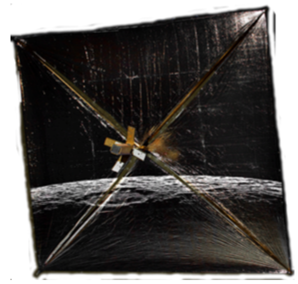
Lunar Flashlight and Near Earth Asteroid Scout: Exploration Science Using Cubesats



Barbara Cohen

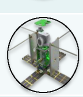
Lunar Flashlight PI, NASA Marshall Space Flight Center

Paul Hayne, Ben Greenhagen, David Paige, *LF Science Team*

Julie Castillo, Paul Abell, Lance Benner, Bill Farrell, Jake Bleacher, Paul Chodas, Lee Graham, *NEAS Science Team*

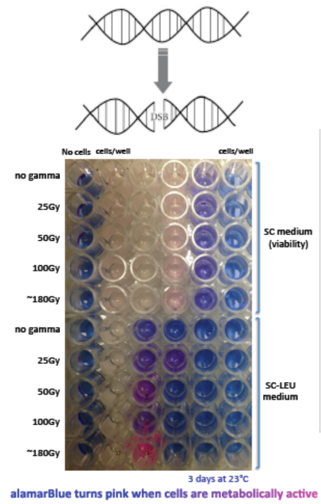
EM1 Secondary Payloads

- EM1 launch opportunity (2018) will have 11 6U cubesat dispensers
- Three payloads manifested from the Advanced Exploration Systems (AES) program
  - Relevance to Space Exploration Strategic Knowledge Gaps (SKGs)
  - Synergistic use of previously demonstrated technologies
  - Life-cycle cost and optimal use of available civil servant workforce
- Other secondary payloads will be added
  - NASA – SIMPLEX, LCAS, Cubesat Challenge
  - Others – universities, research centers, DOD, etc?

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/MHS* 	**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* 	**NEA Characterization** • NEA size, rotation state (rate/pole position) **How to work on and interact with NEA surface** • NEA surface mechanical properties	Slow flyby/rendezvous and characterize one NEA in a way that is relevant to human exploration

Biosentinel: DNA Damage-and-Repair Experiment Beyond Low Earth Orbit

- **What**: Yeast radiation biosensor measures DNA damage caused by space radiation: specifically, double strand breaks (DSBs)
- **Why**: Space radiation's unique spectrum cannot be reproduced on Earth
  - Various high-energy particles/energy spectra; omnidirectional; continuous; low flux
  - Health risk for humans over long durations beyond LEO
- **How**: Before launch, engineered S. cerevisiae cells (brewer's yeast) are dried & placed in arrays of microwells
  - In space, a group of wells is rehydrated every few weeks
  - Cells remain dormant until growth is activated by a DSB + gene repair
  - Yeast repair mechanisms in common with human cells; well studied in space



Near Earth Asteroid Scout

Marshall Space Flight Center/Jet Propulsion Lab/LaRC/JSC/GSFC/NASA

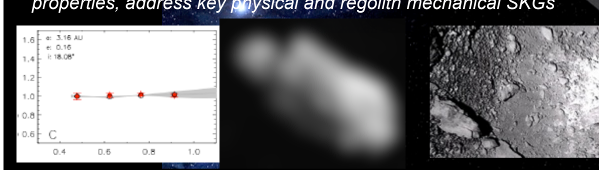
One of three 6U Cubesats sponsored by Advanced Exploration System, Joint Robotic Program to fly on SLS EM-1

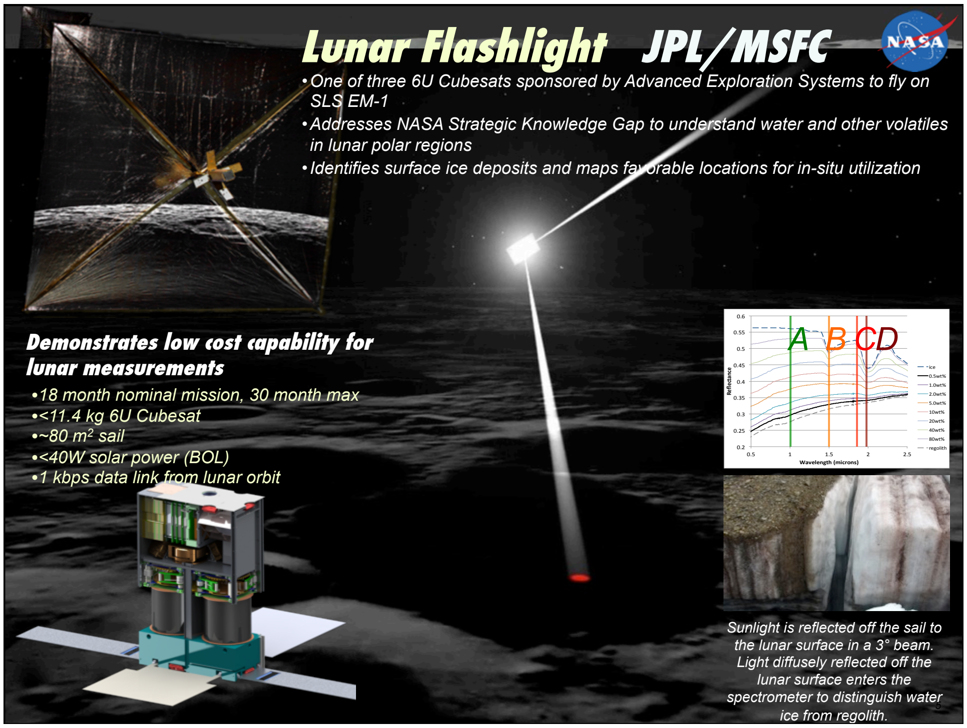
GOALS

Characterize one candidate NEA with an imager to address key Strategic Knowledge Gaps (SKGs)

Demonstrates low cost capability for HEOMD for NEA detection and reconnaissance

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





Lunar Flashlight Goals

Lunar Strategic Knowledge Gaps

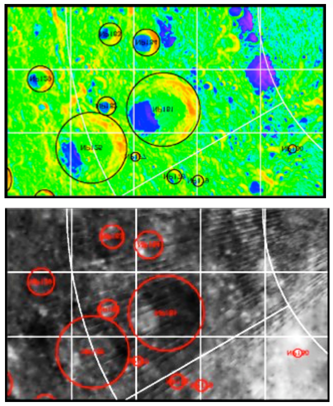
I. Understand the lunar resource potential

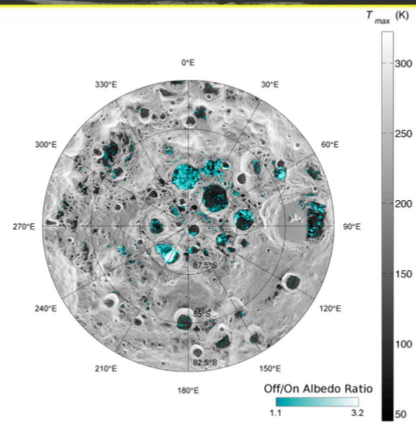
D. Composition/quantity/distribution/form of water/H species and other volatiles associated with lunar cold traps.

Narrative: Required "ground truth" in-situ measurement within permanently shadowed lunar craters or other sites identified using LRO data. Technology development required for operating in extreme environments. Enables prospecting of lunar resources and ISRU. Relevant to Planetary Science Decadal survey.

- Lunar Flashlight will illuminate permanently-shadowed and detect water ice absorption bands in the near-infrared – **Measurement goal**
- By repeating this measurement over multiple points, Lunar Flashlight will create a map of surficial ice concentration that can be correlated to previous mission data and used to guide future missions **– Mapping goal**

Lunar ice frost as a human resource





- Locations where Diviner measures the coldest year-round temperatures also show high albedo in LOLA at 1.064 μm, consistent with water frost
- Ultraviolet albedo data from LAMP also show evidence for water ice at the lunar surface, but are not yet definitive

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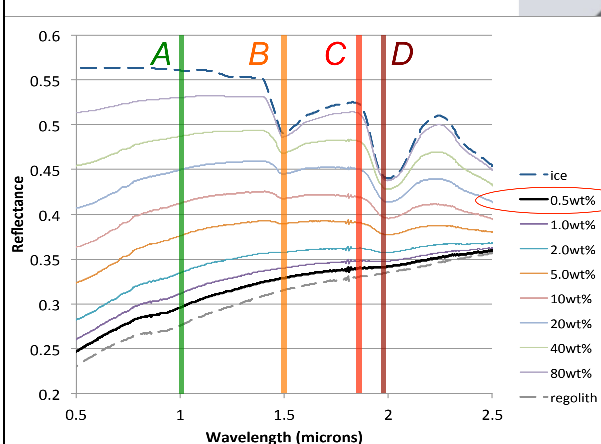
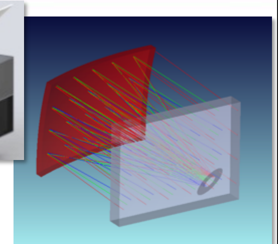
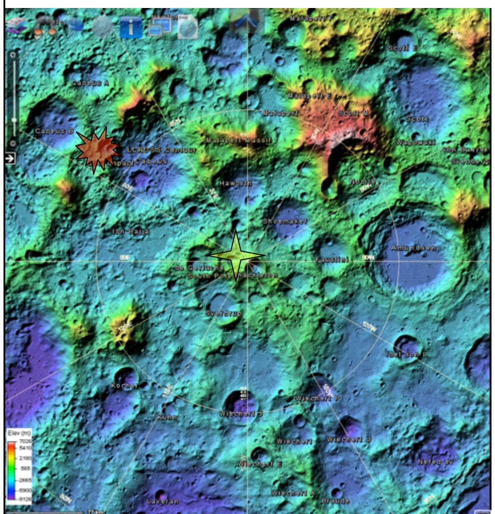
LF Measurement



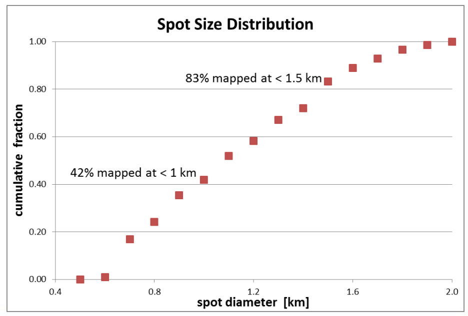


- Four-channel point spectrometer
- Off-axis parabola telescope design
- Judson (Teledyne) strained-lattice InGa:As PVs detectors
  - Passively cooled operation at -65C

LF Mapping



- 10% of PSRs within 10° of pole observed over 60 orbits, covers Shoemaker Crater and LCROSS site with <2 km/px



Near-Earth Asteroid Scout Goals

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	**Characterization of particle density in target vicinity**	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	**Morphology at resolution of astronaut's foot**	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

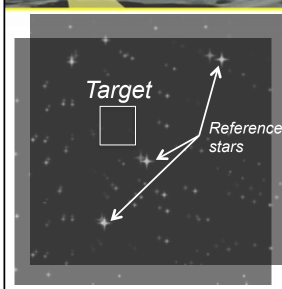
Ref – Abell and Castillo, After SKG Report (Rivkin et al. 2012)

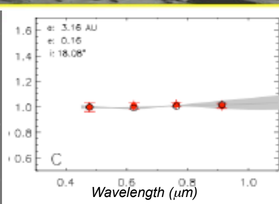
Baseline Target: 1991 VG

- H=28.4±0.7   D~ 5-12 meters   Albedo = unknown
- Position is known within 2700 km (1σ) but optical observation opportunity in July ‘17 will decrease uncertainty to a few 100s km
- Rotation period between a few minutes and less than 1 hr
- Unlikely to have a companion
- Unlikely to retain an exosphere or dust cloud
  - Solar radiation pressure sweeps dust on timescales of hours or day

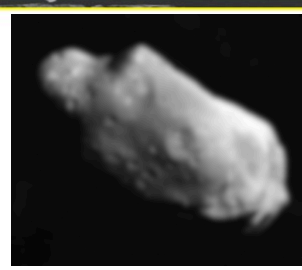
Secondary Targets	Absolute magnitude	30% albedo Diameter (m)	5% albedo Diameter (m)	Orbit Condition Code	Observation Opportunity prior to launch
2001 GP_2	26.9	10	25	6	Depends on launch date 2020-10 (Optical)
2013 BS45	25.9	11	51	0	2015-01 (Optical)
2008 EA_9	27.7	7	17	5	none
2012 UV_{136}	25.5	19	47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

NEAS Science Products





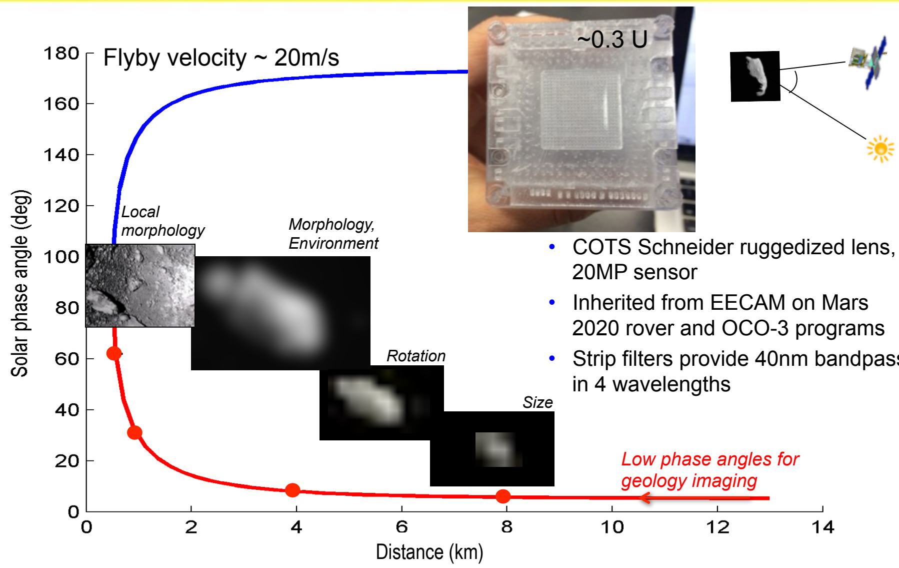
Target Detection and Approach
Light source observation
SKGs: Ephemeris determination and composition assessment



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 over >30% surface
SKGs: Medium-scale morphology, regolith properties, and local environment characterization

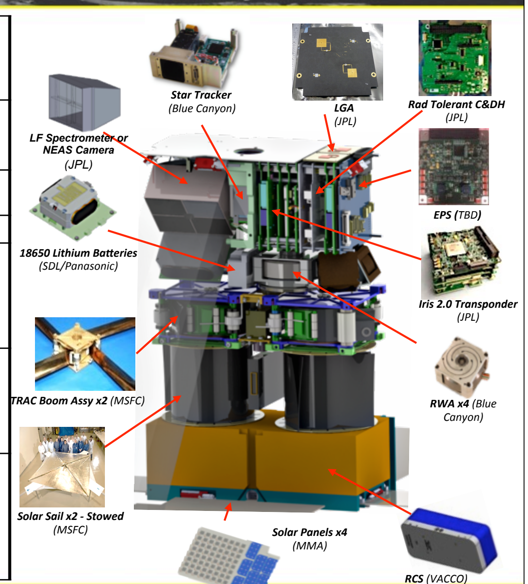
NEAS Proximity Science



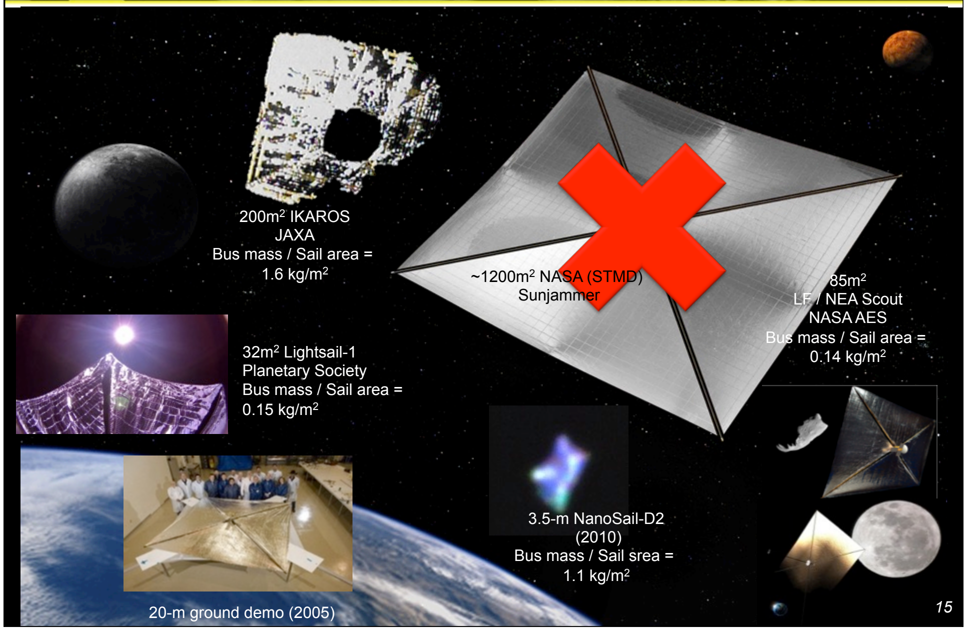
- COTS Schneider ruggedized lens, 20MP sensor
- Inherited from EECAM on Mars 2020 rover and OCO-3 programs
- Strip filters provide 40nm bandpass in 4 wavelengths

Fitting into 6U is challenging

Payload	• Lunar Flashlight: Custom spectrometer built in-house • NEA Scout: Heritage JPL MSL/Mars 2020 imager (400-900 nm)
Mechanical & Structure	• "6U" CubeSat form factor (~10x20x30 cm) • <12 kg total launch mass • Modular flight system concept
Propulsion	• ~85 m^2 aluminized Kapton solar sail (based on NanoSail-D2)
Avionics	• Radiation tolerant LEON3-FT architecture
Electrical Power System	• Simple deployable solar arrays with UTJ GaAs cells (~35 W at 1 AU solar distance) • 6.8 Ah Battery (3s2p 18650 Lithium Cells) • 10.5-12.3 V unregulated, 5 V/3.5 V regulated
Telecom	• JPL Iris 2.0 X-Band Transponder; 1 W RF, supports doppler, ranging, and D-DOR • 2 pairs of INSPIRE-heritage LGAs (RX/TX) • Lunar Flashlight: ~500 bps to 34m DSN at all times.
Attitude Control System	• 15 mNm-s (x3) & 100 mNm-s RWAs • Zero-momentum slow spin during cruise • VACCO R-236fa (refrigerant gas) RCS system • Nano StarTracker, Coarse Sun Sensors & MEMS IMU for attitude determination



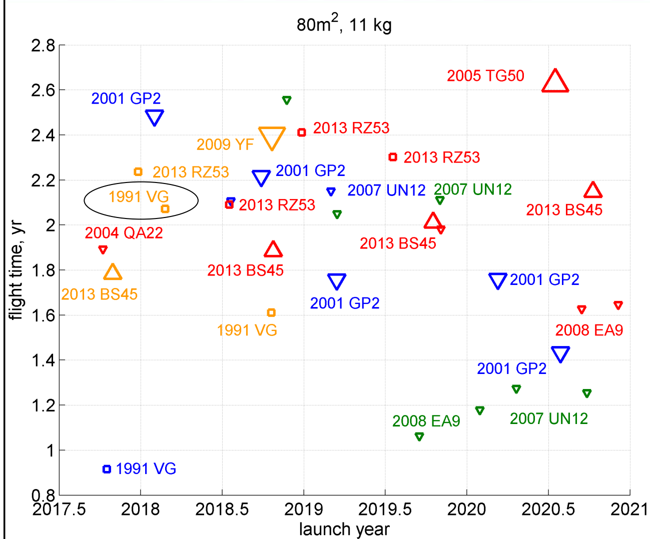
Solar sailing is challenging



Summary

- NASA is using cubesat missions to address Exploration SKGs and conduct science
- These missions further the maturity of CubeSats
  - Long-lived CubeSat bus for deep space missions (C&DH, EPS, ADCS, Deep Space Transponder)
  - Characterization of deep space environment effects on CubeSats (building on INSPIRE)
  - Mature CubeSat propulsion methods
- Future potential of small missions for science & exploration
  - Part of 1st generation of cubesat-style planetary missions to conduct real science measurements
  - Secondary spacecraft hosted on interplanetary missions

NEAS Rendezvous Target Search



Telecom Distance (AU)

- blue < .25
- green < .5
- orange < .75
- red < 1

OCC

△ under 2

□ under 4

▽ under 7

Appx diameter

- small < ~15 m
- med. < ~30 m
- large < ~50 m