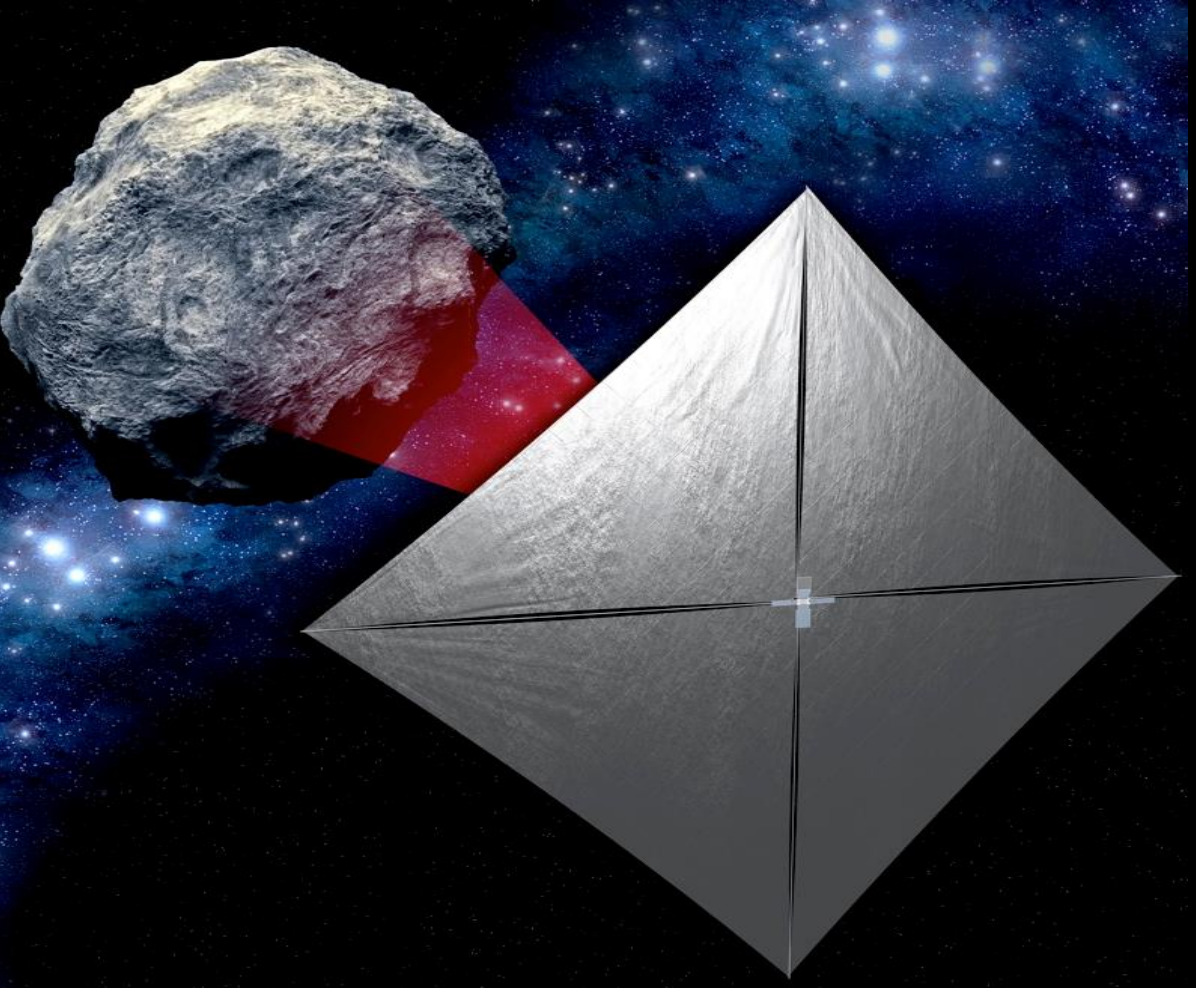

Near Earth Asteroid Scout (NEA Scout) Science Concept of Operations Utilizing Onboard Data Analysis

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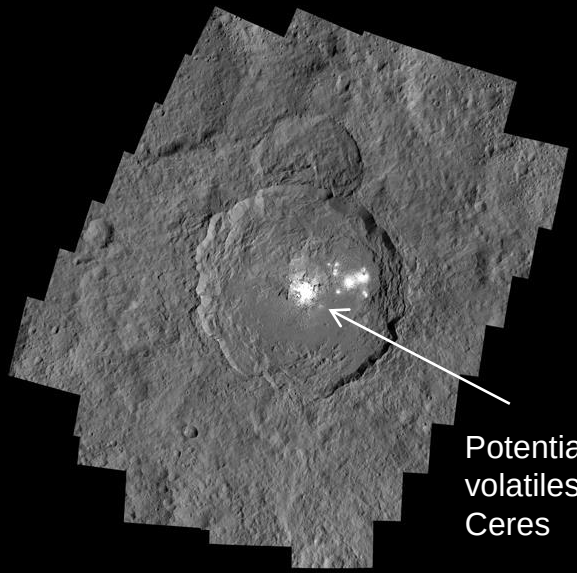
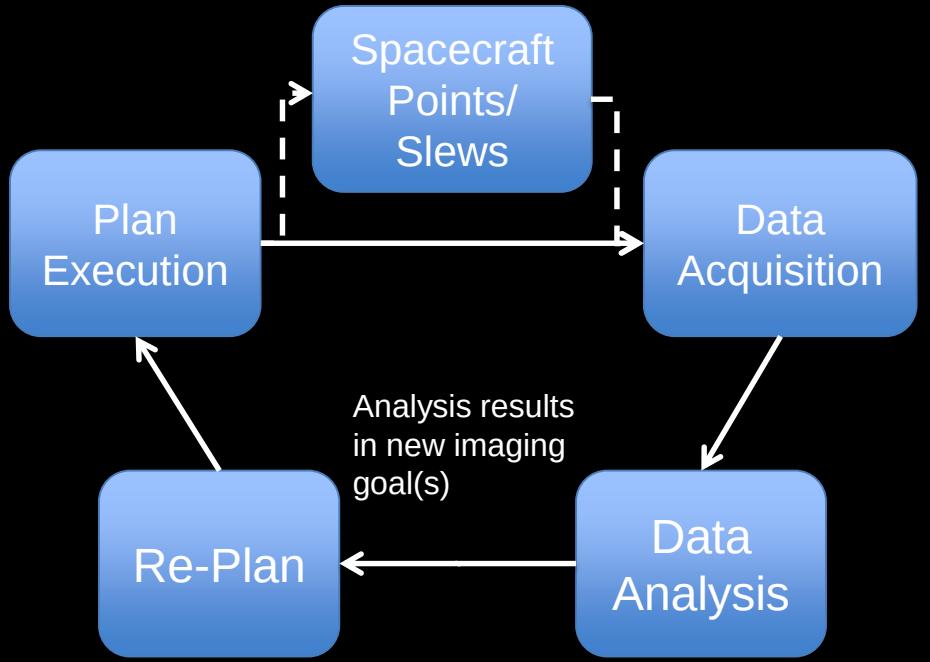
The Agile Science Paradigm

Analyze data acquired onboard spacecraft and respond based on analysis



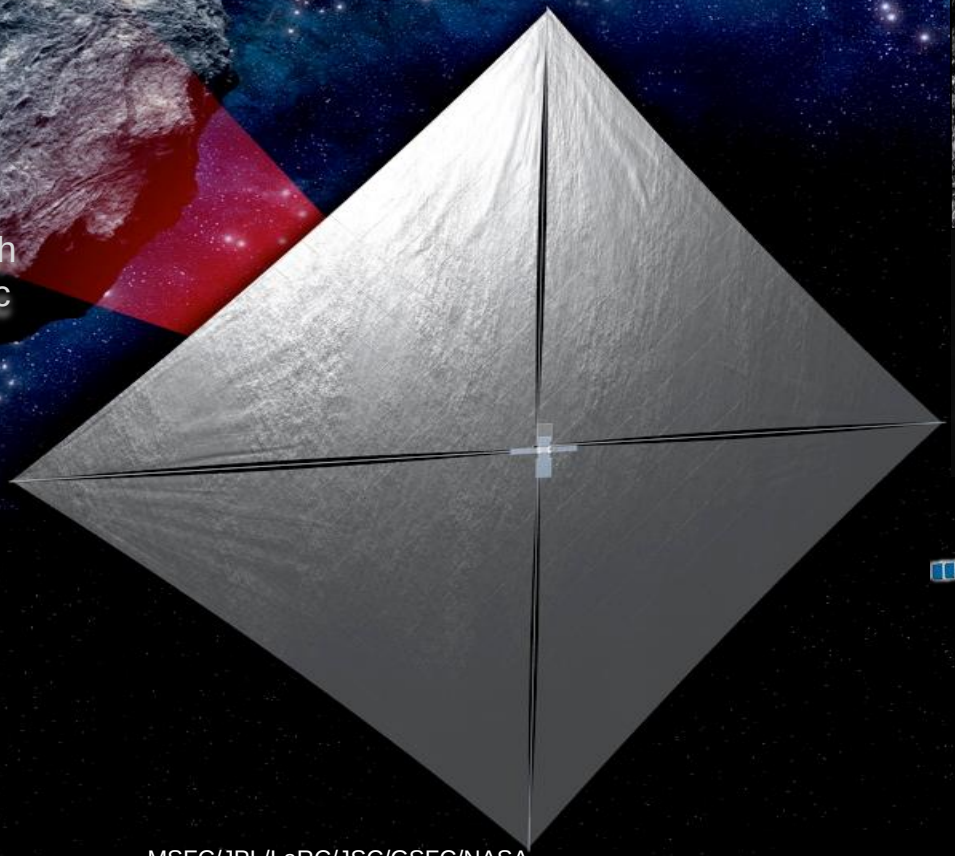


Near Earth Asteroid Scout

GOALS

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

Demonstrates low cost capability for HEOMD for NEA detection and reconnaissance

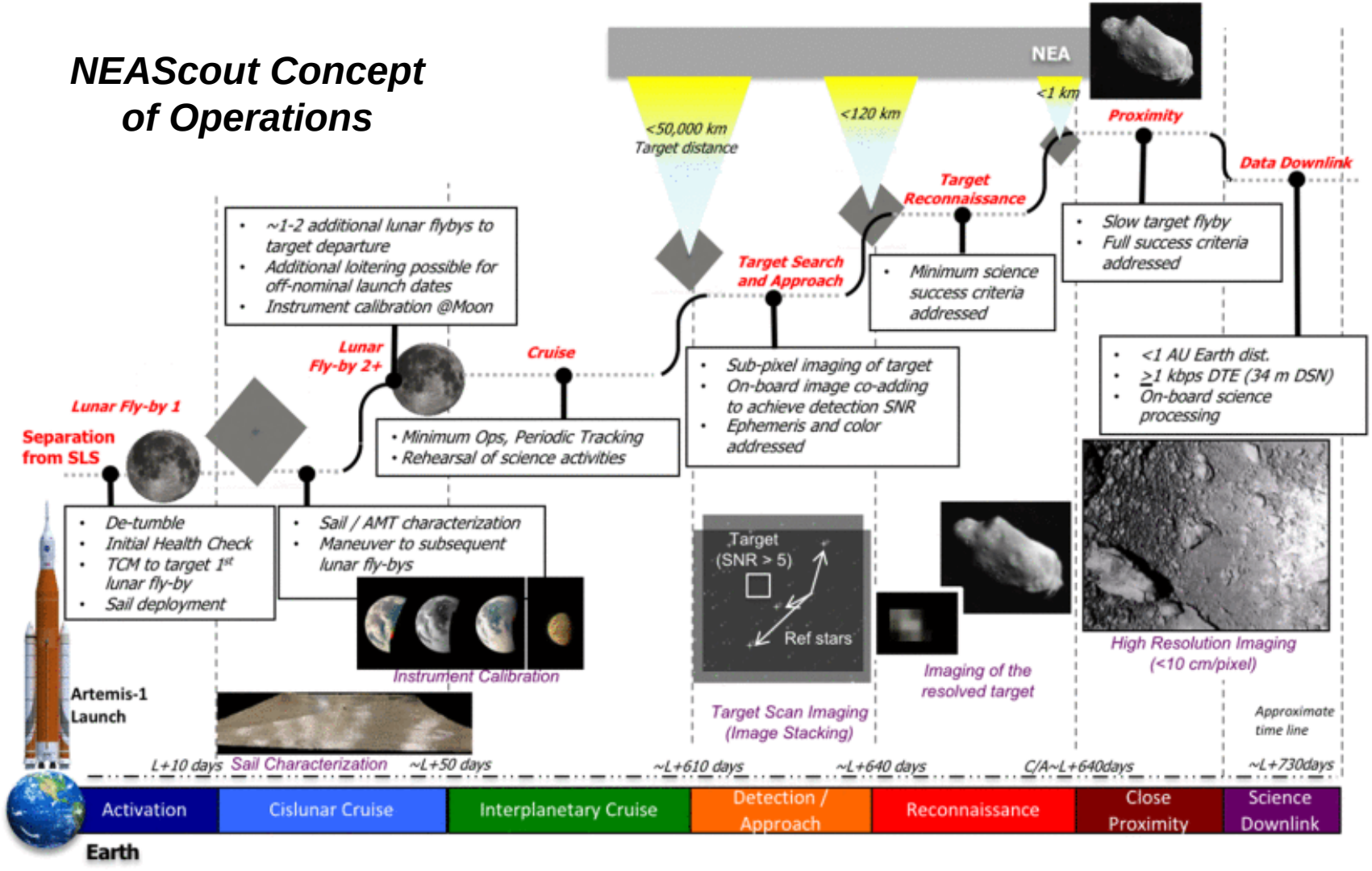


MSFC/JPL/LaRC/JSC/GSFC/NASA

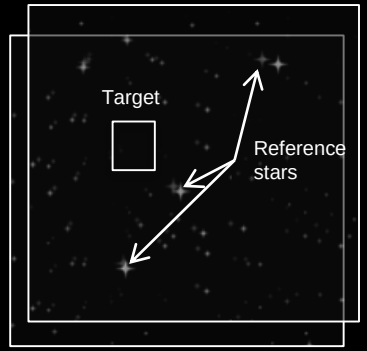
NEA Scout

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

NEAScout Concept of Operations



Imaging Challenges



Target Detection and Approach
Ephemeris determination

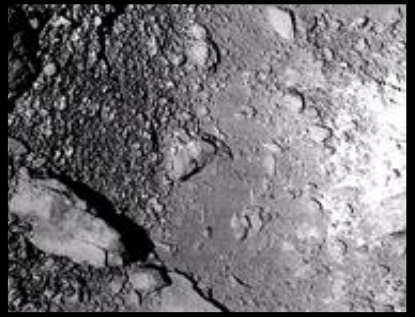
Target Position Uncertainty

Spacecraft Pointing and Camera Limitations

Medium Field Imaging
Shape, spin, and local environment

Short Flyby Time (<30 minutes)

Uncertain Environment



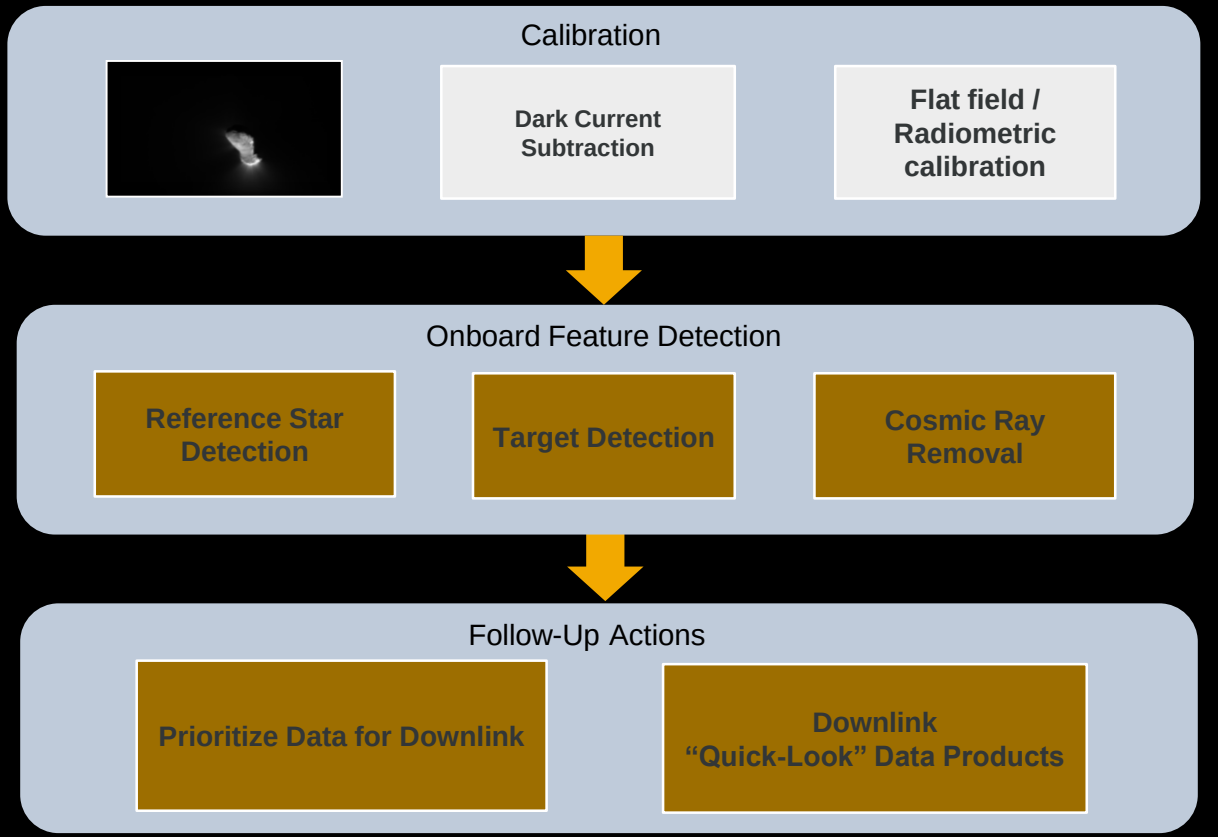
Close Proximity Imaging
Local scale morphology, terrain properties

Data Value Analysis and Sorting

Short Time at Closest Approach (<10 minutes)

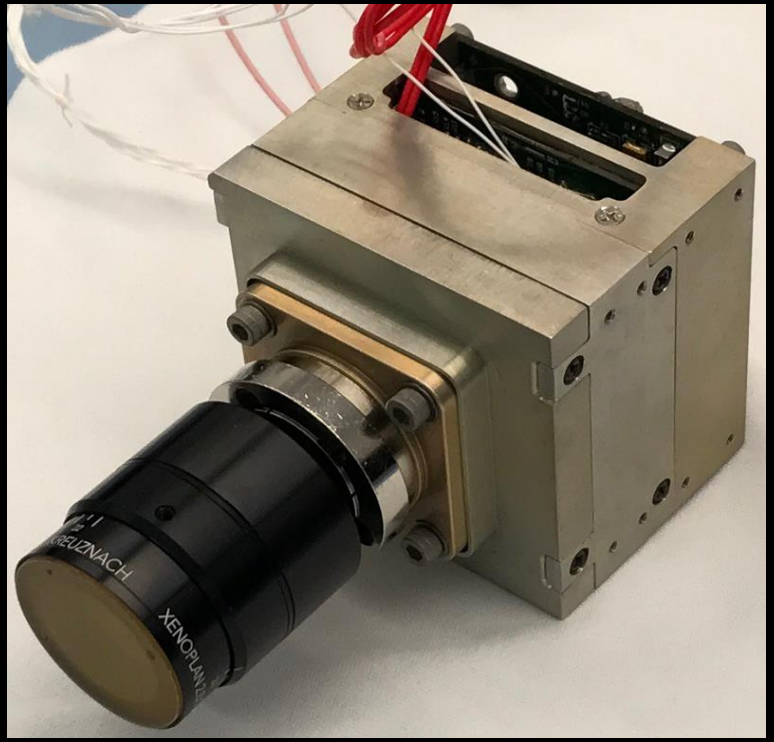
Limited downlinks of 30 minutes at 1 Kbps

Mission Operations Flexibility



Instrument Calibration

NEA Scout Camera



NEA Scout flight camera, based on Orbital Carbon Observatory 3 (OCO-3) mission context camera.

Sensor Capabilities	
Type	20M pixel CMOS image sensor
Useful array size	3840 x 3840 pixels
Pixel size	6.4µm^2
Full well	15,000e$^-$
Dark noise	8e$^-$ RMS
Windowing	Y-direction only
Shutter	Global
Color	Monochrome (with microlenses)
Quantization	12-bit per pixel
Electrical interface	
Physical	LVDS
Protocol	Spacewire RMAP
Power	< 3 Watts
Memory	64Mbits
FPGA	Microsemi Rad-tolerant ProASIC3
Camera Specifications	
Mass	390g
Volume	63mm x 63mm x 71mm
Operating temperature	-25C to +50C
Survival temperature	-35C to +70C
Optics	27° FOV, f/2.8, 50.2mm iFOV=0.09mrad/ pix

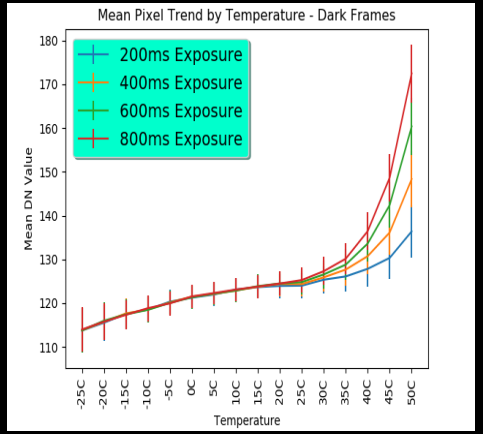
Onboard Image Calibration

- Onboard L1 calibration including:
  - Flat field normalization
  - Dark current subtraction
  - Bad pixel mask application

- Lab calibration products dynamically applied based on camera temperature at acquisition.

- Linear interpolation applied between calibration products bounding the raw image temperature.

- Ability to apply flat fields and dark current maps acquired in flight.



Laboratory calibration trends, across camera allowable flight temperatures

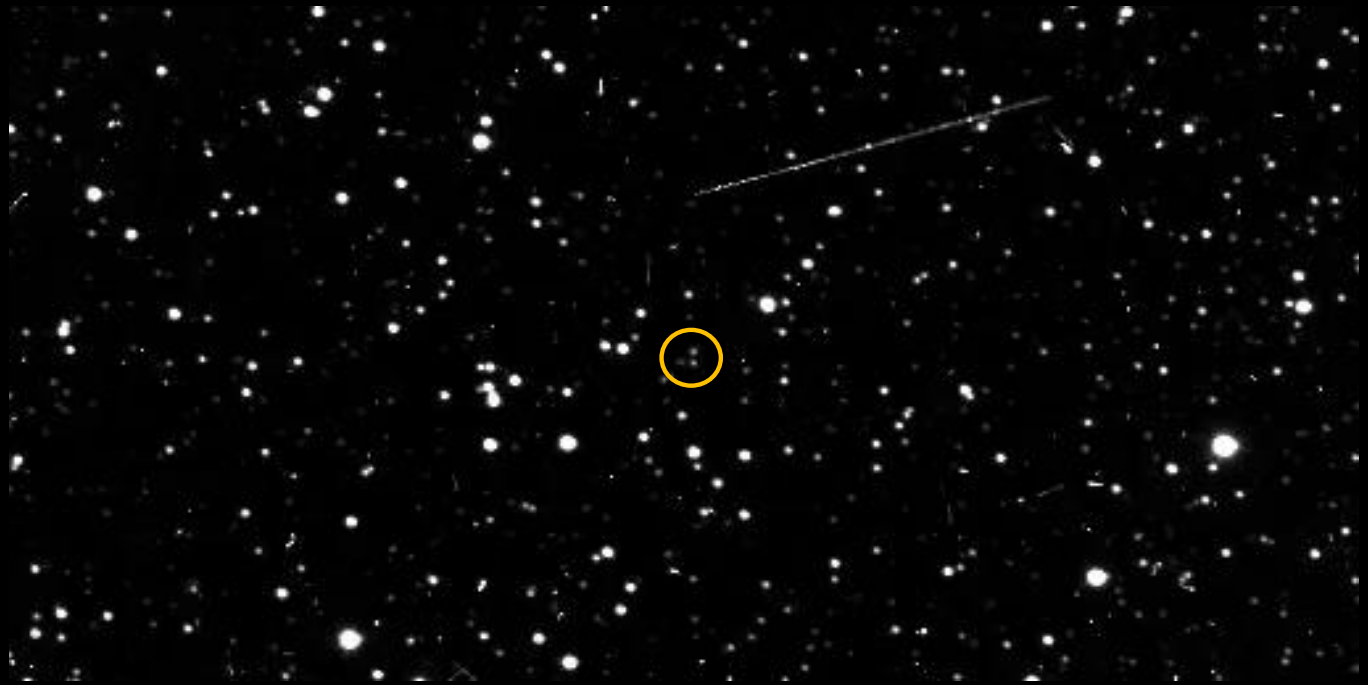
Calibration laboratory setup


Target Detection

Raw Data is Messy

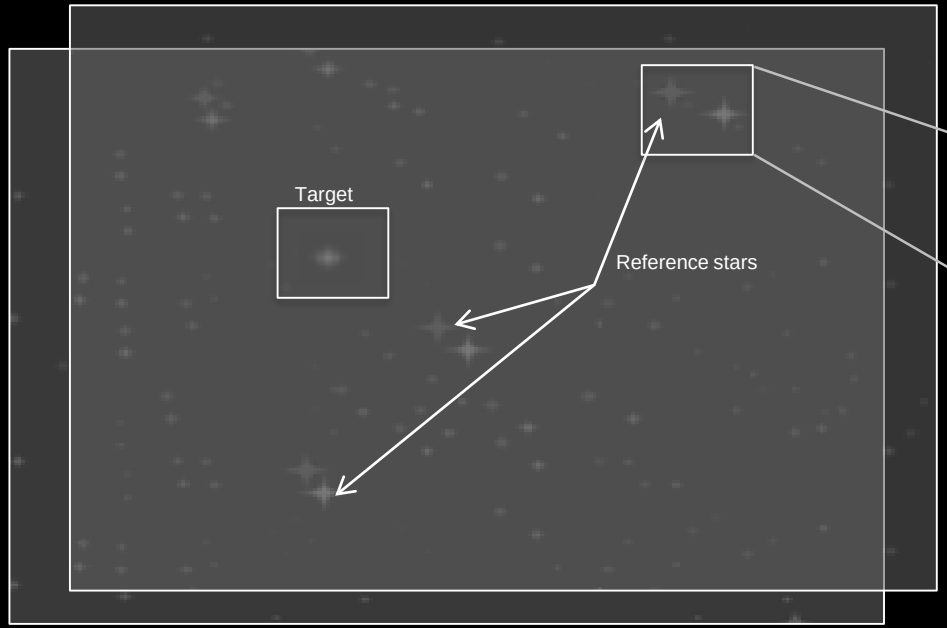
- Rosetta OSIRIS Narrow Angle Camera Detection of 2867 Steins

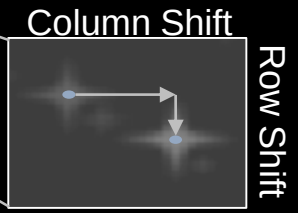
Raw Data is Messy



- Rosetta OSIRIS Narrow Angle Camera Detection of 2867 Steins

Cleaning Up the Noise





Sub-windowing around reference stars makes the problem computationally reasonable for flight hardware.

Onboard co-registration of images improves SNR and reduces downlink requirements

[Thompson et al. 2015]

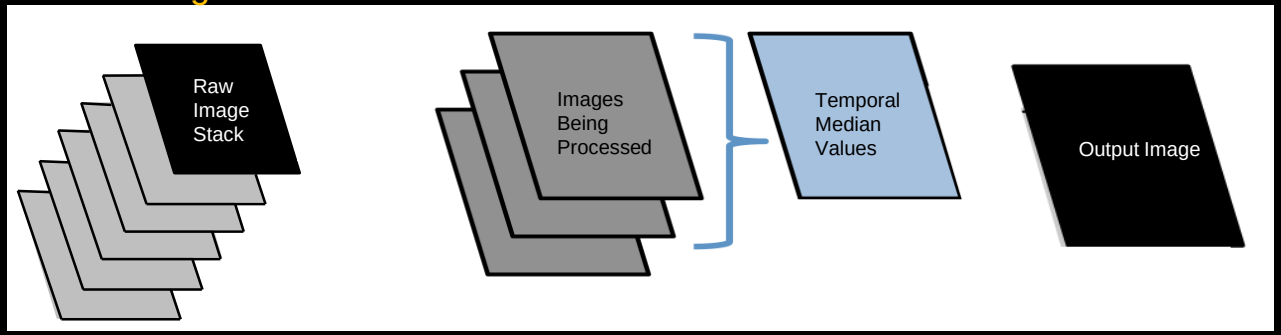
Computation is additionally constrained by onboard memory limitations.

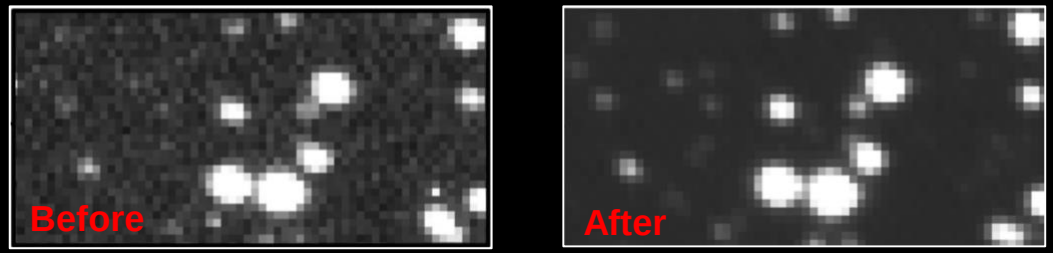
< 100 MB RAM

Pick Data to Co-register

Process in Batches of 3

Place Temporal Median on Output Stack



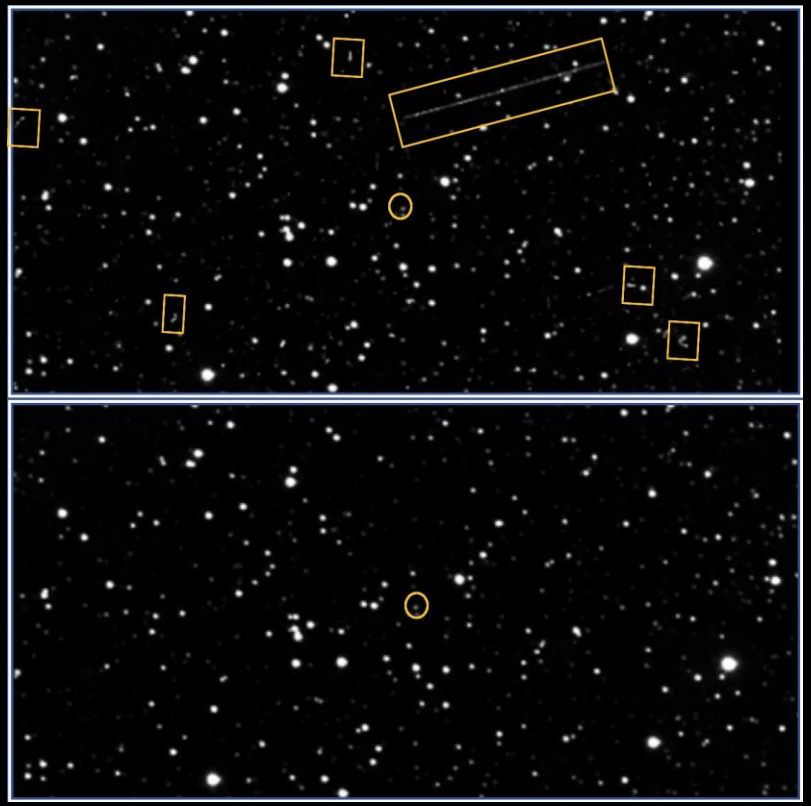


Stepwise processing keeps the necessary memory small.

[Thompson et al. 2015]

Cleaning Up the Noise

- Increase signal to noise without long exposure imaging.
- Decreases spacecraft pointing requirements.
- Removal of transient artifacts, such as cosmic rays.



Processed Data

Rosetta OSIRIS Narrow Angle Camera Detection of 2867 Steins

Identify Targets with Onboard Image Subtraction

Determine the shift between two images, subtract with (x,y) offset.

This type of information has many mission applications.

Current trajectory verification and refinement

Automated target tracking

Target of opportunity detection

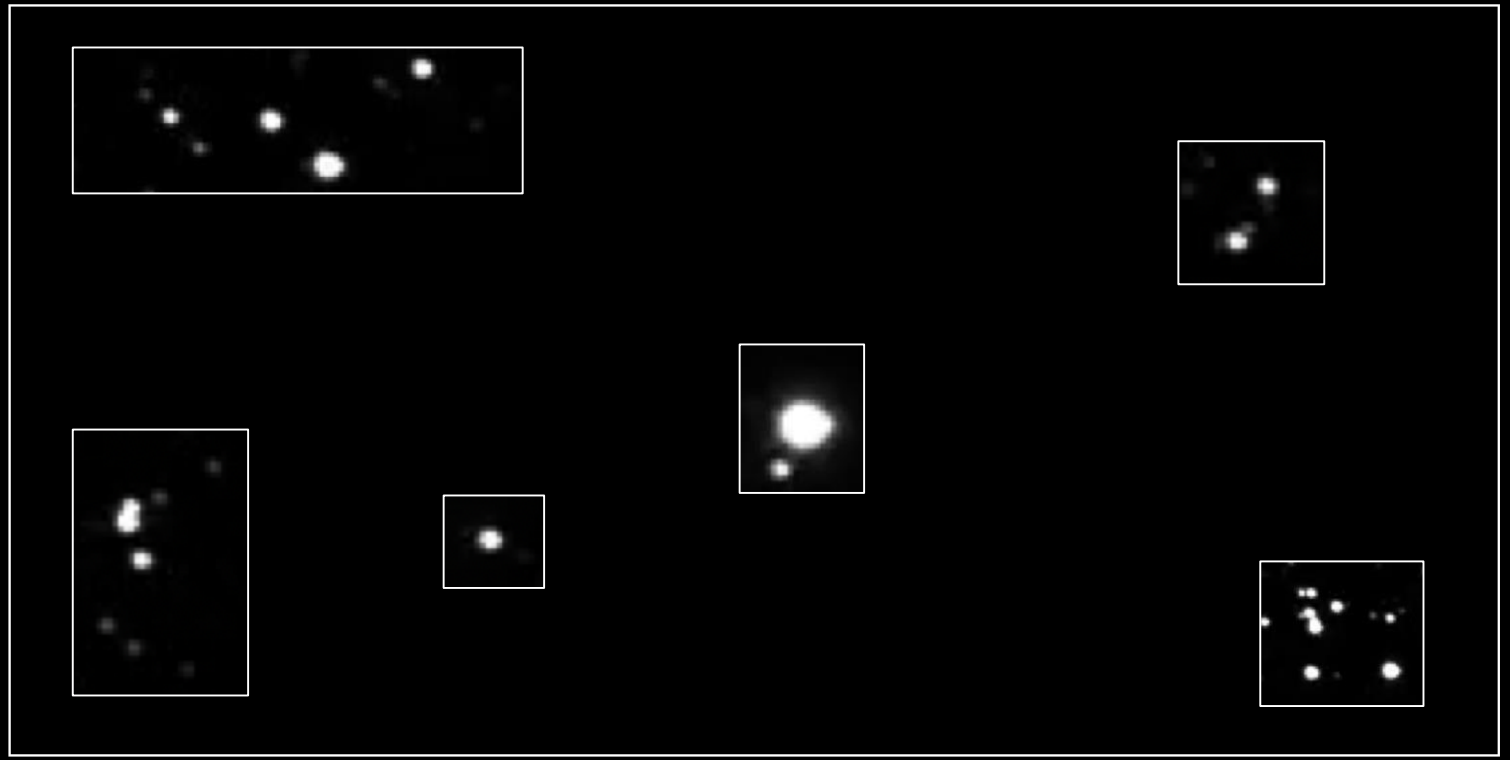
Target survey and classification

Does Your Target Look “As Expected”?

New Horizons Long Range Reconnaissance Imager Detection of Pluto/Charon


Target Approach and Flyby

Optical Navigation Products



Reconstructed optical navigation ground product resulting from window snapshots of uncertainty ellipses for target and reference star regions.

Flyby Data Curation & Prioritization

- Extremely limited bandwidth (1 kpbs) for future data downlink
- Limited flyby time (<1 hour)
- Limited image acquisition rate (15/min)
- No auto-exposure of camera
  - Utilize exposure bracketing
- Onboard image statistics to assess quality with limited data volume
  - Contrast calculation
  - Pixel histogram
  - Header information

Data Prioritization Strategies:

- Box crop around brightest pixel
- Box crop around specified coordinates
- Downsample
- ICER Compression (Lossy & Lossless)

Conclusions

- Software techniques can supplement spacecraft hardware limitations to achieve comparable science objectives.
  - reduced pointing precision
  - limited bandwidth volume
- Distilling science data return enables increased focus of attention by human operations, reducing turnaround time for critical decision making.
- Onboard data analysis enables new mission profiles which are not possible with traditional methods for analyzing science return.
- Onboarding image processing enables target location quantification and imaging using small amounts of bandwidth.
  - Enables new smallsat mission scenarios, where communications passes are short and infrequent.

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