National Aeronautics and Space Administration

Near Earth Asteroid Scout Mission

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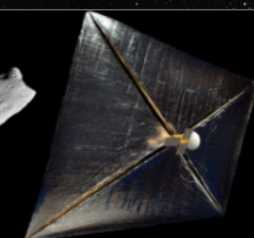
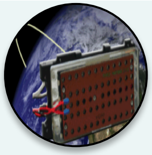
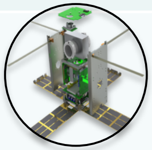
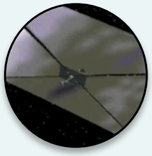
And the NEAScout Team

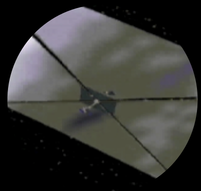


SLS EM-1 Secondary Payload Overview

- **19 NASA center-led concepts were evaluated and 3 were down-selected for further refinement toward an Mission Concept Review (MCR) 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**
- **MCR/SRR to be held in August**

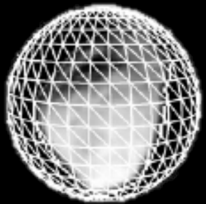
Payload *NASA Centers*	**Strategic Knowledge Gaps Addressed**	**Mission Concept**
BioSentinel ***ARC**/JSC* 	**Human health/performance in high-radiation space environments** • Fundamental effects on biological systems of ionizing radiation in space environments	Study radiation-induced DNA damage of 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

OUTLINE



Introduction to NEAScout

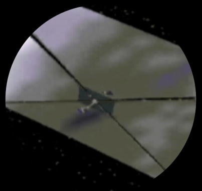
NEAScout Target



NEAScout Science Definition

Science Implementation

OUTLINE



Introduction to NEAScout

NEAScout Target

NEAScout Science Definition

Science Implementation

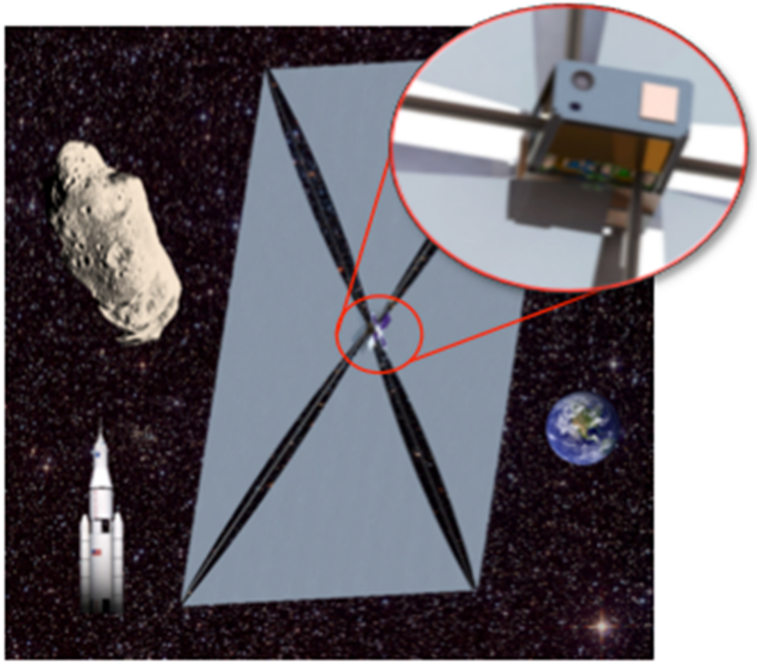
NEA Scout Overview

Why NEA Scout?:

- Characterize one candidate 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)



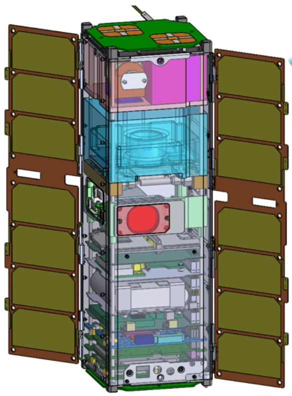
Measurements: *NEA volume, spectral type, spin mode and orbital properties, address key physical and regolith mechanical SKG*

- ≥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

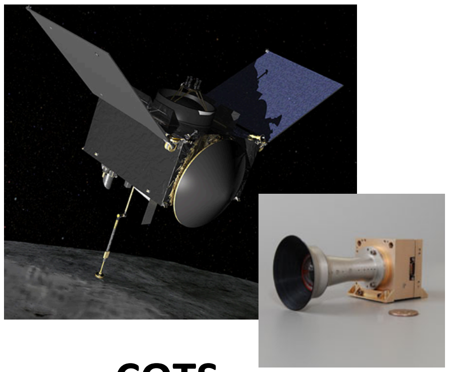
Key Technical Constraints:

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

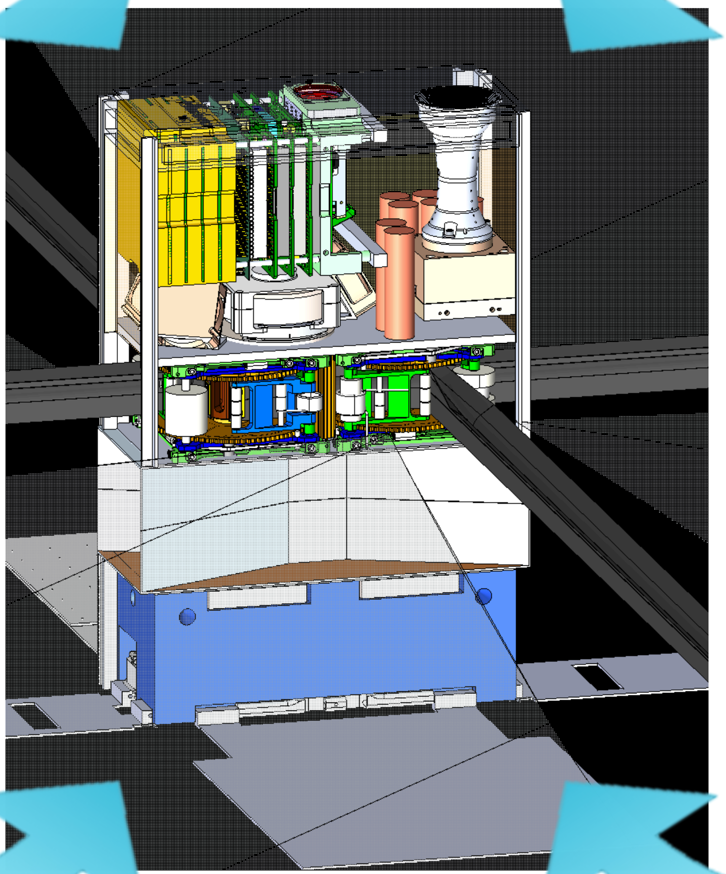
NEA Scout Heritage & Capability Infusion

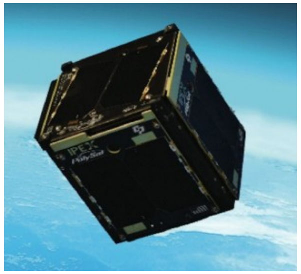


JPL INSPIRE
Spacecraft Bus



COTS
NEA Camera

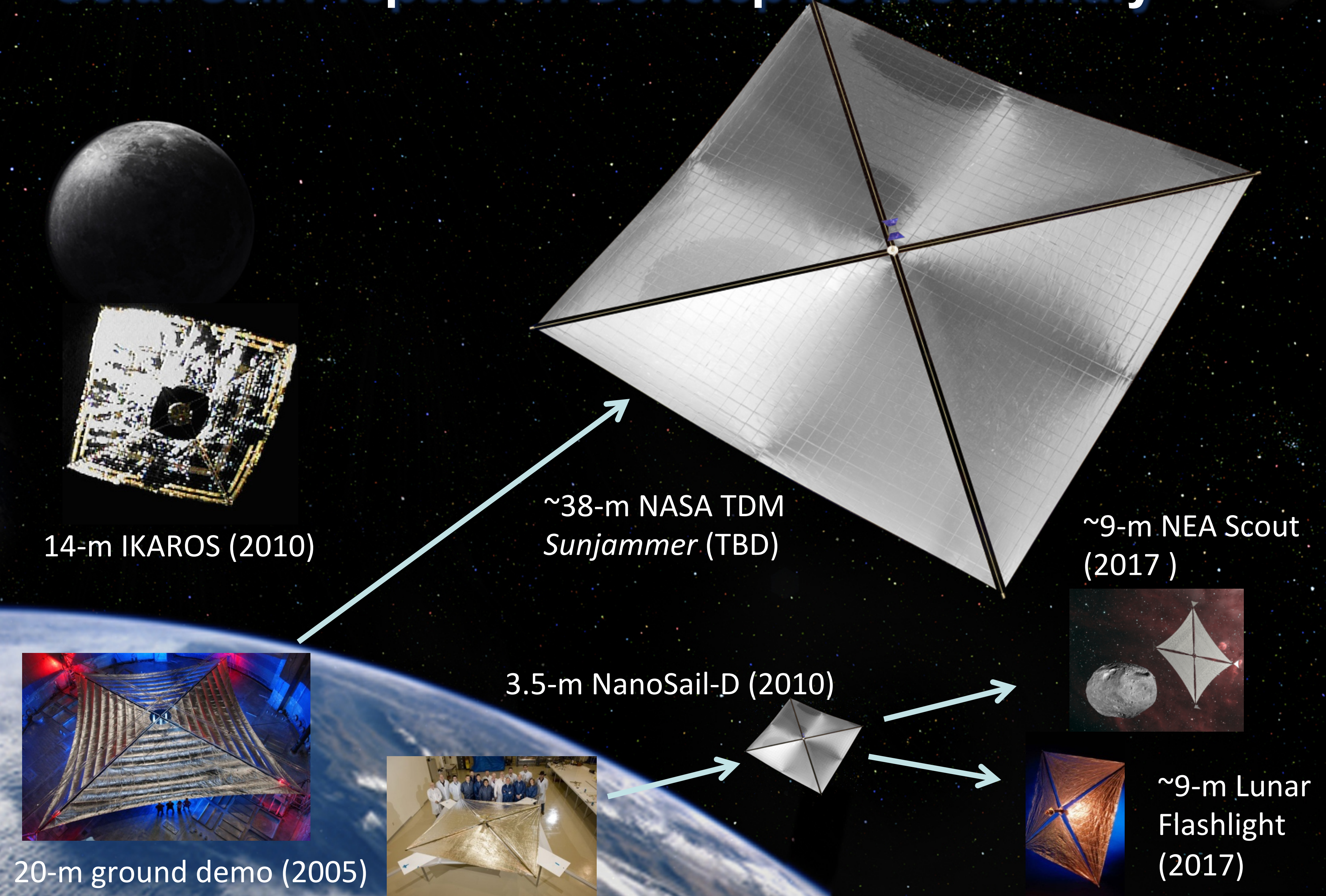




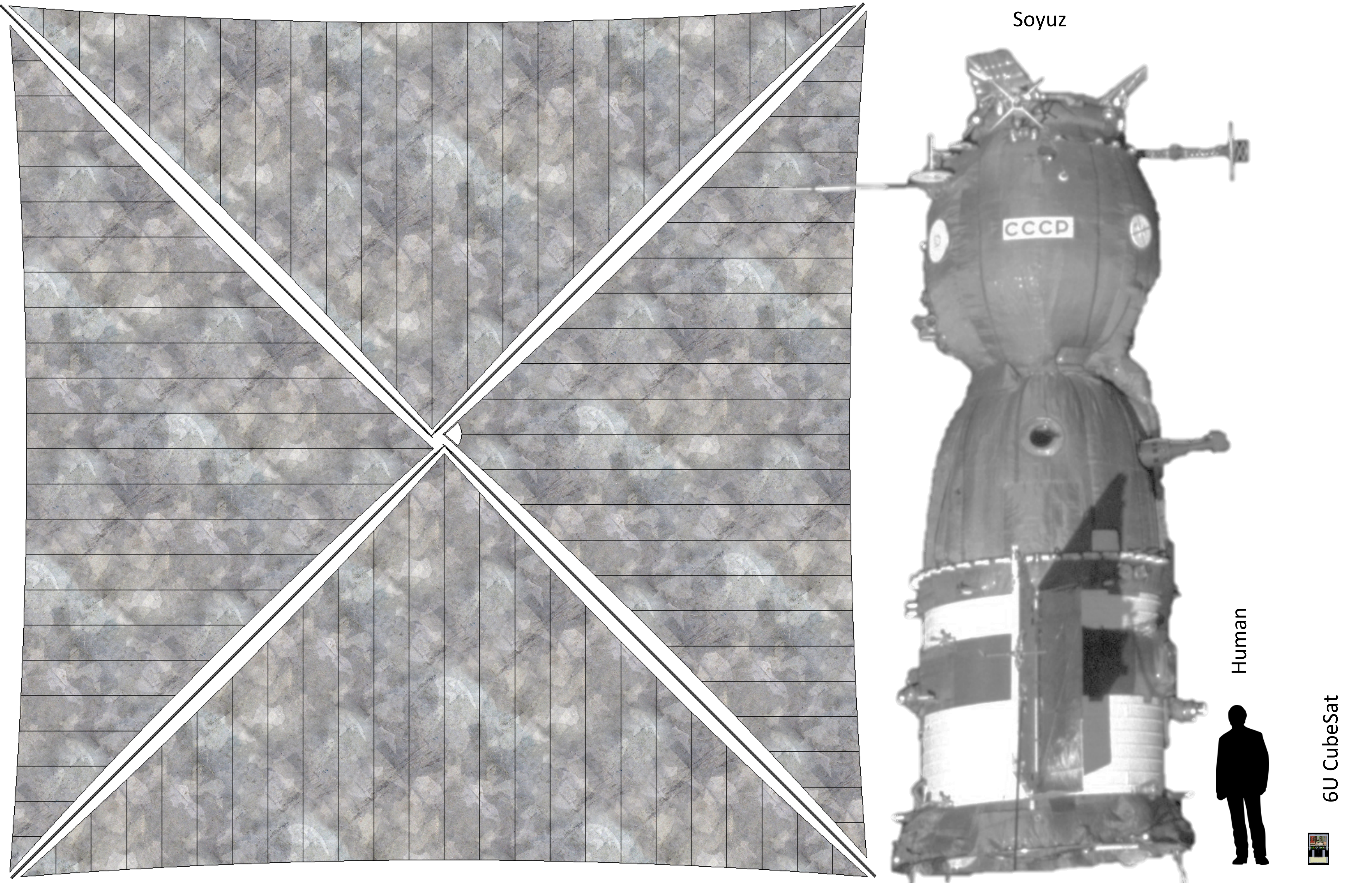
JPL/CalPoly IPEX
Agile Science Algorithms

MSFC NanoSail-D
Solar Sail

Solar Sail Propulsion Development Summary



Solar Sail Approximate Scale



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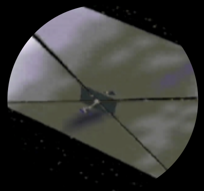
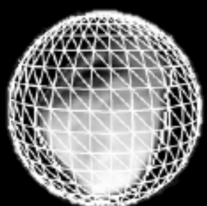


Introduction to NEAScout

NEAScout Target

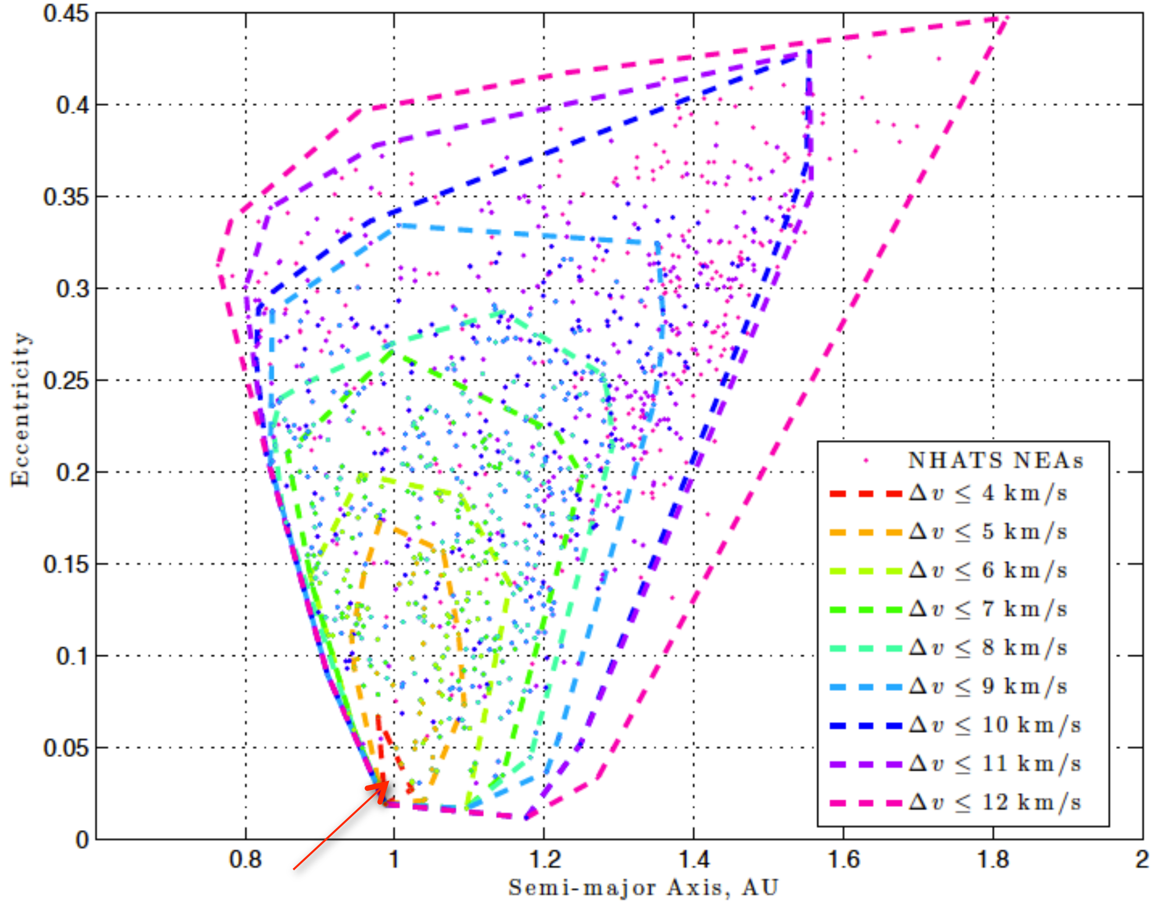


NEAScout Science Definition

Science Implementation

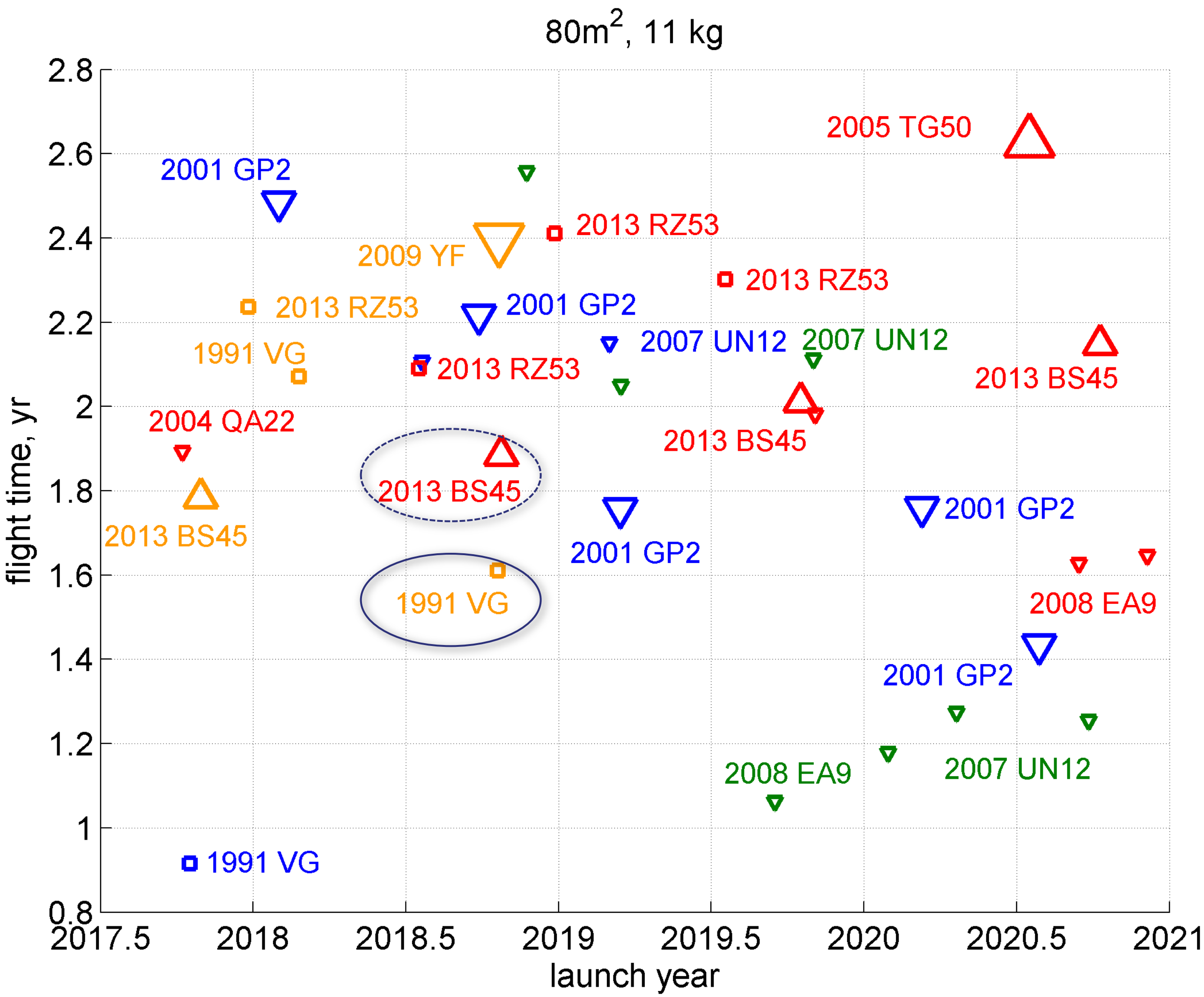
NEAScout Targets an NHAT

- NHATS database contains targets from 1 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 NEAScout are < 50m



From B. Barbee (2013)

Rendezvous Target Search



- **Telecome 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

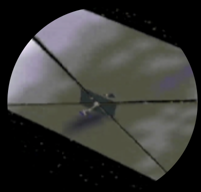
Flight time increases non-linearly with delayed escapes

What do we Know about 1991 VG and Backups

- 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

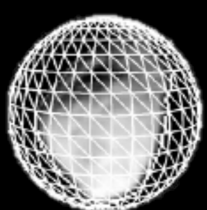
NEA	Absolute magnitude	30% albedo Diameter (m)	5% albedo Diameter (m)	Orbit Condition Code	Observation Opportunity prior to launch
1991 VG	28.5	5	12	2	2017-07 (Optical)
2001 GP_2	26.9	10	25	6	Depends on launch date 2020-10 (Optical)
2007 UN_{12}	28.7	4	11	4	none
2008 EA_9	27.7	7	17	5	none
2012 UV_{136}	25.5	19	47	1	2014-08 (Optical) 2020-05 (RADAR)

OUTLINE



Introduction to NEAScout

NEAScout Target



NEAScout Science Definition

Science Implementation

L1 Science Requirements

- **NEA SCOUT SHALL HAVE THE CAPABILITY TO ADDRESS KEY STRATEGIC KNOWLEDGE GAPS AT A NEAR EARTH ASTEROID**
- Full Success Criteria: Fly by a near Earth asteroid and acquire images sufficient to determine the target volume, shape model, asteroid spectral type and meteorite analogs, rotational properties (pole position, rotation period), orbit, debris/dust field in local environment, and regolith characteristics.
-
- Minimum Success Criteria: Fly by a near Earth asteroid and acquire images sufficient to constrain the target volume, the asteroid spectral type, determine rotational properties (pole position, rotation period), and orbit.
-
- Rationale: This requirement addresses the need to fill Strategic Knowledge Gaps related to asteroids as a precursor to subsequent safe and successful human missions. The data obtained will also support the advancement of science interests in asteroids.

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 (light blue) Operations (red) Cost (yellow) Performance (green) Science/Engineering (black)

Ref – Abell and Castillo

Synergies Across Fields

HUMAN OPERATIONS

Internal structure (regolith vs. monolith)
Sub-surface properties
General mineral, chemical composition

SCIENCE

Internal structure (regolith vs. monolith)
Sub-surface properties
Detailed mineral, chemical, isotopic composition

Intersection of All

Location (position prediction, orbit)
Size (existence of binary/ternary)
Rotation rate and pole position
Particulate environment/Debris field
Electrostatic charging and Plasma field
Thermal environment
Gravitational field structure
Mass/density estimates
Surface morphology and properties
Regolith mechanical and geotechnical properties

Internal structure (regolith vs. monolith)
Sub-surface properties (→ beta)
General mineral, chemical composition

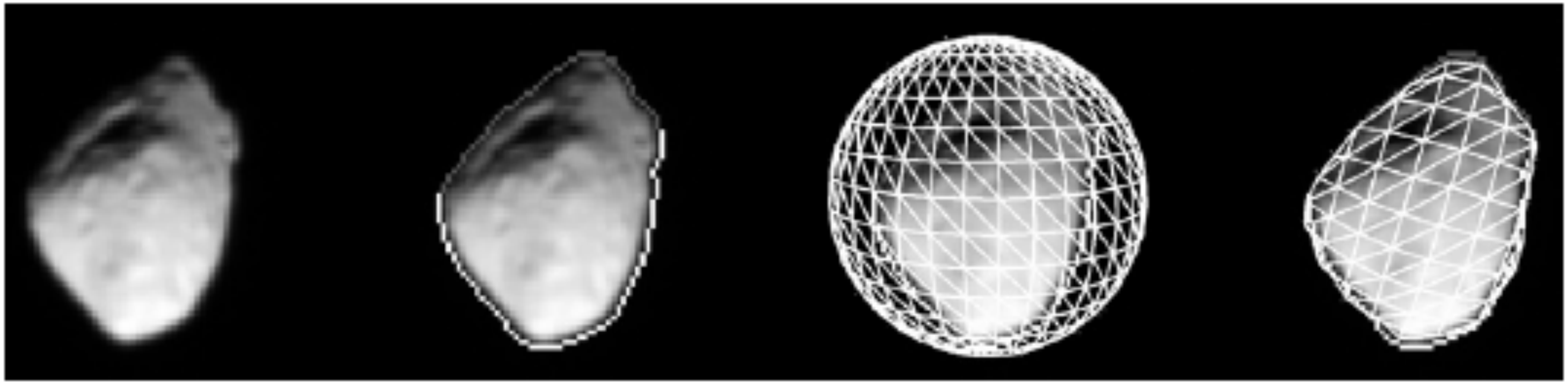
PLANETARY DEFENSE

Detailed mineral, chemical composition

RESOURCE UTILIZATION

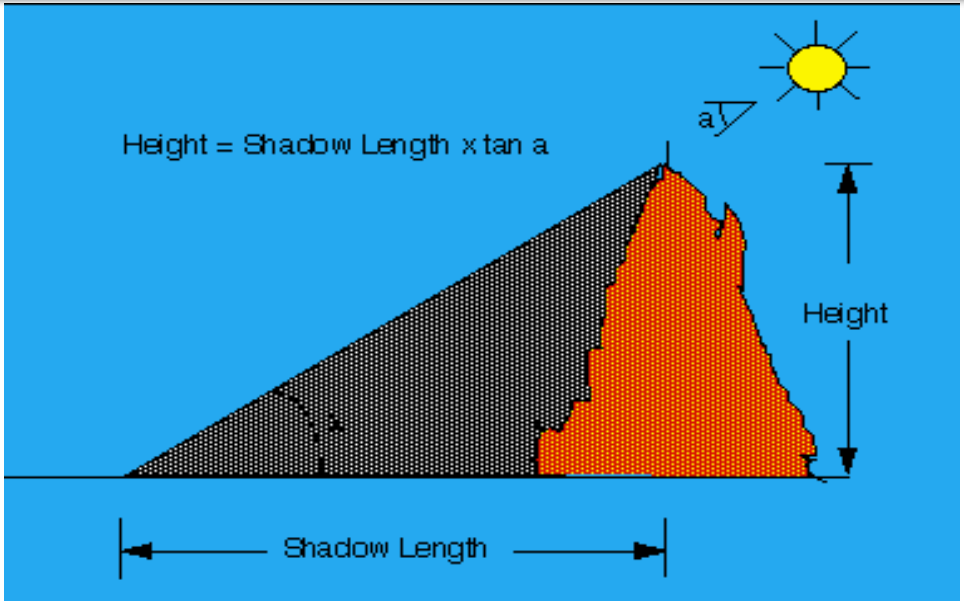
From P. Abell (2011)

Shape, Rotation Rate and Pole Position



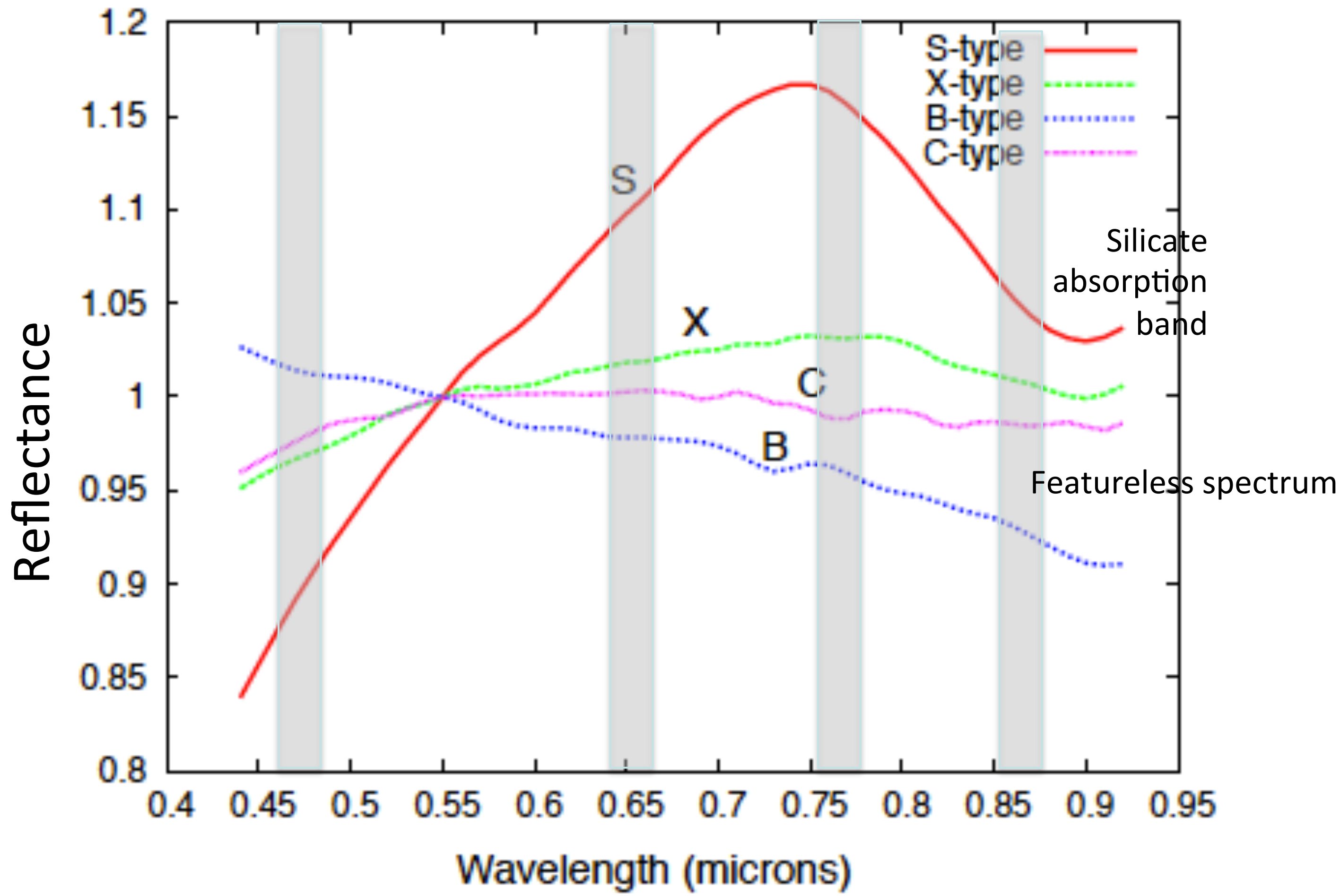
- Measured from limb fitting observed over a rotation
- Rotation properties (pole position, rate, state) and albedo are inferred form the same set of images
- Requirements:
  - Coverage (>80%),
  - Photometry accuracy (<5%),
  - Resolution (<50 cm/px)

Morphology



- Morphology informs on landing side selection
  - Topography, slope stability, regolith properties
- Inferred from shadow length measurements
- Requirements:
  - Solar phase angle: multiple, < 50 deg.
  - Spatial resolution (<10 cm/px)

Spectral Type Determination

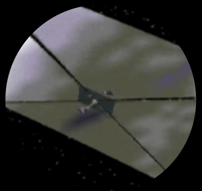


- Will be accomplished on unresolved target following detection
- Comparison with meteorites leads to general information on chemical and mineralogical composition
- Drives stability requirements (cf. camera slide)

Observation of the Local Environment

- Background emissivity (halo) and search for satellites
- Requirements:
    - Coverage: ~10 radii around target)
    - Resolution: 20 cm/px
    - Ops (backscatter imaging)

OUTLINE



Introduction to NEAScout

NEAScout Target

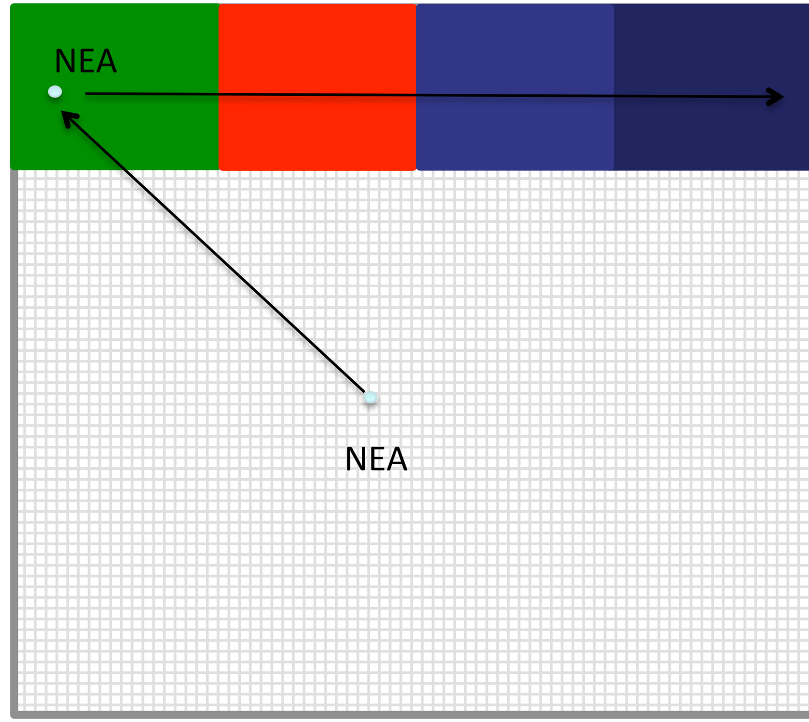
NEAScout Science Definition

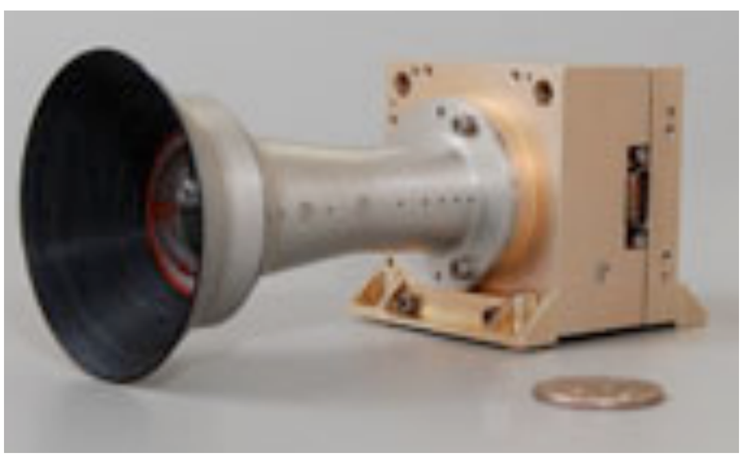
Science Implementation

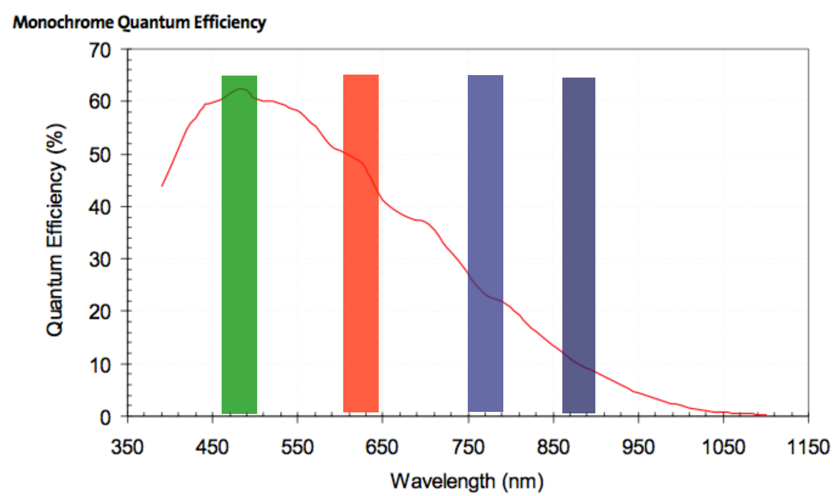
Instrument Concept

Baseline

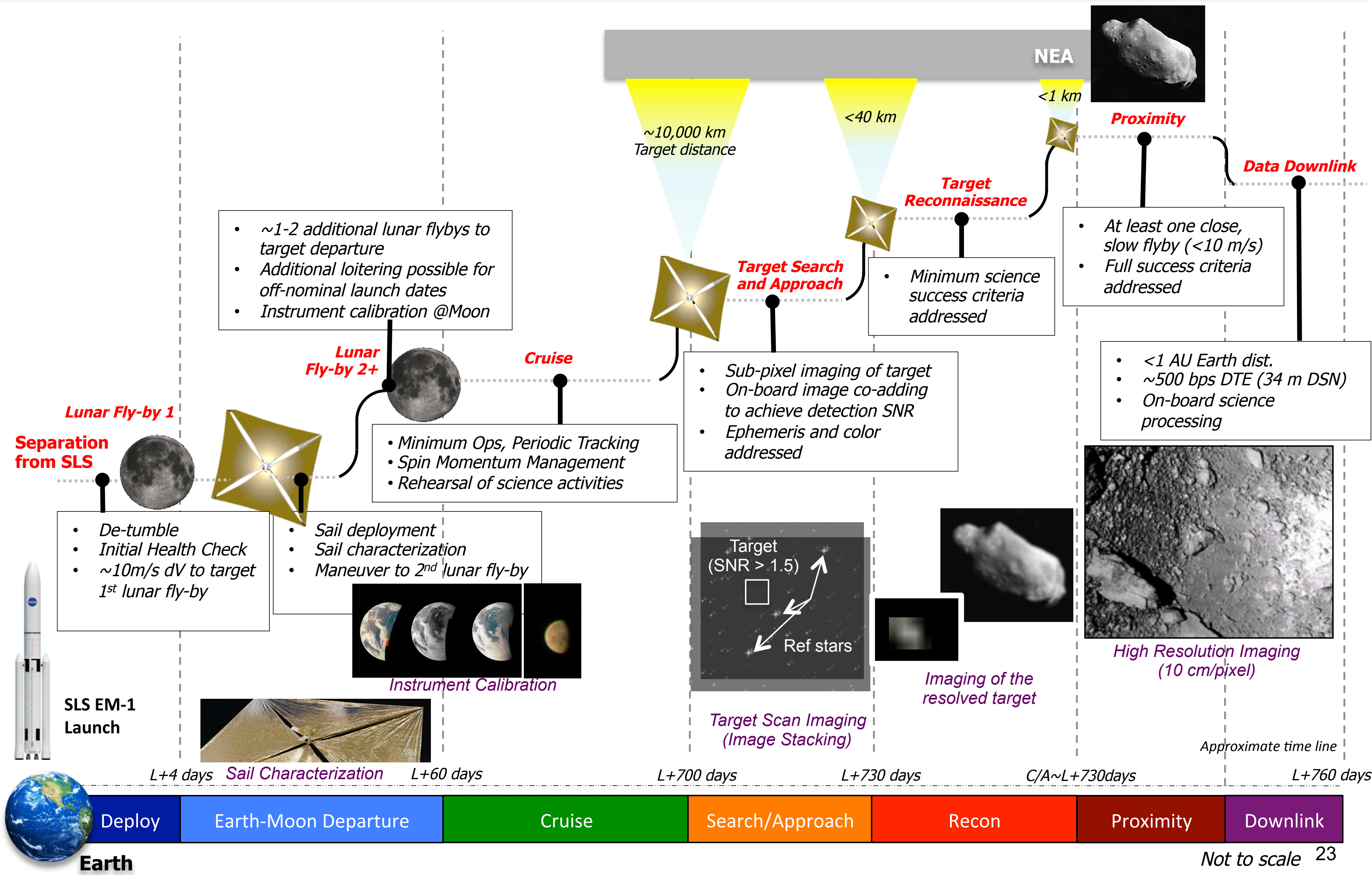
- MSSS ECAM M-50 camera with NFOV lens
- COTS, TRL 8 via OSIRIS-Rex, excellent IFOV & FOV, volume, power
- Aptina MT9P031 FPA



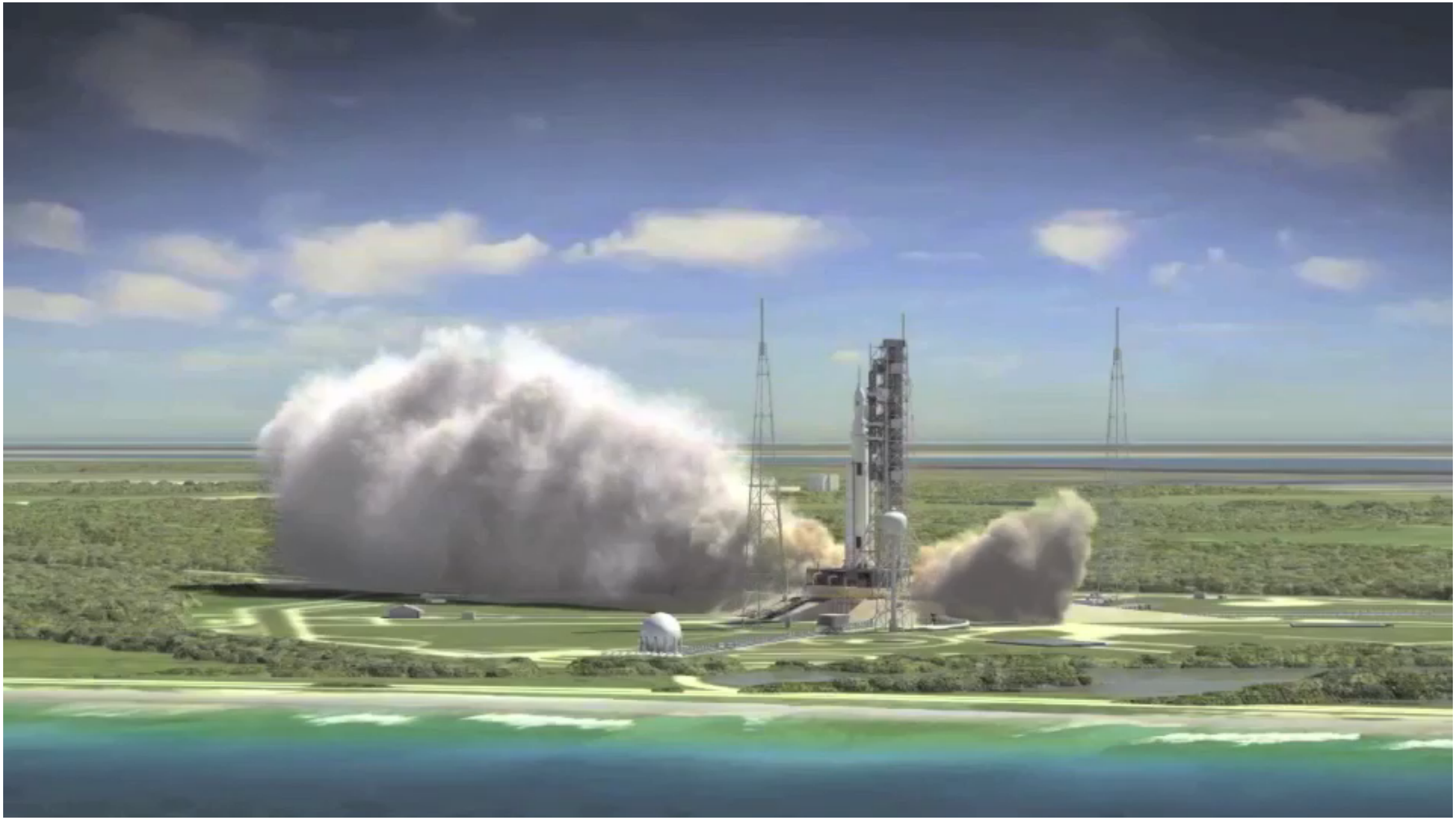




ConOps Overview

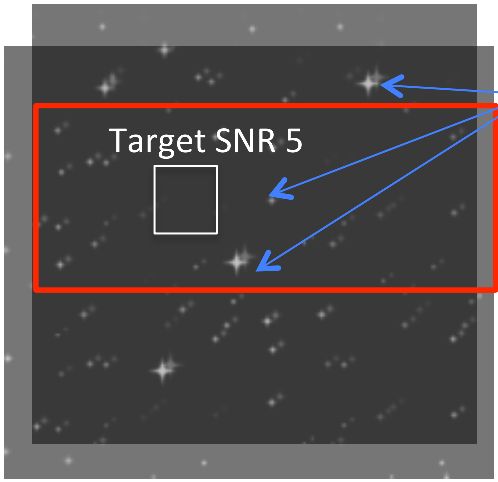


Concept of Operations



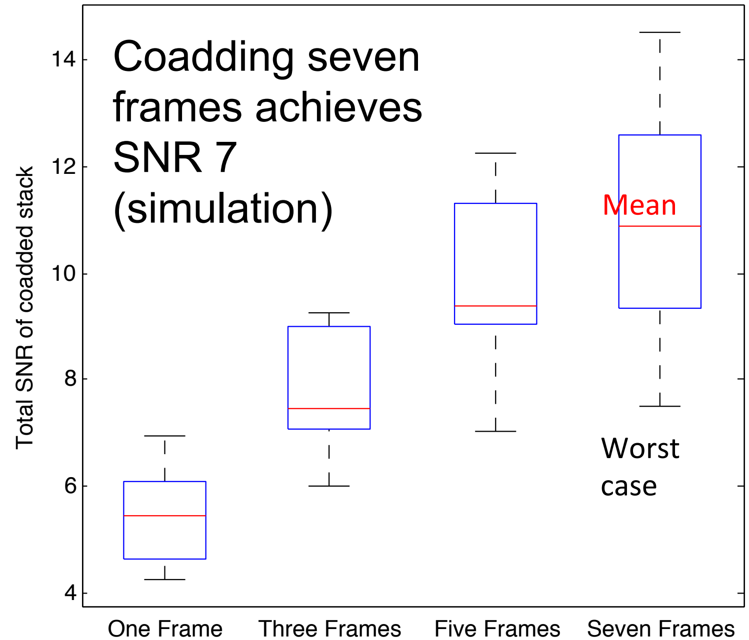
Target Detection Strategy

Co-add multiple frames onboard to increase target SNR



Align images using reference stars SNR > 5

Downlink the coadded subframe containing the target uncertainty ellipse (20% of the FOV)



Onboard timeline

1. **Capture 10 frames** from fixed inertial orientation. 1s exposure yielding SNR 5
2. **Find reference stars** in each frame
3. **Fit a row/column shift** to align adjacent frames
4. **Perform robust co-adding** with cosmic ray removal SNR >7

On ground

- **Perform image subtraction** with previous frames to find asteroid

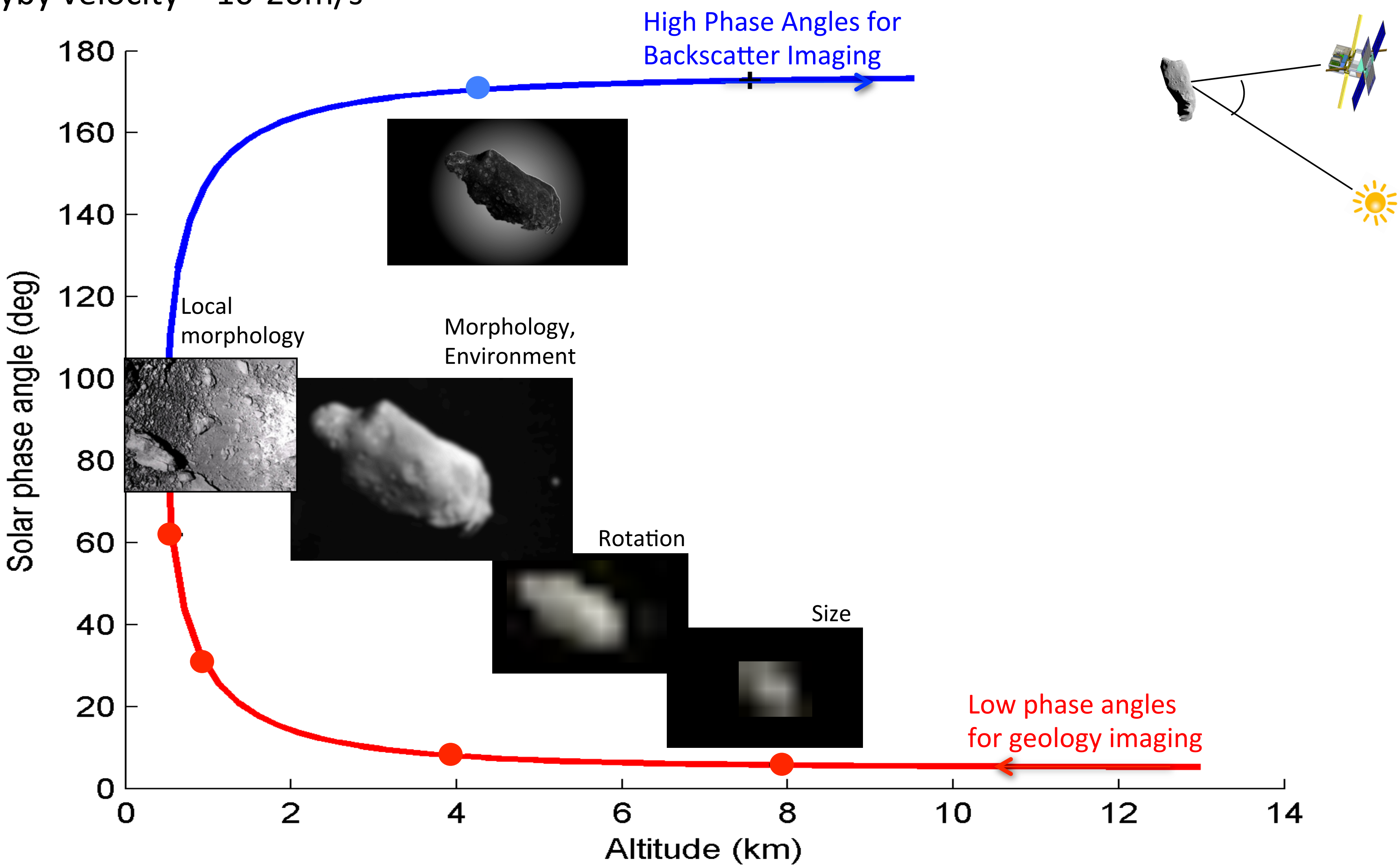
T = 0

T = ~10 min

T = ~1 day

Proximity Science

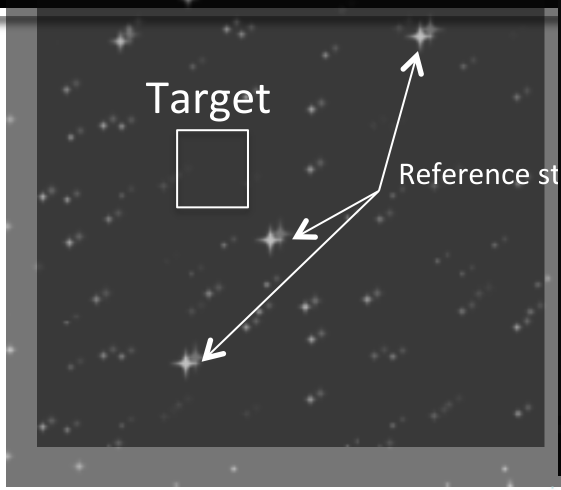
Flyby velocity ~ 10-20m/s



Target rotation period is key uncertainty on the science capture timeline

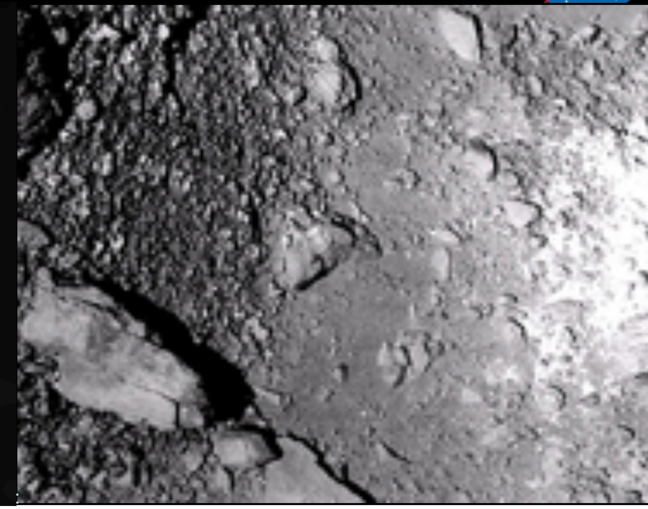
Strategies for Science Imaging with Constrained Resources

ACTIVITIES



Target Detection and approach with wide field imaging
Ephemeris determination

Target Reconnaissance with medium field imaging
Shape, spin, and local environment



Close Proximity Imaging
Local scale morphology, terrain properties, landing site survey

CHALLENGES

Target detection and approach:
- Limited downlink (<500 bps)
- Limited camera capability
- Large target position uncertainty

Target reconnaissance:
- Limited downlink (<500 bps)
- Short flyby time (<30 min)
- Uncertain environment

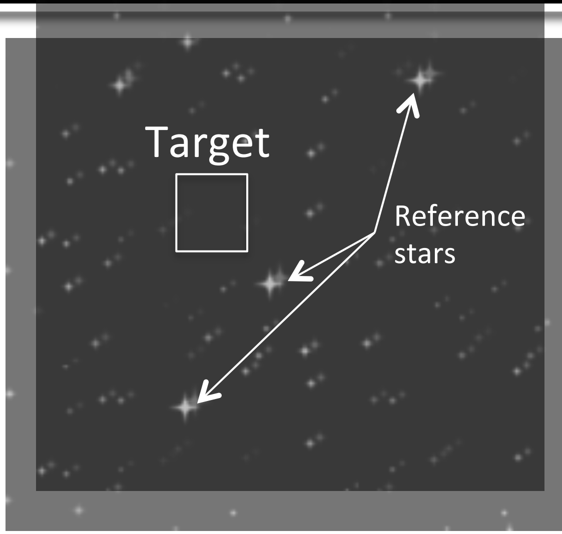
Close proximity imaging:
- Limited downlink (<500 bps)
- Short time at closest approach (<10 min.)

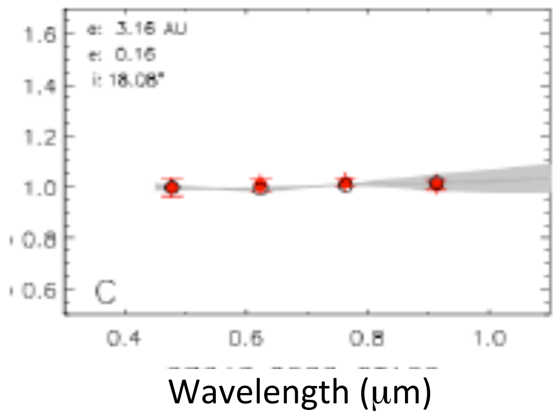
APPROACH

Target detection and approach:
- Autonomous sky scanning sequence
- Image co-adding
- subwindowing
- Compression

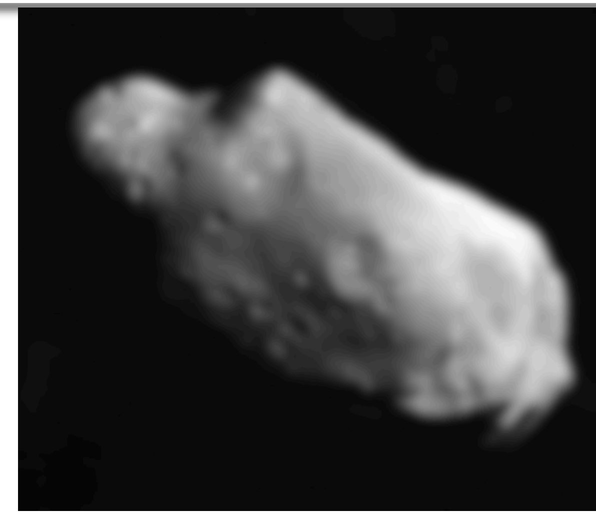
Target reconnaissance and close proximity imaging:
- Autonomous target pointing
- Thumbnails, triage, lossless compression, subwindowing

Summary: NEAScout Observation Plan





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

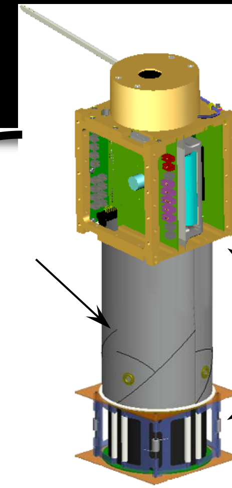
Close Proximity Imaging
High-resolution imaging,
10 cm/px GSD
SKGs: Medium-scale morphology, regolith properties, and local environment characterization

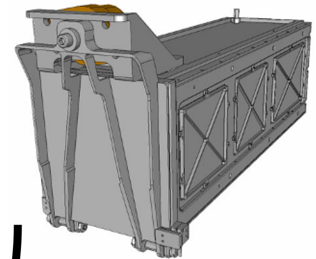
Summary: Contribution to NEA SKGs

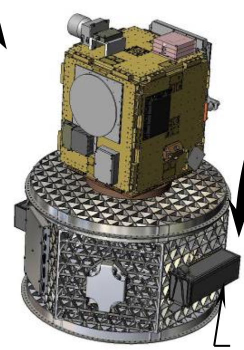
- First imaging and characterization of an NEA smaller than 100 m
  - Will retire SKGs at 1991 VG (size, rotation)
  - Will also address SKGs that are relevant to all objects in that class range (e.g., surface state, local environment)
- First demonstration of a low-cost, SKG-driven mission
  - Combines asteroid detection/tracking and close proximity science capabilities
  - Paves the way for multi-spacecraft exploration of NEAs
  - Complementary to Earth-based surveys with ground truth connection to astronomical observations
- Complementary to other missions to NEA: OSIRIS REx, Hayabusa 2

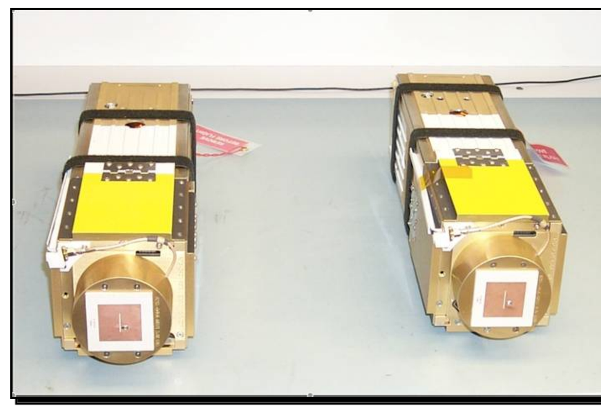
NEA
Scout

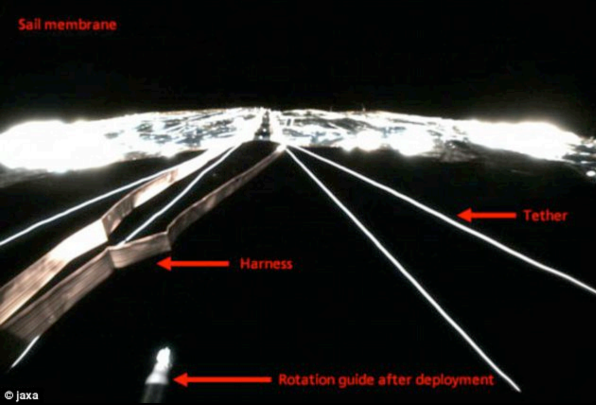
NanoSail-D2 Demonstration Mission (2010)

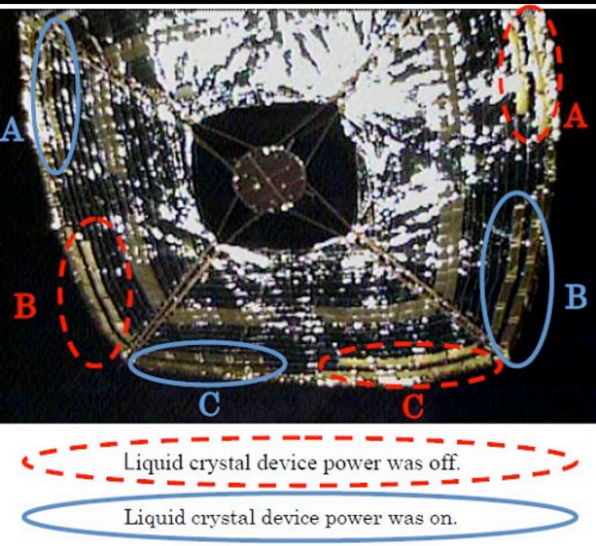


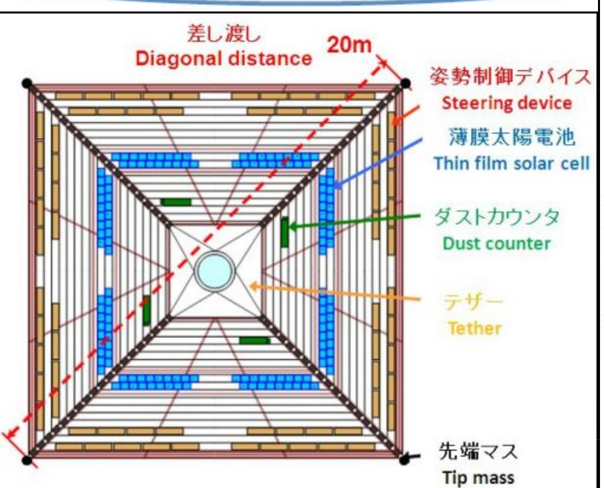












Interplanetary Kite-craft Accelerated by Radiation of the Sun (IKAROS) 2010

- IKAROS was launched on May 21, 2010
- The Japan Aerospace Exploration Agency (JAXA) began to deploy the solar sail on June 3, 2010.
- IKAROS has demonstrated deployment of a solar sailcraft, acceleration by photon pressure, and attitude control.
    - Deployment was by centrifugal force
    - Sail membrane is 7.5 mm thick

Configuration / Body Diam.	1.6 m x Height 0.8 m (Cylinder shape)
Configuration / Membrane	Square 14 m and diagonal 20 m
Weight	Mass at liftoff: about 310 kg