



OSIRIS REx

Science Processing & Operations Center (SPOC) and Science Engineering Peer Review

April 21 - 23, 2015

OSIRIS-REX™
ASTEROID SAMPLE RETURN MISSION



16 – Satellite Search Processing
Carl Hergenrother – Astrometry and
Photometry Lead



Driving Requirements

- MRD-144 — Detect with 95% confidence natural satellites ≥ 10 -cm diameter with albedo ≥ 0.02 within 31 km of Bennu.
- In the case of a positive natural satellite detection
 - MRD-146 — OSIRIS-REx shall produce four light curves of detected satellites by measuring the time variation in their irradiance in four distinct wavelength regions that can be compared with observations of one or more recognized ECAS standard stars in the b, v, w, and x ECAS filters.
 - MRD-147 — OSIRIS-REx shall measure the integrated spectral properties of detected satellites and compare them to those of Bennu.
 - MRD-148 — OSIRIS-REx shall determine their average ECAS b-v color index, v-x color index, and the depth of the 0.7micron absorption feature, relative to one or more recognized ECAS standard stars.
 - MRD-196 — OSIRIS-REx shall determine the orbital properties and stability of detected satellites.
 - shared responsibility with RSWG, APWG produces astrometry & photometry, RSWG produces orbits and ephemerides



Relevant Schedule and Inputs (1/2)

- **1-meter Natural Satellite Search**
- Observations for product begin: 10/27/18
- All observations for product in to SPOC: 10/28/18
- Processing begins on or before: 10/29/18
- Product Complete: 10/30/18
- Data product lead : Carl Hergenrother
- Backup data product lead: TBD

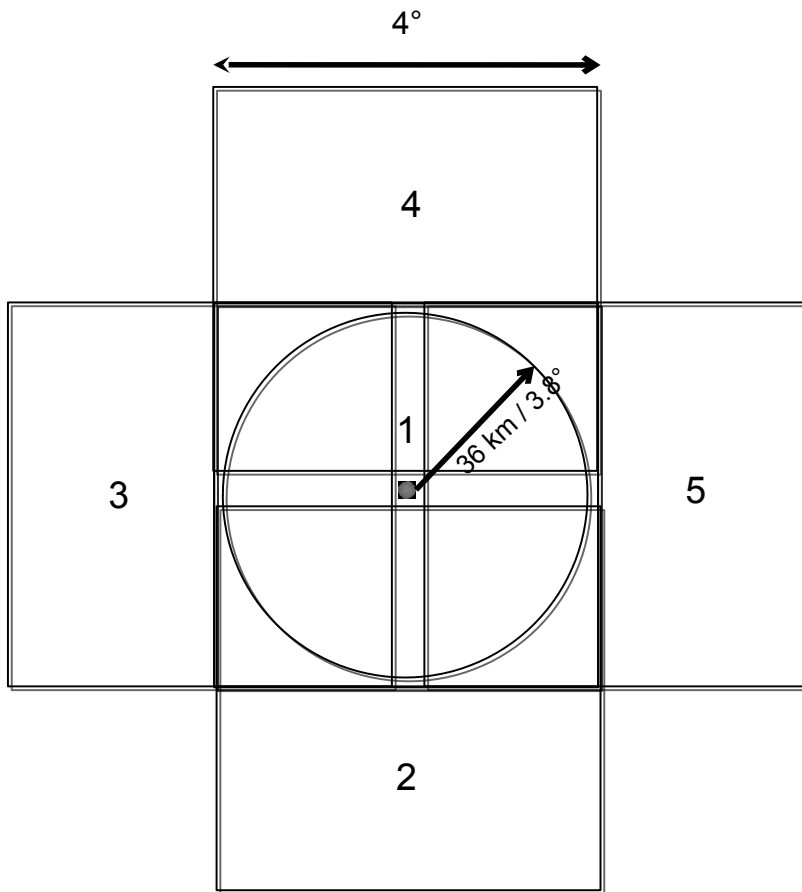


Relevant Schedule and Inputs (2/2)

- **10-cm Natural Satellite Search**
- Observations for product begin: 11/04/18
- All observations for product in to SPOC: 11/05/18
- Processing begins on or before: 11/06/18
- Product Complete: 11/07/18
- Data product lead : Carl Hergenrother
- Backup data product lead: TBD



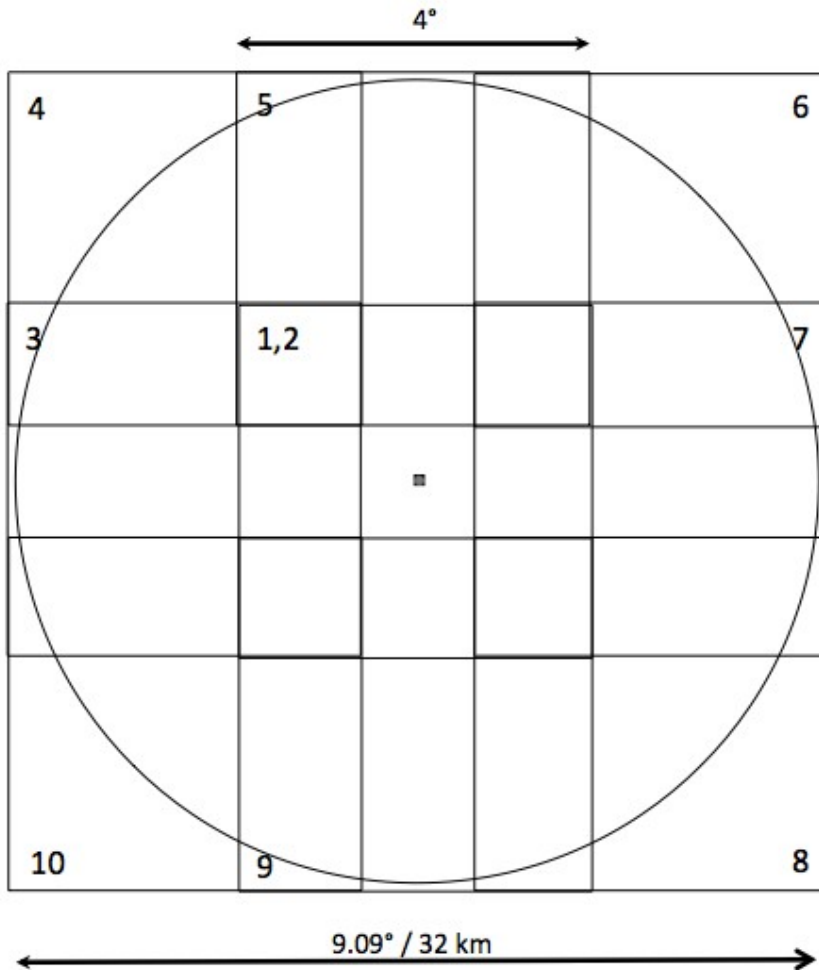
1-m Natural Satellite Search



- Search the Hill Sphere (out to 36-km from Bennu) for 1-m or larger satellites
- Search consists of 5 pointings (4 long, 1 short exposure) repeated 5 times over 5 hours for a total of 20 images
- The short exposure field is to prevent saturation or blooming of Bennu in order to measure its position relative to any satellites
- Conducted at a range of ~ 1060 km and phase angle of $\sim 51^\circ$
- At a range of 1060 km, Bennu will be integrated $V_{\text{mag}} \approx -3$
- $D = 60$ cm satellites detectable at $V = 11.9$ and $S/N = 2$



10-cm Natural Satellite Search



- Search for 10-cm or larger satellites within 16-km of Bennu
- Search consists of 10 pointings (9 long, 1 short exposure) repeated 5 times over 5 hours for a total of 60 images
- The short exposure field is to prevent saturation or blooming of Bennu in order to measure its position relative to any satellites
- Conducted at a range of ~ 201 km and phase angle of $\sim 0.4^\circ$
- At a range of 201 km, Bennu will be integrated $V_{\text{mag}} \approx -8.7$
- $D = 4.5$ cm satellites detectable at $V = 11.9$ and $S/N = 2$



10-cm Natural Satellite Search

$D \sim 10 \text{ cm}$



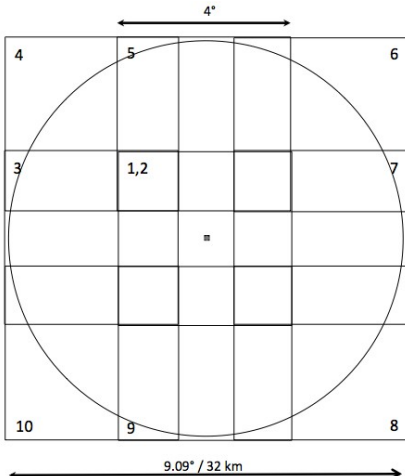
$D \sim 4.5 \text{ cm}$



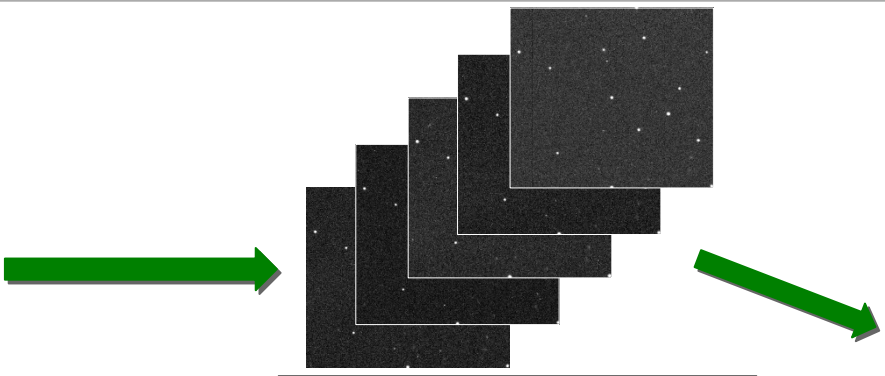
- $D = 4.5 \text{ cm}$ satellites detectable at $V = 11.9$ and $S/N = 2$



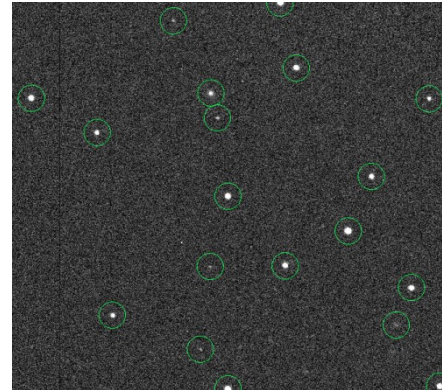
Nominal Product Development Process



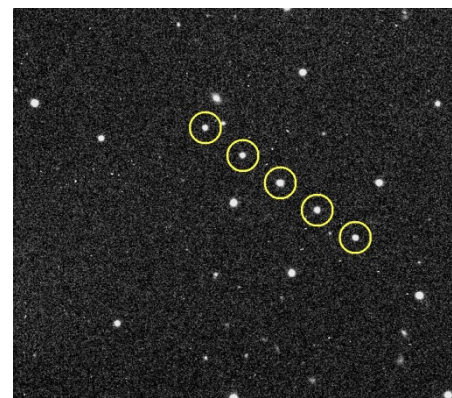
Satellite search conducted



Each field imaged 5 times over ~5 hours



Sources identified
 Astrometry and photometry conducted relative to standard catalog (UCAC4)
 Fixed and transient objects identified



Moving objects identified
 Manual scan for missed objects
 Manually inspection of all suspects

Produce astrometry and photometry for Bennu and each satellite
 Send to Radio Science WG and Flight Dynamics System

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natsat1 C2015 01 01.04172 03 51 56.17 +24 45 25.7 6.2 V XXX
natsat1 C2015 01 01.08339 03 52 06.56 +24 47 44.5 6.2 V XXX
natsat1 C2015 01 01.12506 03 52 16.94 +24 50 03.0 6.2 V XXX
natsat1 C2015 01 01.16672 03 52 27.33 +24 52 21.7 6.2 V XXX
natsat1 C2015 01 01.20839 03 52 37.73 +24 54 40.4 6.2 V XXX
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Status of Software Development (1/2)

- Astrometrica to be used for natural satellite search
 - Commercial software used by many ground-based asteroid observers around the world, already well developed
 - Spacecraft heritage (used by Dawn for Vesta satellite search)
 - Automated detection of moving objects and manual inspection for missed objects (useful for non-linear movers)
 - Significantly easier to use than other considered software (e.g., Catalina Sky Survey moving object software)
- Build 1 delivered July 2014
- Build 2 delivered March 2015
- Tests completed on ground-based asteroid data and synthetic MapCam data
- Documentation of use and testing of software complete



Status of Software Development (2/2)

- Astrometrica in action

The screenshot displays the Astrometrica software interface. The main window shows a stack of five image frames labeled 'Image - Benu_natsat_1.fits' through '5.fits'. A 'Verify Object 1/8 (3.30"/min, PA 45.0°)' dialog box is open, showing a zoomed-in view of a star with a red circle around it and a PSF fit graph. The PSF fit parameters are: x = 159.00, y = 359.01, SNR = 38.0, Flux = 14509, FWHM = 41.5", and Fit RMS = 0.004. Below the main window is a 'Data Reduction Results' table.

Image	Stars	Ref. Stars	Ref./Ast.	Fit Order	dRA	dDe	Ref./Phot.	dmag	Zero Pt.
Benu_natsat_1.fits	664	196	184	1	0.43"	0.48"	16	0.04mag	16.62mag
Benu_natsat_2.fits	659	196	184	1	0.38"	0.48"	19	0.04mag	16.61mag
Benu_natsat_3.fits	655	196	183	1	0.40"	0.46"	17	0.04mag	16.62mag
Benu_natsat_4.fits	660	196	182	1	0.39"	0.41"	10	0.04mag	16.65mag
Benu_natsat_5.fits	629	194	180	1	0.42"	0.48"	16	0.04mag	16.62mag

UCAC-4 Fit Order: 1 V mag MapCam.cfg



Minimal Mission Scenario

- In the case of approach data products, there is no change.
- Natural Satellite search
 - decreases risk to the mission.
 - occurs at a time of low resource load on the mission.
 - will be a part of the minimal mission.



Off-Nominal Discussion

- Current plan is for a 5-hr search for >1 -m satellites and a 5-hr search for >10 -cm satellites
 - Many reasons why search may be affected (s/c-instrument unavailable, poor s/c-instrument performance, CME impact)
- Investigating two paths to minimize data loss
 - Adding additional dates for satellite searching
 - 2-3 consecutive dates of searching rather than 1
 - Decreases risk of losing entire survey
 - Increases fidelity of orbit determination
- Wider FOV camera search for satellites at closer range
 - Pre-programmed braking maneuver uploaded to s/c
 - Use SamCam/NavCam to search at range of ~ 40 km
- No proxies for lost data.



Work to go

- Minimize contingency efforts in case satellite is found
 - Conduct searches on multiple dates to extend orbit arc
 - 1-day (5 hr arc), 2-day (29-hr arc), 3-day (53-hr arc)
 - Longer arc would remove need to re-survey region around Bennu
 - Instead a single pointed FOV would suffice to recover satellite
- Dealing with scattered light from Bennu
 - Bennu will be very bright during the satellite searches (-3rd magnitude during the 1-m and -7th magnitude during 10-cm)
 - Investigating 'gradient removal' techniques
 - Conduct test with Earth/Moon post-EGA
- Identify back-up responsibility for search



Next Topic (This slide will be done for you)

#	Start Time	Topic	Presenter
	7:45 AM	Coffee/Refreshments	
1	8:00 AM	Welcome	E. Beshore
2	8:10 AM	OSIRIS-REx Mission Overview and Priorities	D. Lauretta
3	9:10 AM	DRM Science Collection Overview	B. Boynton/J. Kidd
	9:55 AM	Break	
4	10:10 AM	Ground System Overview	J. Gal-Edd
5	11:10 AM	SPOC Overview	C. Shinohara
	11:55 AM	Lunch	
6	12:55 PM	Operations Overview	S. Barnes
7	1:40 PM	SPOC/Science Planning Process	B. Boynton/C. Hergenrother
	2:40 PM	Break	
8	2:55 PM	SPOC Implementation Process	S. Barnes
9	4:25 PM	SPOC Downlink Process	S. Balram
	4:55 PM	Board Caucus	Board



Backup

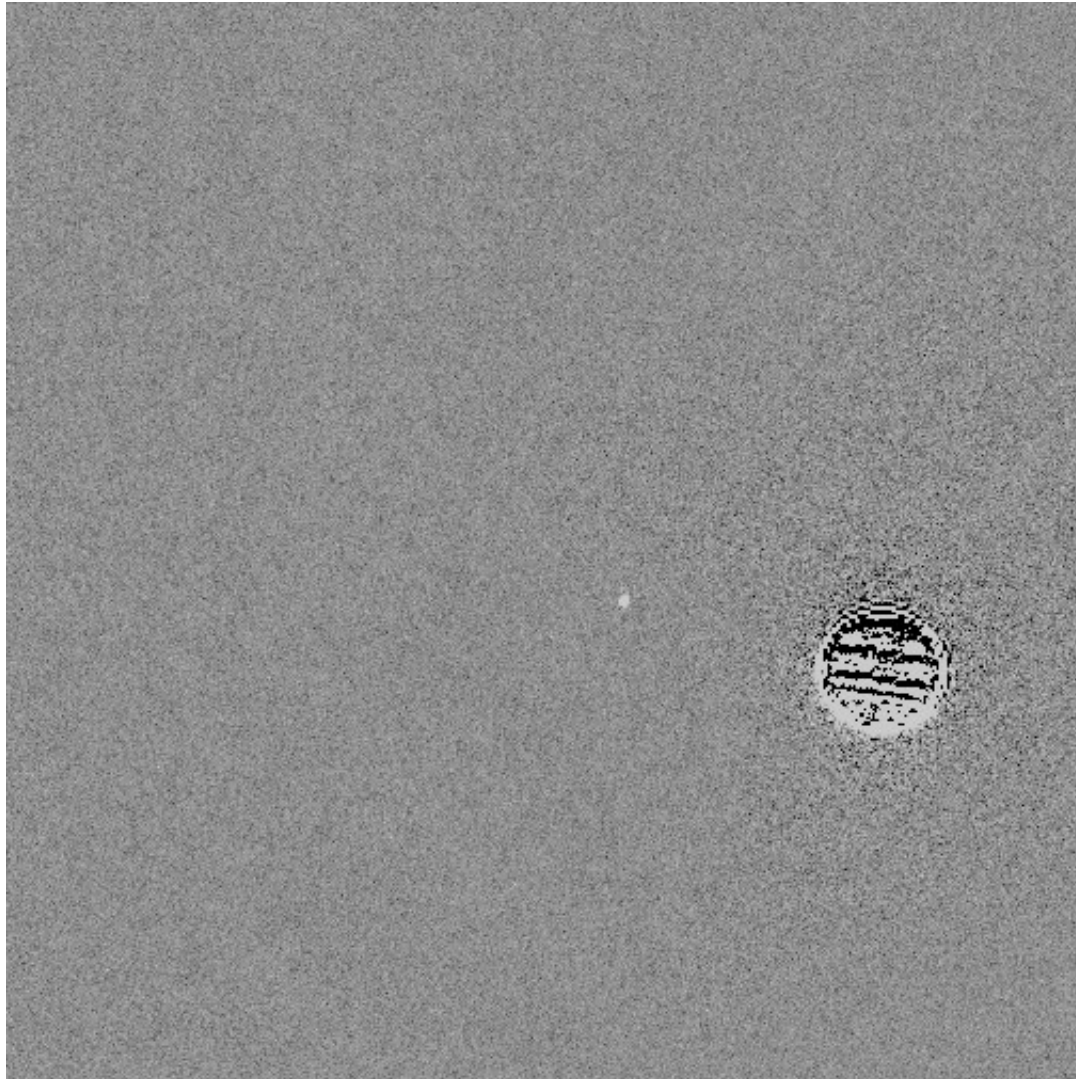


Make the glare...





...go away



- SExtractor used to model the glare from a bright object (in this case Jupiter)
- Glare model subtract from original image
- Allows detection of faint objects close to source of glare
- Astrometrica can be run on the glare subtracted images