Depends on flyby vs. rendezvous	Crew/Mission, Operations, Cost, Performance, Science/Engineering
Regolith mechanical & geotechnical properties	Indirect (imagery interpretation)	Crew/Mission, Operations, Cost, Performance, Science/Engineering
Mass/density estimates (internal structure)	Indirect (based on taxonomic characterization)	Operations, Cost, Performance
Surface morphologies and properties	Depends on flyby vs. rendezvous	Crew/Mission, Operations, Cost, Performance, Science/Engineering
Mineralogical & chemical composition	Indirect from taxonomic characterization	Crew/Mission, Operations, Cost, Performance, Science/Engineering

Crew/Mission Operations Cost Performance Science/Engineering

Ref – Abell and Castillo

Summary: NEAScout Observation Plan



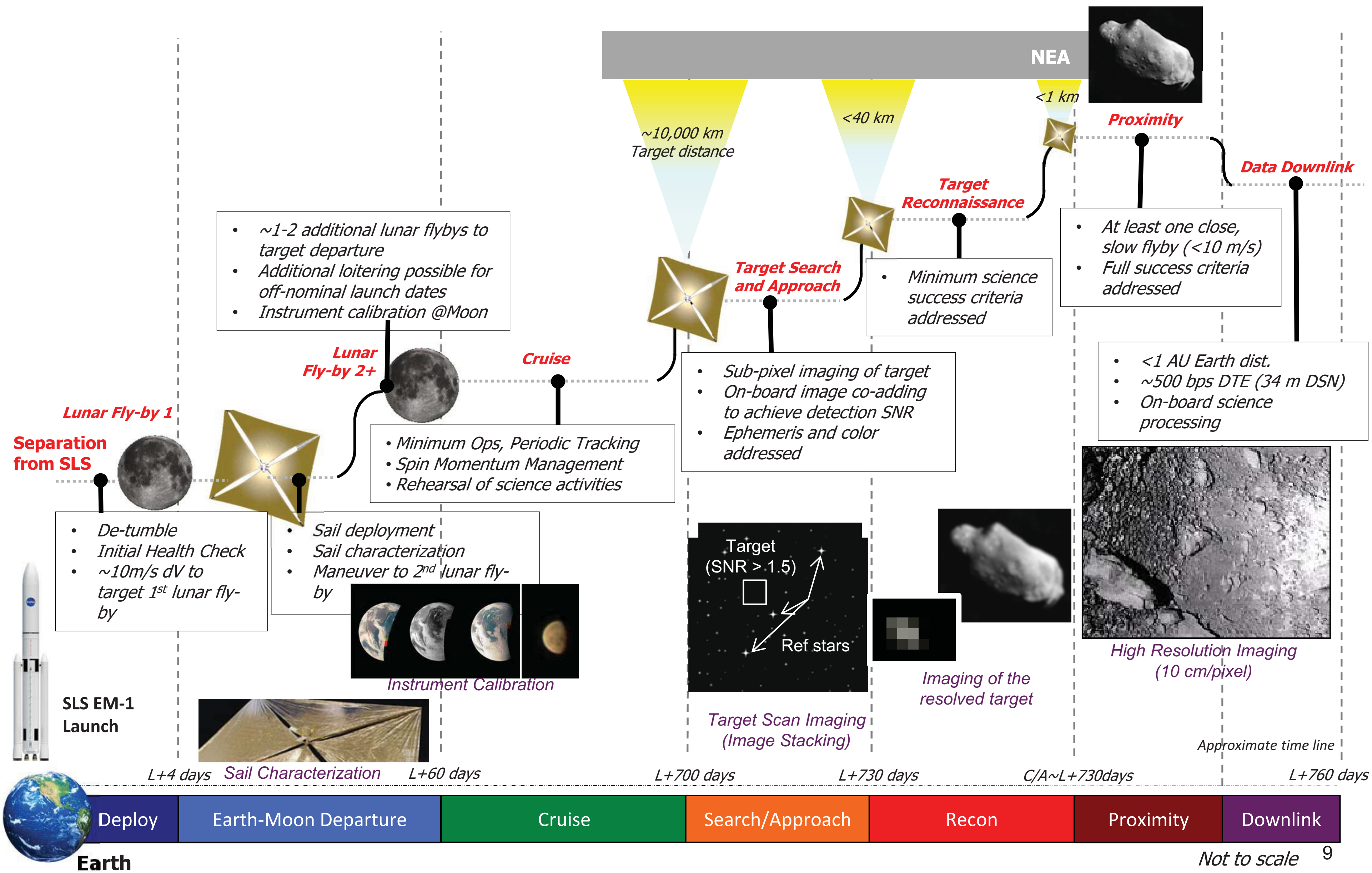


Target Detection and Approach
SNR >1.5 of target at 10K km, before frame co-adding, spectral class
SKGs: Ephemeris determination and composition assessment

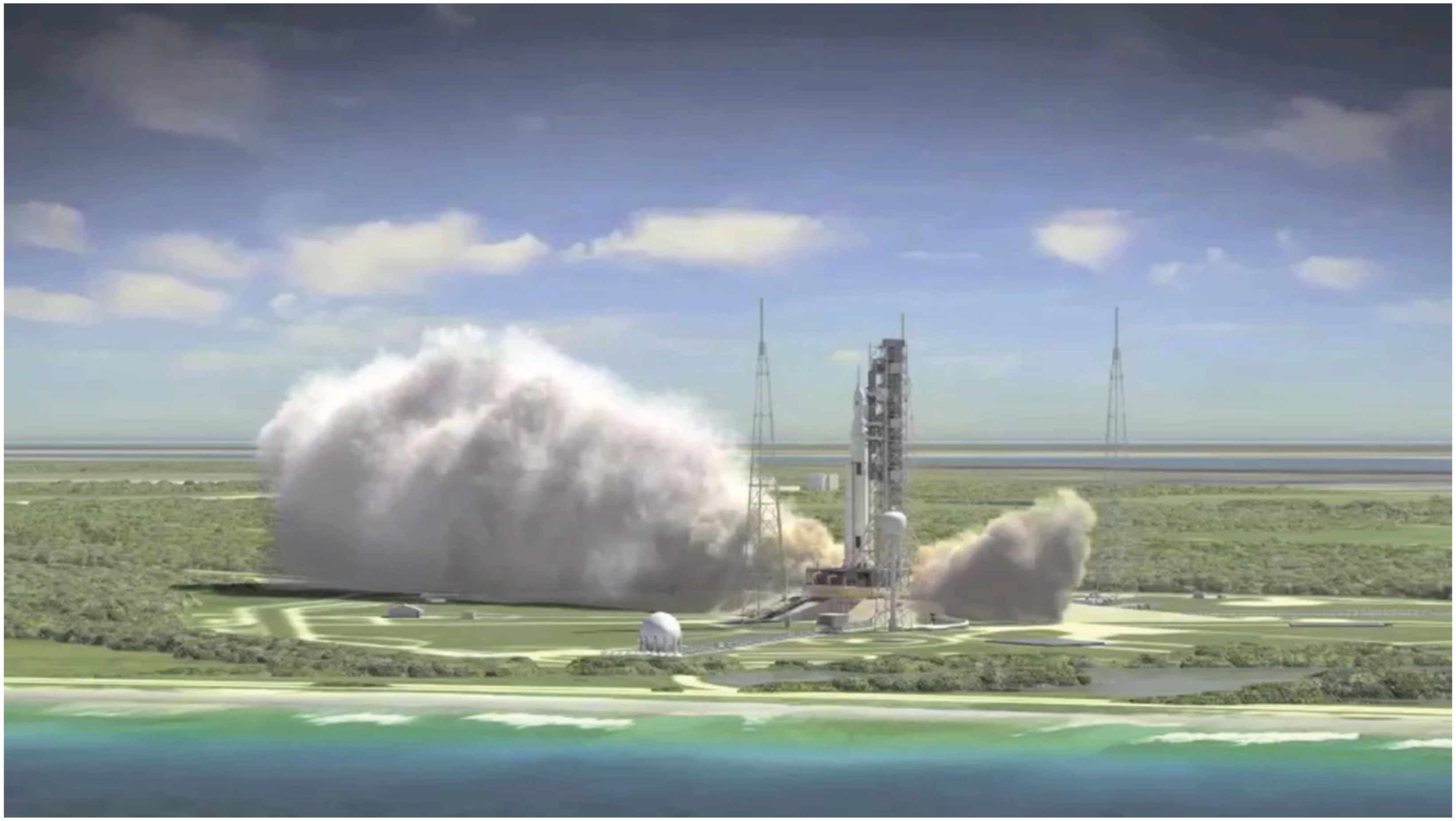
Target Reconnaissance
50 cm/px resolution over 80% surface
SKGs: volume, global shape, spin rate and pole position determination

Close Proximity Imaging
High-resolution imaging,
10 cm/px GSD
SKGs: Medium-scale morphology, regolith properties, and local environment characterization

NEA Scout ConOps Summary

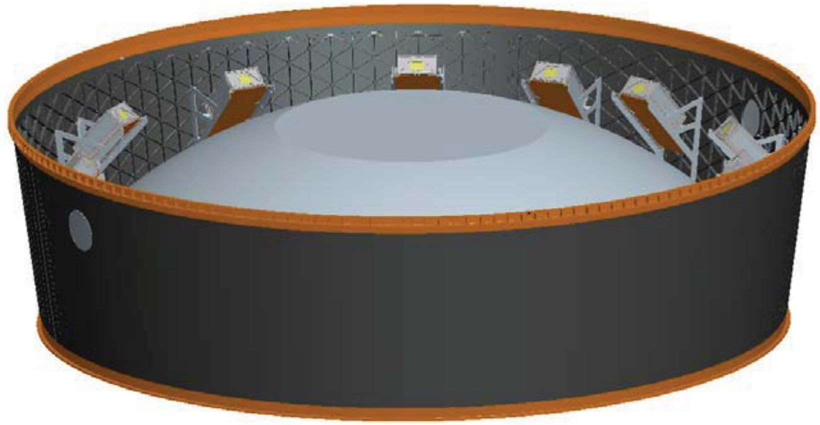


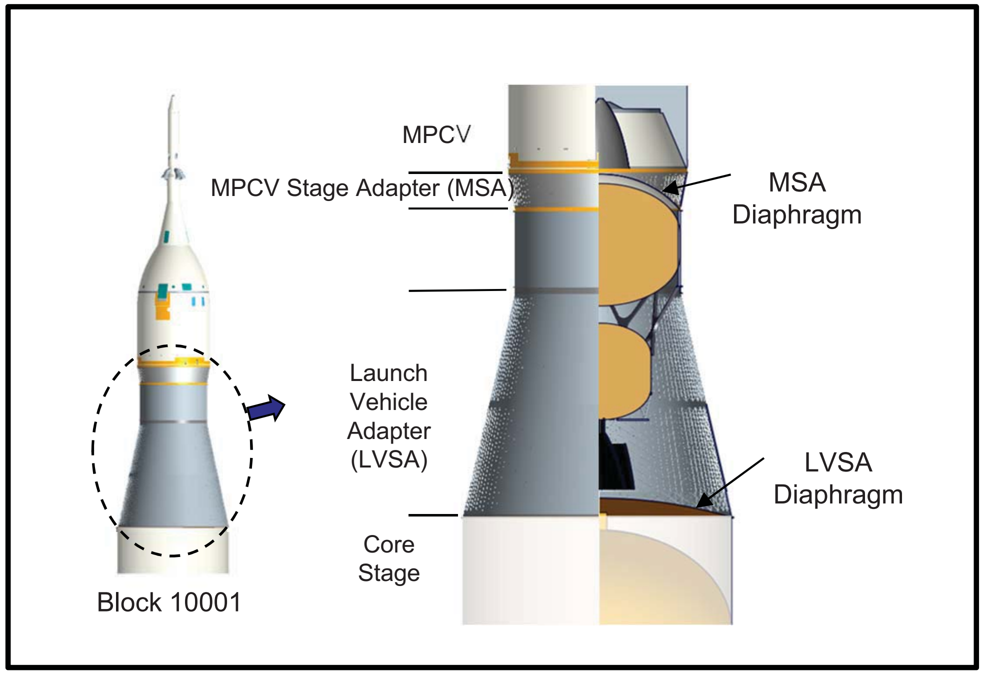
NEA Scout Animation



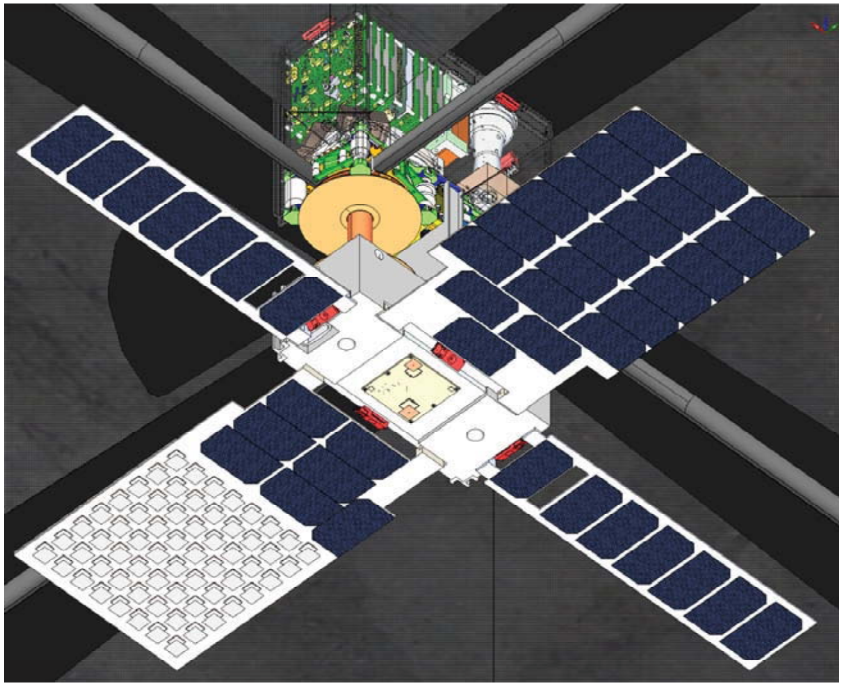
SLS Integration

- Notional Launch on SLS EM-1 (Dec. 2017)
- Secondary payloads will be integrated on the MPCV stage adapter (MSA) on the SLS upper stage.
- Secondary payloads will be deployed on a trans-lunar trajectory after the upper stage disposal maneuver.





NEA Scout Flight System Overview



Mission: Retire Strategic Knowledge Gaps at a Near-Earth Asteroid

Launch Opportunity: SLS EM-1 (Dec. 2017 notional launch)

Bus: JPL Deep Space NanoSat Bus (based on INSPIRE)

Form Factor: “6U” CubeSat (<12kg)

Main Propulsion: MSFC ~80 m^2 Solar Sail (based on NanoSail-D)

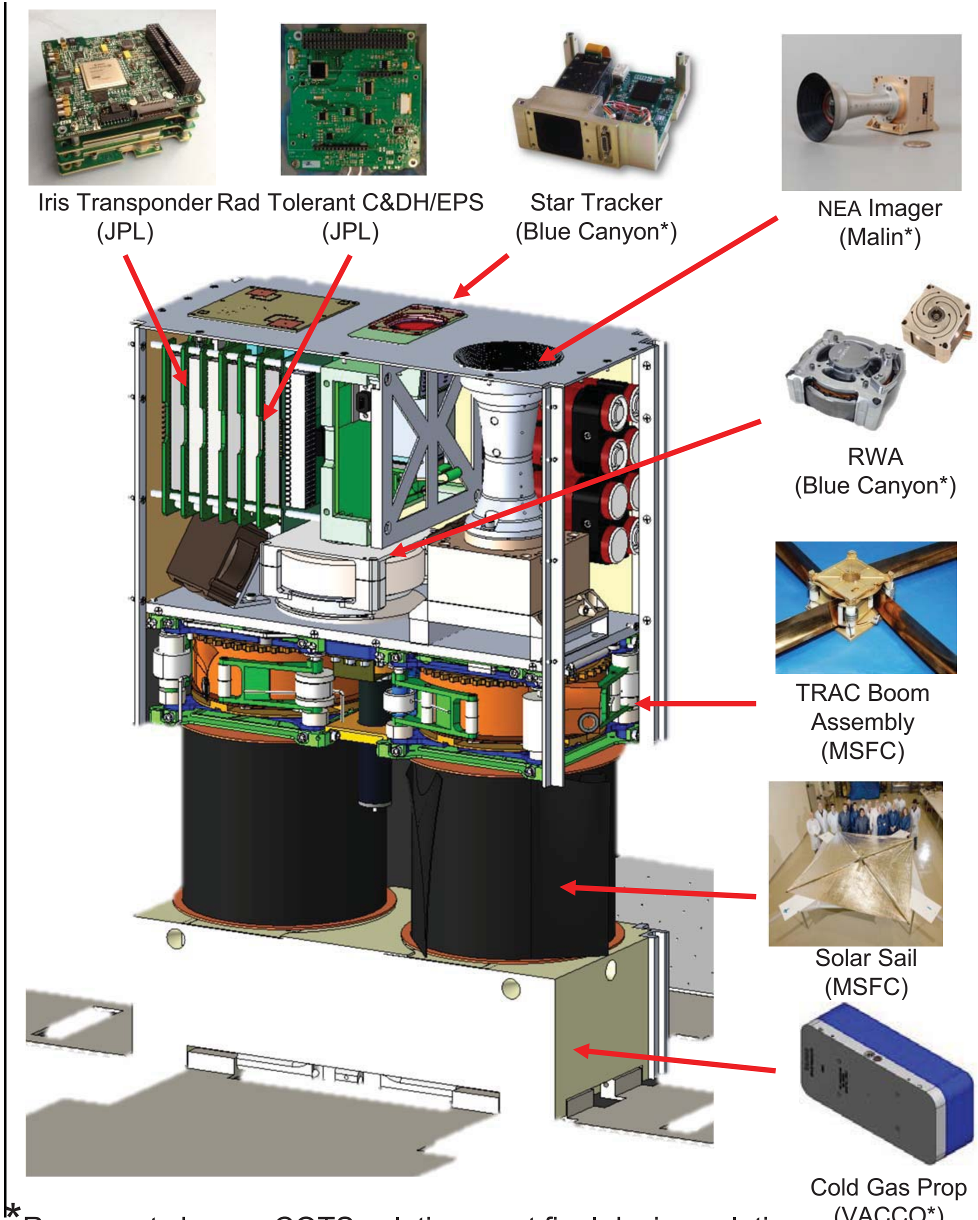
Payload: COTS NEA Imager, e.g. MSSS ECAM M-50

Command & Data Sys.: Radiation tolerant LEON3 architecture

Attitude Control: 3-Axis Control (Zero-momentum spin cruise)

Electrical Power: ~35W (@1 AU)

Telecom: JPL Iris, INSPIRE LGA (2 Pair) + Microstrip Array HGA (~500 bps @ 0.75 AU to 34m DSN)

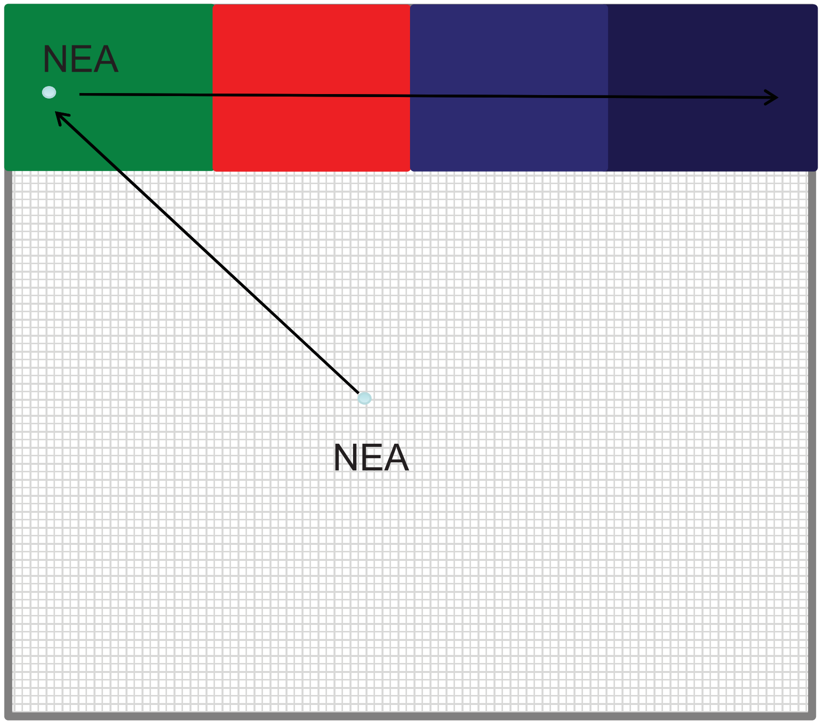


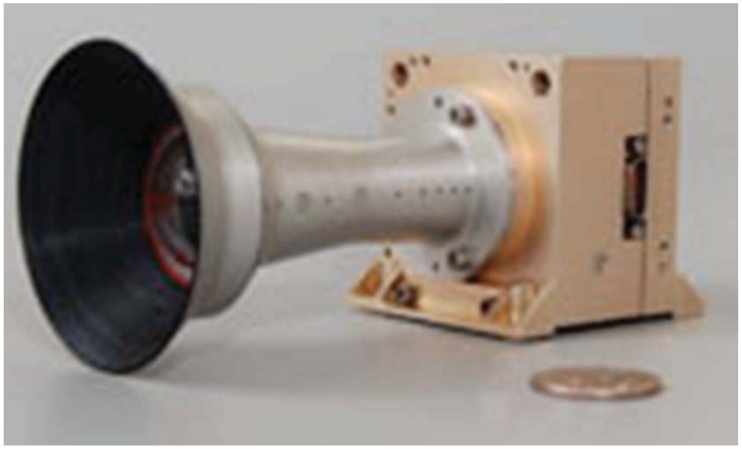
*Represents known COTS solutions, not final design solution

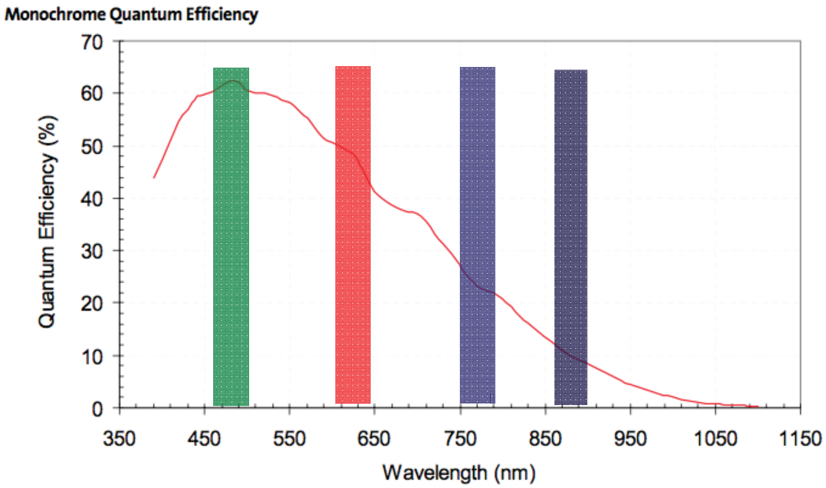
Instrument Concept

<u>Baseline</u>

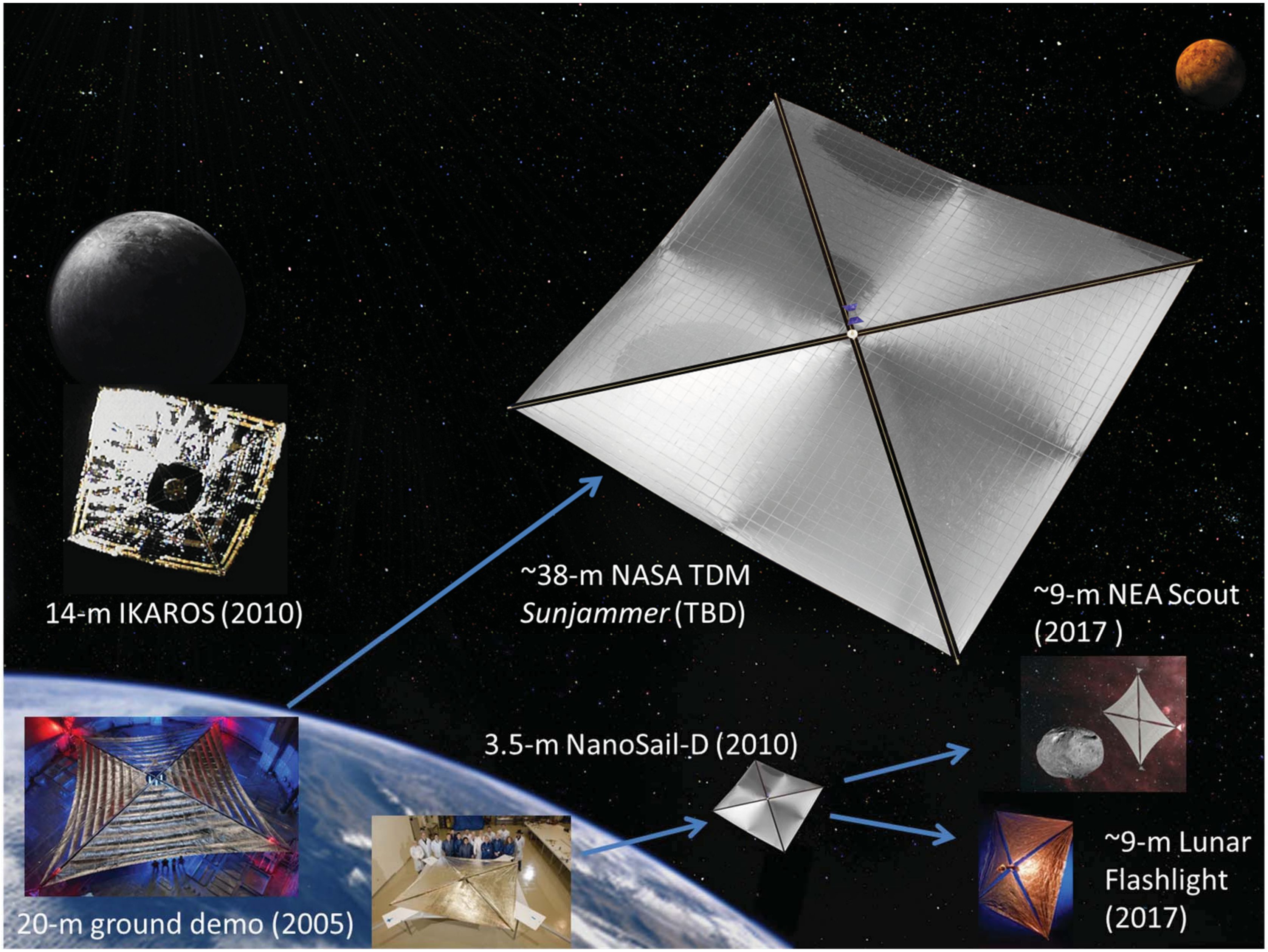
- MSSS ECAM M-50 camera with NFOV lens
- COTS, TRL 8 via OSIRIS-Rex, excellent IFOV & FOV, volume, power
- Aptina MT9P031 FPA





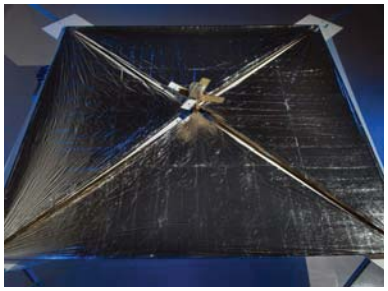


Solar Sail Propulsion Summary



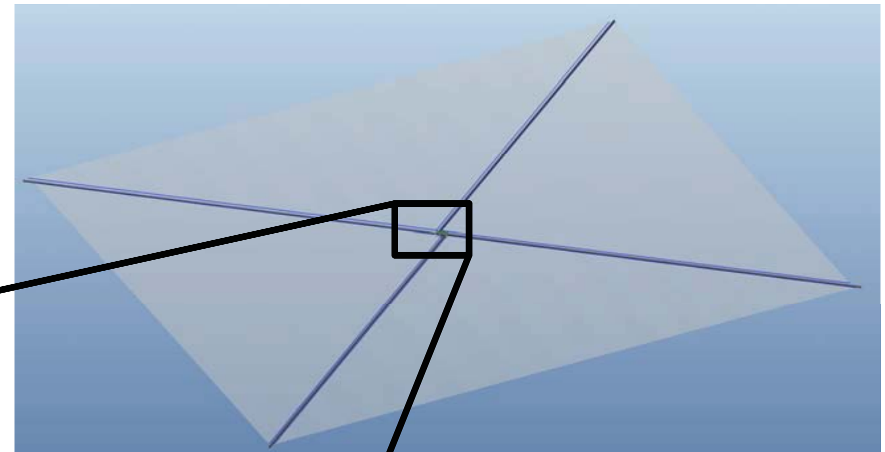
Solar Sail Design

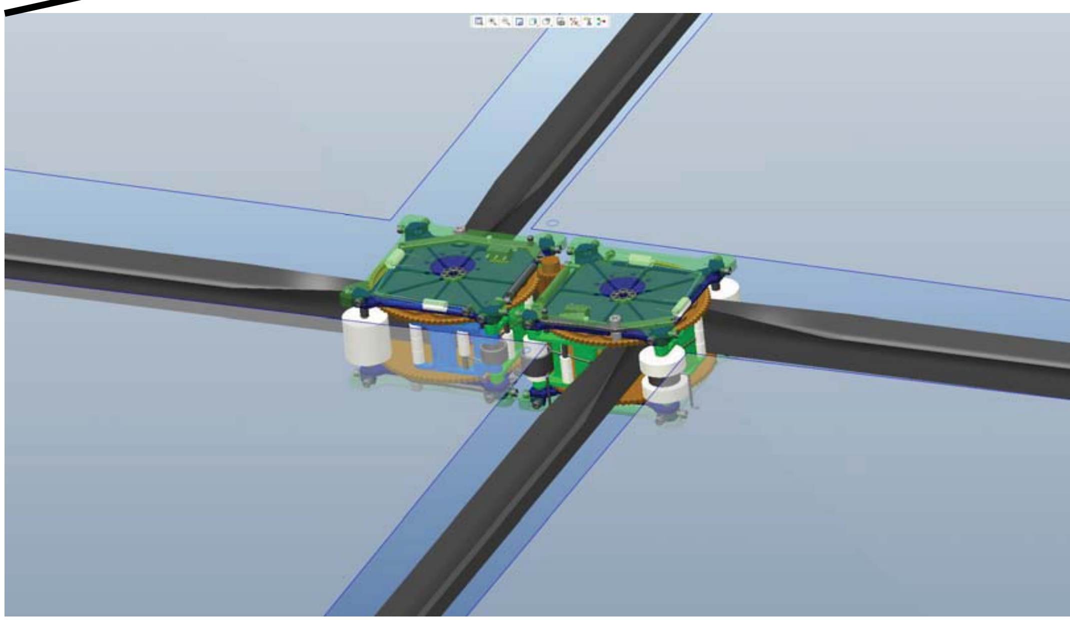
Sail Design by MSFC

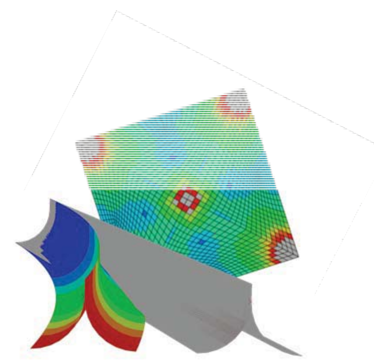


NanoSail-D2 (flown in 2010)

TRAC Boom Deployer



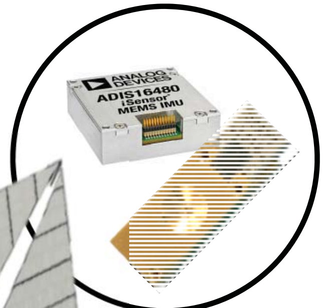




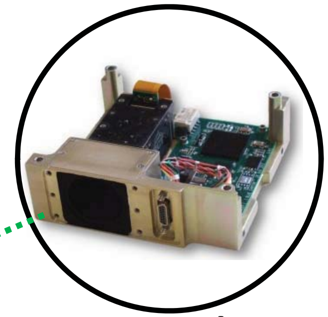
Structural Analysis by LaRC

ACS Architecture

Spinning Sail
- Induce a slow, 1 rev/hour spin about the norm of the sail
- Averages momentum accumulation over mission

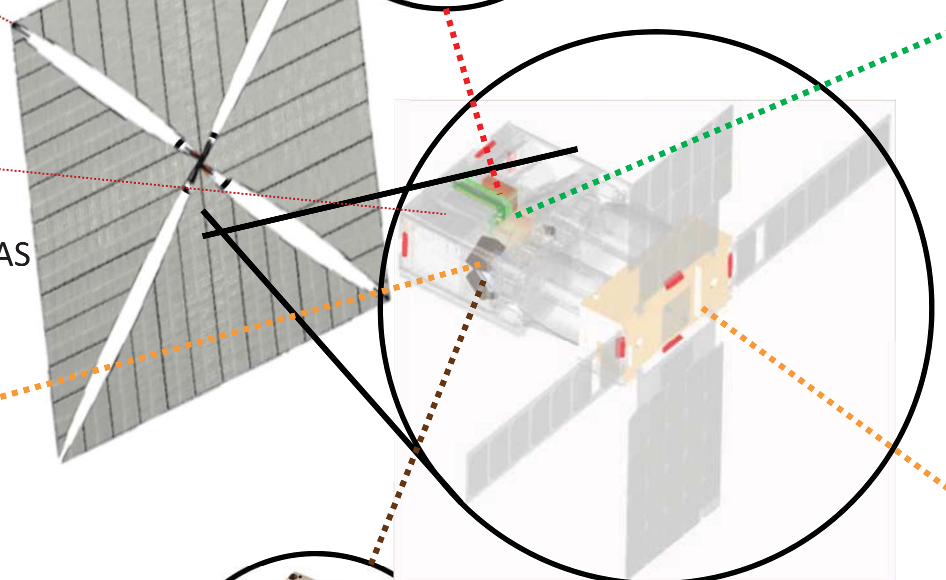


Sun Sensors/IMUs
- ~0.5 deg accuracy
- Detumbling
- Safe mode
- Rapid slews



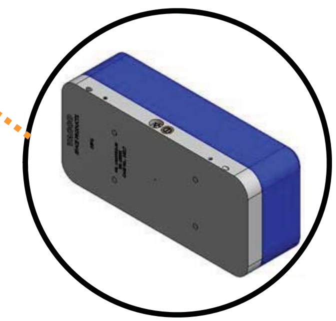
Star Tracker
- ~0.01 deg accuracy
- Fine pointing in interplanetary space

Pointing Algorithms
- Pointing accuracy for thrust vectoring, LF science
- Pointing stability for NEAS science



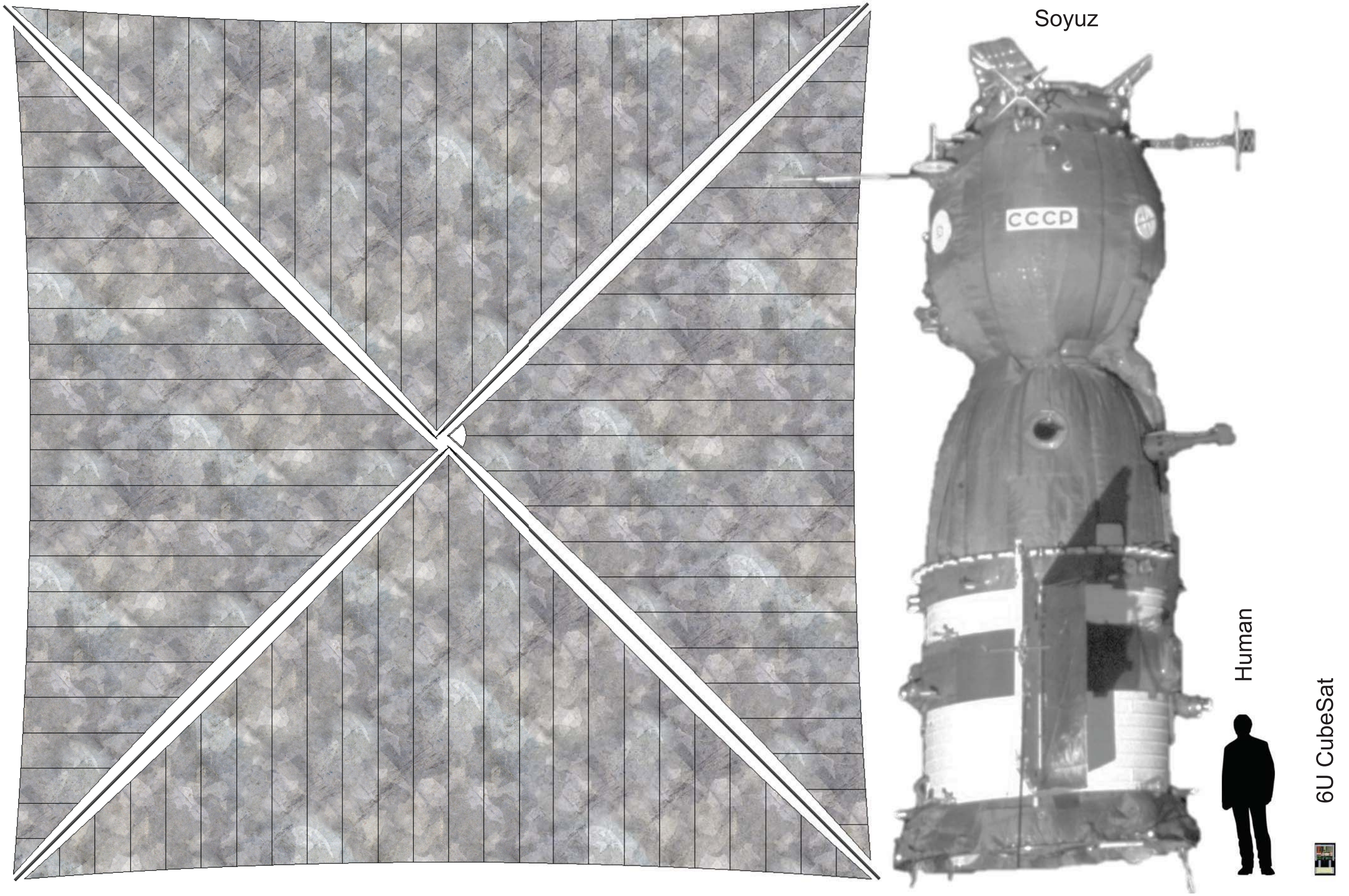
Zero-Momentum RWA
- One 100 mNms wheel
- Controls spin of the sail
- Maintain a zero-momentum system

Steering RWA
- Three 15 mNms wheels
- Attitude control for science, telecom, and nav. pointing



Cold Gas System
- Isp>= 40s
- ~ 1.5 kg of fuel
- Momentum mgmt
- Initial delta-V burn

Size comparison



Impact and Future Outlook

- **Contribution to the CubeSat Community**
  - Long-lived CubeSat bus for deep space missions (C&DH, EPS, ADCS, Deep Space Transponder)
  - Further characterization of deep space environment effects on CubeSats (building on INSPIRE)
  - First science-grade observations of solar system objects
  - Mature CubeSat Solar Sail propulsion

- **Future Potential of Small Missions for Big Science**
  - Secondary spacecraft hosted on interplanetary missions
  - NEA Scout could be repeated to characterize additional NEAs or increase coverage of lunar ices (possibly with different, complementary payloads)
  - Other solar sail applications (e.g. Space Weather Monitoring constellation at Lagrange Points)