Post-TAG Bennu Farewell Observations

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Purpose

The purpose of this document is to describe the nominal observation plan for the Bennu farewell observations. It is intended to provide enough information for the science teams and instruments teams to ensure that the plan is consistent with the instrument capabilities and that it meets the observation goals, or where it does not, the plan is nevertheless acceptable. Engineering details sufficient to determine if the plan fits within the spacecraft capabilities and available mission resources are provided here and in the Mission Plan Workbook.

Inputs

Mission Plan Workbook: Post-TAG Observations 2021-01-21

Kernels used for Science Phase Plan development:
LSK = naif0012.tls
PCK = pck00010.tpc
PCK = bennu_v16.tpc
SPK = de424.bsp
SPK = orx_210103_210525_210103_od297-R-PTO1-F-PTO5_v2.bsp
FK = orx_v14.tf
IK = orx_navcam_v02.ti
IK = orx_ocams_v07.ti
IK = orx_ola_v01.ti
IK = orx_otes_v00.ti
IK = orx_ovirs_v00.ti
IK = orx_rexis_v01.ti
IK = orx_struct_v00.ti
DSK = g_03170mm_spc_obj_0000n00000_v042.bds
SCLK = ORX_SCLKSCET.00063.tsc

TSE for Science Phase Plan development: orx_tse_210405_210601_POST-TAG_v1.txt

Observation Plan Summary

The OSIRIS-REx spacecraft will approach and fly by Bennu one final time on April 7, 2021. The goal of the Bennu farewell observation is to acquire a near-global dataset that allows asteroid surface change detection when compared to pre-TAG science observations from Detailed Survey. These data will also be used to assess instrument performance degradation from TAG and instrument viability for a possible extended mission.

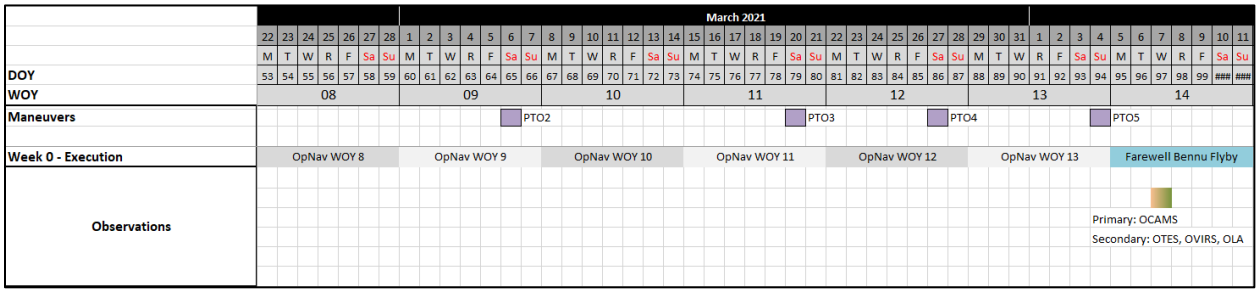


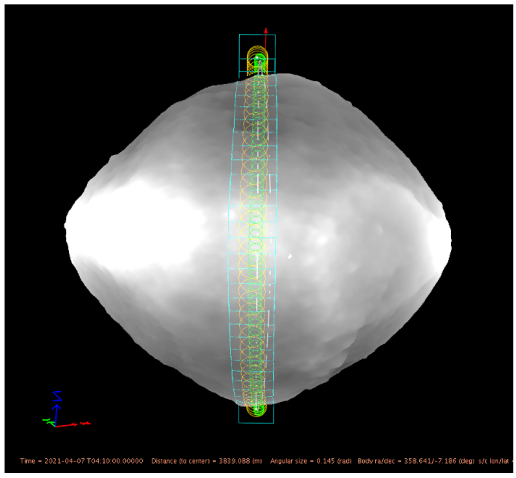
Figure 1 Timeline covering WOY 8 (first week of OpNavs) through the Bennu farewell observation scheduled in WOY 14.

FDS has designed a trajectory that imitates a hybrid of Detailed Survey Baseball Diamond Flyby1 and Flyby2, with a Flyby1-like equatorial sub-spacecraft latitude and a 12:30pm local solar hour sub-spacecraft longitude and a Flyby2-like range to Bennu COM of 3800m. On this trajectory, the spacecraft will perform NADIR-pointed north-south linear scans that extend across Bennu's polar dimension plus navigation uncertainties, with PolyCam as the primary instrument and OTES, OVIRS, and OLA as secondary instruments. Additionally, slews of MapCam color will be interspersed throughout the observation at regular intervals. This observation requires an ephemeris late update to repoint the observations at Bennu. To avoid a late update time-shift, utilized for re-centering the observation over the equator, the instruments will observe for more than one Bennu rotation.

Table 1 Proposed observation summary for the Bennu farewell observation.

Trajectory	Participating Instruments	Sub-spacecraft latitude (deg)	Local Solar Hour	Radius (km)	Slew Config	Slewing profile
FB1/FB2	OCAMS OTES OVIRS OLA	0°	12:30 PM	3.8	2 mrad/sec	Linear scan

Single Slew All: PolyCam



Single Slew All: MapCam

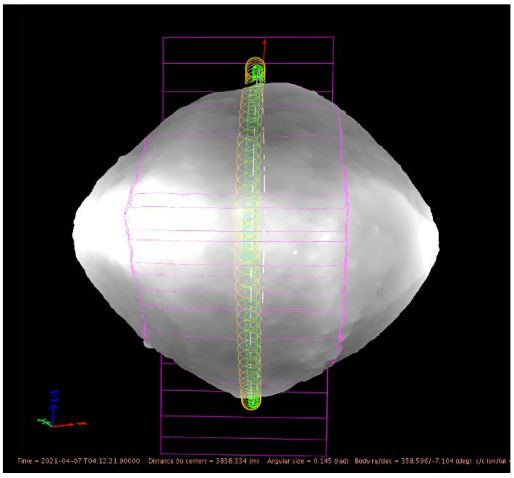


Figure 2 Demonstrations of single linear scans showing PolyCam and MapCam footprints.

Table 2 Viewing conditions for the linear scans.

North End Slew (+40˚to +90˚ lat.)

	Phase (deg.)	Incidence (deg.)	Emission (deg.)	LSH	Range (m)
Min.	7.54	8.27	8.98	01:17:04	3590.14
Max.	11.79	84.63	88.46	12:26:05	3875.73

Mid Slew (-40˚ to +40˚ lat.)

	Phase (deg.)	Incidence (deg.)	Emission (deg.)	LSH	Range (m)
Min.	7.46	0.77	0.89	12:24:44	3493.35
Max.	10.98	76.47	78.31	12:33:49	3688.12

South End Slew (-40˚to -90˚ lat.)

	Phase (deg.)	Incidence (deg.)	Emission (deg.)	LSH	Range (m)
Min.	7.43	2.93	3.8	12:33:46	3601.58
Max.	11.81	87.54	88.23	22:48:18	3818.14

*All values reported by J-Asteroid for OVIRS boresight.

Table 3 Approximate Nightingale viewing conditions. While the observation is planned to obtain global coverage of Bennu, Nightingale is the area of highest priority for imaging and change detection.

Best Guess for Nightingale

Lat. (deg.)	Lon. (deg.)	Phase (deg.)	Incidence (deg.)	Emission (deg.)	LSH	Range (m)
55.04	43.09	8.06	45.1	47.58	12:22:13	3686.26
57.04	42.89	8.1	41.4	42.91	12:21:35	3692
57.07	40.81	8.08	38.66	39.05	12:21:35	3691.19
55.21	40.95	8.05	46.03	47.57	12:22:10	3686.04

*All values reported by J-Asteroid for OVIRS boresight.

Observational Parameters

Table 4 Detailed observation parameters for a 4.5 hour linear scanning duration. The plan is to observe for ~1.4 Bennu rotations so the actual number of images will increase proportionally with the increased observation duration. Note that these image totals do not include PolyCam or MapCam dark images.

Observation Date:	2021-04-06 (DOY096)
Observation Duration (# of Bennu Rotations):	4.5 hrs. (1.05 Bennu Rotations)
Range to Bennu COM:	3493–3876m
Sub-Spacecraft Latitude:	0˚
Sub-spacecraft Longitude:	7.9˚
Local Solar Hour:	12:30pm
Observation Type:	Linear Scan (North-South scanning)
Spacecraft Pointing:	NADIR
Scan Range:	499m (Bennu polar diameter) + 2-sigma
Planning Radius:	249.5 + 2-sigma
Slew Rotational Resolution:	3.3˚
PolyCam Imaging Cadence:	6.6˚ (every other slew)
PolyCam Across-Slew Overlap:	32–33% (near equator, increasing towards poles)
Number of PolyCam Images Per Slew:	16
Total Number of PolyCam Images:	928
MapCam Imaging Cadence:	26.4˚ (every 8 slews)
MapCam Across-Slew Overlap:	46–48% (near equator, increasing towards poles)
Number of MapCam Images Per Slew:	8 (two color-sets)
MapCam Along-Slew Overlap:	70-90%
MapCam Along-Slew Color-Set Overlap:	~50% based on visual inspection
MapCam Along-Slew Filter Overlap:	~10-20% based on visual inspection
Total Number of MapCam Images:	120
Total Number of OCAMs Images:	1048
Spectrometer Imaging Cadence:	Continuous; same as slew rotational resolution, 3.3˚

OVIRS Across-Slew Overlap:	0% near the equator (~4m gores that decrease and close towards the poles)
OTES Across-Slew Overlap:	40–43% near the equator

Table 5 Approximate navigational uncertainties for the observation in meters.

	Start of Primary Observation:	Middle of Primary Observation:	End of Primary Observation:
1-Sigma Along-Track:	7.86950	8.79250	9.78267
1-Sigma Across-Track:	3.69200	3.91742	4.13033
X Planning Radius (across-track) + 2-sigma:	7.38400	7.83483	8.26067
Y Planning Radius (along-track) + 2-sigma:	265.239	267.085	269.065

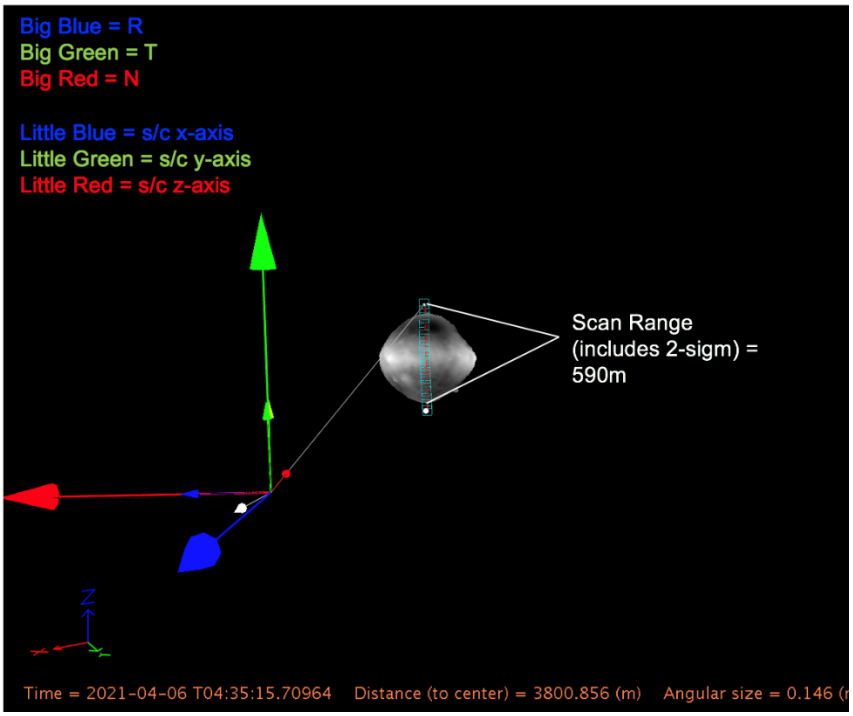


Figure 3 J-Asteroid illustration of spacecraft axes.

PolyCam Imaging

Though the spacecraft will be boresighted to OVIRS to optimize across-slew overlap for the smallest FOV, PolyCam is the driving instrument for this observation. The spacecraft will

perform continuous Linear Scans at a cadence of 3.3˚ of asteroid rotation which is the lowest rotational resolution achievable while extending the length of Bennu's polar diameter plus navigation uncertainties. Due to data volume limitations, PolyCam will only image along every other slew, at a cadence of 6.6˚, such that consecutive PolyCam images have ~30% overlap along slew and ~30% overlap across-slew.

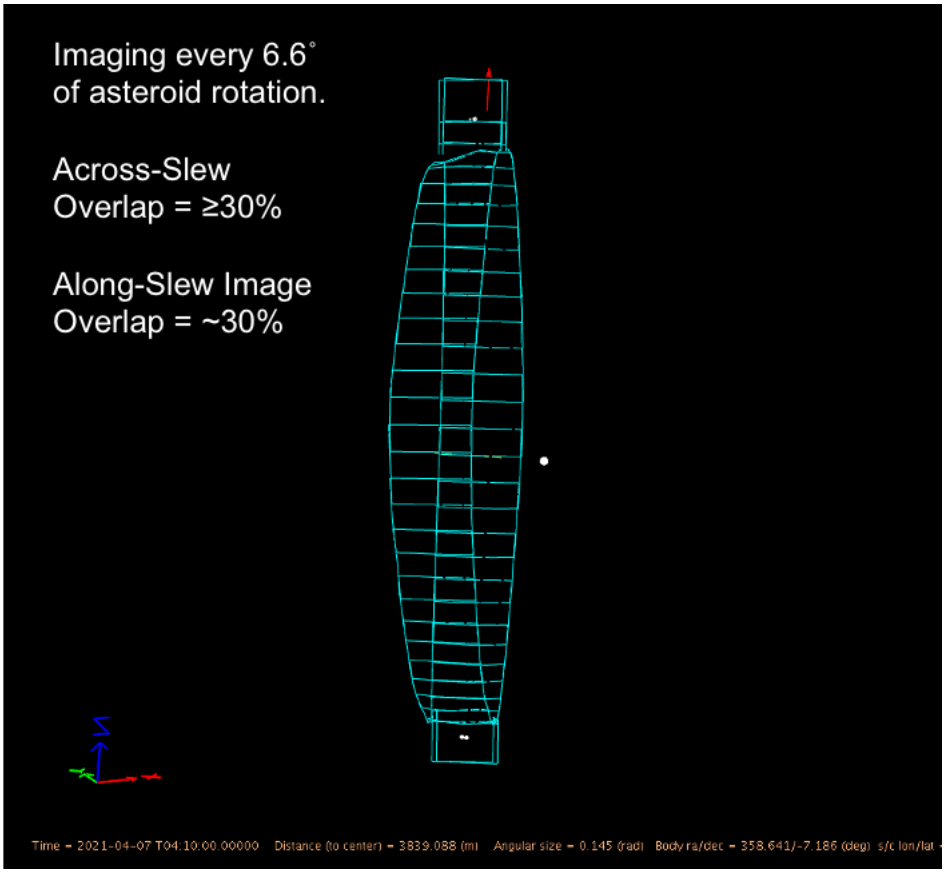
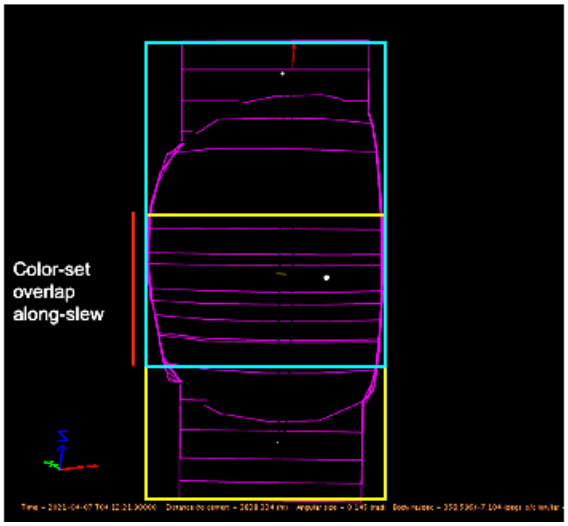


Figure 4 PolyCam across-track overlap.

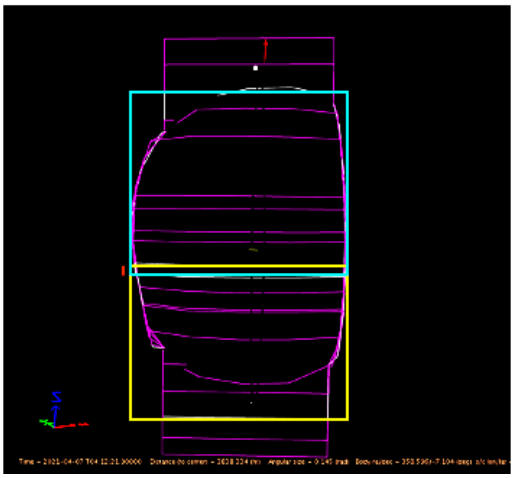
MapCam Imaging

MapCam imaging will occur every 8th slew (~26.4˚ of asteroid rotation). MapCam will acquire two color-sets without the pan filter (b, v, w, x) per slew that extend the length of Bennu's polar diameter plus navigation uncertainties. The decision to remove pan filter imaging was driven by a desire to increase like-filter-to-filter (e.g. v-to-v) overlap. With pan imaging included, like-filter-to-filter overlap was less than 10%. With the pan images removed, like-filter-to-filter overlap increases to 10-20%, based on visual inspection. Consecutive image overlap and color-set overlap along-slew is primarily limited by the spacecraft nominal SLOW_SLEW configuration (2 mrad/sec.). Across-slew image overlap is driven by the frequency of MapCam slews. This cadence can be adjusted based on science needs and data volume restrictions.

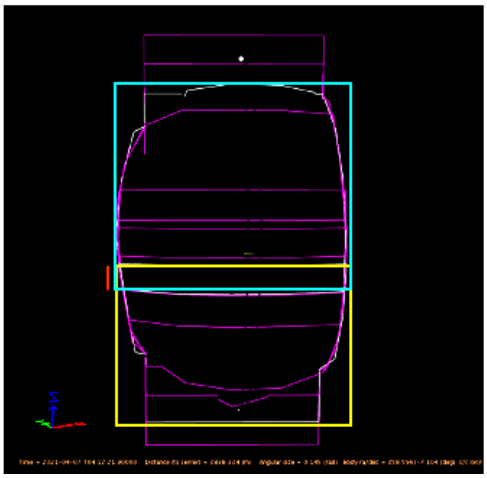
MapCam Color-Set Overlap Along-Slew



MapCam Filter Overlap Along-Slew: All Filters



MapCam Filter Overlap Along-Slew: Pan Removed



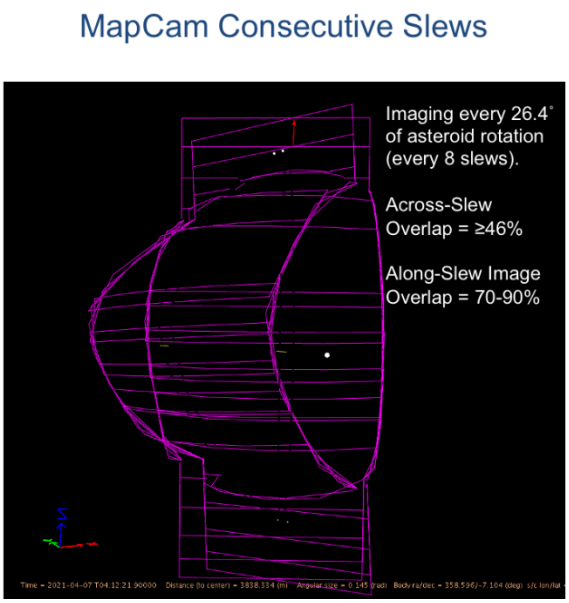


Figure 5 MapCam footprints demonstrating along-slew overlap and across-slew overlap.

Spectrometers

OVIRS and OTES will observe continuously for the duration of the observation. Deep space calibrations will be performed ahead of and after the primary observation. If time allows in the observation window, the deep space calibrations will be deconflicted from the initial and final slews of the ATF to avoid concurrent solar array movement.

OTES is expected to collect spectra using the nominal 2-second integration time. OVIRS integration time and super-pixel summing settings will be specified to fit within the onboard storage constraints without need for custom data routing. We expect SP=8 will be utilized though a final determination has not yet been made on the feasibility of the preferred SP=2 setting.

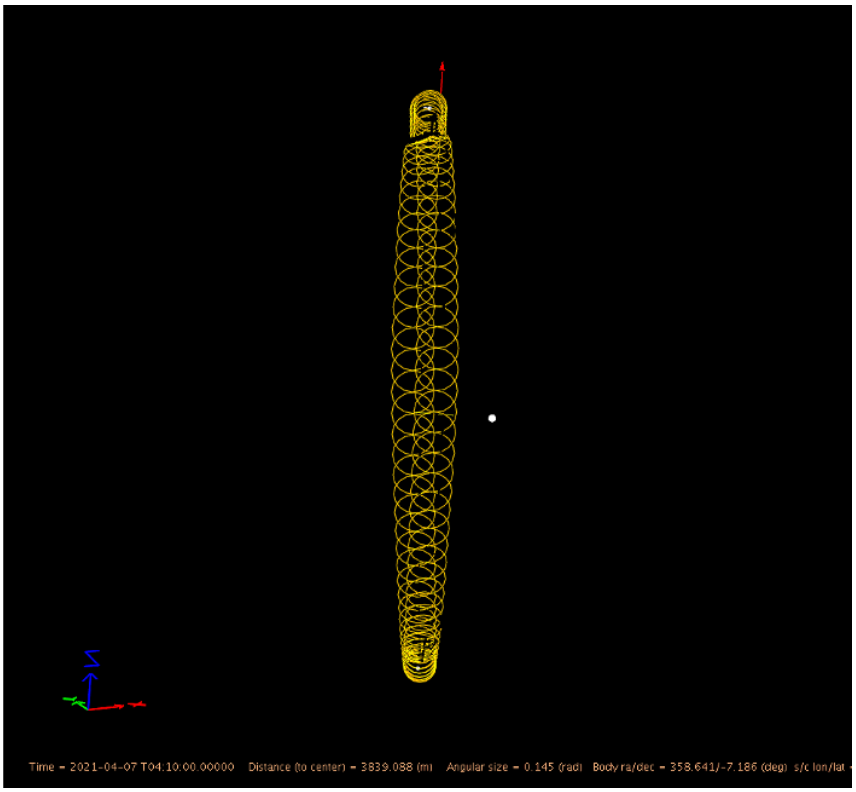


Figure 6 OTES across-slew overlap shows no OTES gores.

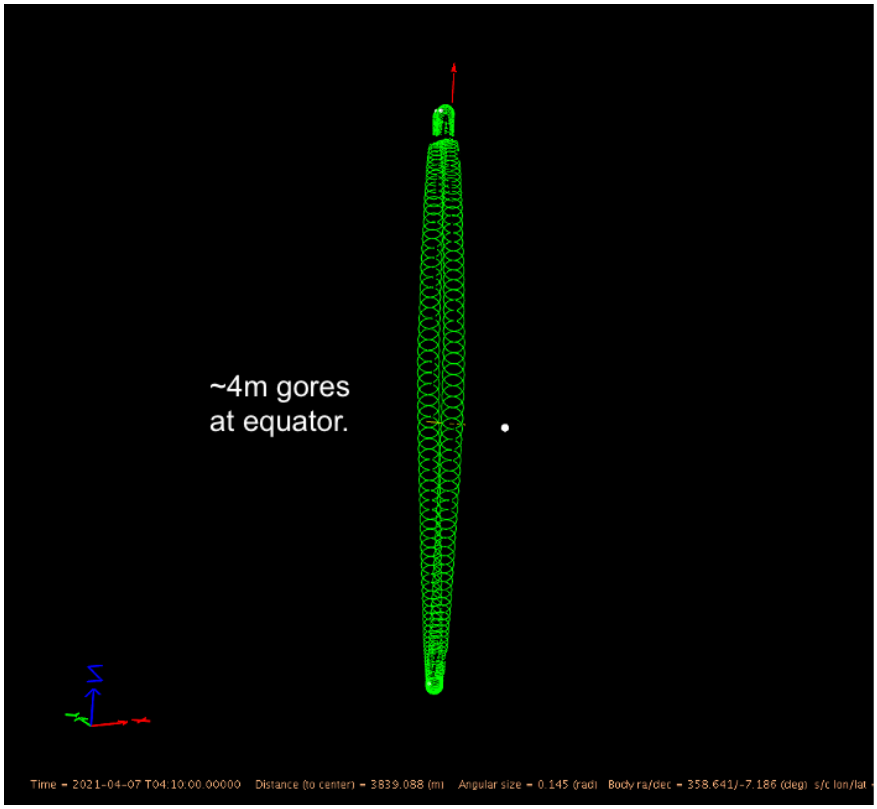


Figure 7 OVIRS data will have gores near the equator, decreasing towards the poles and eventually closing.

OLA Observations

OLA data will be collected using the High-Energy Laser Transmitter (HELT). The scan mirror will be operated in a linear scan in the cross-track direction. Additional details will be determined during tactical planning.

Operational Considerations

Fast slew = 5 mrad/s
Slow slew = 2 mrad/s
Slew acceleration = 0.0582 mrad/s/s
Spacecraft Clocking = VELOCY with s/c +Y-axis aligned with the s/c velocity vector
Slew Margin = 30sec.

The observation will require a ~36-hour ephemeris late update to repoint the observation at Bennu. To avoid a late update time-shift (for re-centering the observation over the equator), the instruments will observe for ~1.4 Bennu rotations.

Custom data routing will not be required for these observations. OCAMS images will be routed to the OCAMS partition, and once filled, additional images will go into the overflow partition. The details of the observation design, including the exact data volume, will continue to be refined until the beginning of tactical planning. The time it will take to downlink the acquired data is TBR and will be determined based on the pass0 background sequence.

Since OCAMS will be utilized for OpNavs in the weeks leading up to the Bennu farewell observation, the ocm_weekly_reset will be run weekly. For the science observation, PolyCam should be run at warm temps using the thm_sensors_sci_polycam10.cfg, set at least 20 hours prior to the first science activity. There should be a manual focus motor move before the science observation, and PolyCam should returned to infinity position after the science activity.

OTES will follow its standard power on and off procedure. OVIRS heaters will be maintained at non-op. OVIRS will be powered on the day prior to the observation with the Earth Comm Cal GV set to 1.This allows for acquisition of Earth Comm calibrations prior to the science observation. After the science activity, OVIRS is powered off and the Earth Comm GV is returned to 0.

The OLA thermal preheat will occur the day prior to the observation during the HGA pass (need a minimum of 1.5 hours), using manual thermal commanding. OLA will be powered on shortly before the science ATF.

Sun Point will be the default attitude. The plan will be built nadir-relative with an initial attitude of Sun Point and will include a slew at the end of science that returns the spacecraft back to Sun Point.

NavCam1 OpNavs will be added on a best effort basis to the dedicated spectrometer deep space calibrations which will occur before and after the science observations.

Flight Rule Violations/Soft Constraint Alerts:

- **0306-D-GNC:** STU1 KOZ violated by Bennu for total of 156.40s on the initial NADIR slew.