DETAILED SURVEY: BASEBALL DIAMOND

Table of Contents

Purpose

The purpose of this document is to describe the nominal observation plan for the Detailed Survey Baseball Diamond phase of the mission. 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 constraints, 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.

The first half of this document focuses on the description of the observation plan. The second half of this document describes requirements, the constraints needed to meet those requirements and whether the constraints are met in the plan, and the resulting data products.

REXIS calibration activities covered in SPP SOCR-41 includes activities that may take place during Detailed Survey Baseball Diamond.

Inputs

Observation Constraints Spreadsheet:
UA-OPS-4.0-1001_Observation Constraints_DRAFT_4.n_CCv0061

Mission Plan Workbook: OSIRIS-REx 02.0 PSE\Mission Plan\Mission Plan Workbook\Mission Plan Workbook 2018-05-08.xlsx

FDS delivery of products used for science planning of the orbital portion of Baseball Diamond are described here on ODOCS. TSEs with filter case CBE and OpNav type LM should be used, specifically orx_tse_190111_190114_Orbital-A-CBE-LM_v2.
OSIRIS-REx Mission Operations System 7.0\Science Operations Planning Group (NON-US persons access)\Supporting Material\Detailed Survey Baseball Diamond\OA_SOPG.docx

Kernels used in planning the Baseball Diamond flybys:
LSK = naif0012.tls
PCK = pck00010.tpc
PCK = bennu_v10.tpc
SPK = de424.bsp
SPK = orx_190220_190608_DS_MPRevB.bsp
FK = orx_v07.tf
IK = orx_navcam_v01.ti
IK = orx_ocams_v06.ti
IK = orx_ola_v00.ti
IK = orx_otes_v00.ti
IK = orx_ovirs_v00.ti
IK = orx_rexis_v00.ti

IK = orx_struct_v00.ti
DSK = RQ36mod.oct12.bds
SCLK = ORX_SCLKSCET.00016.tsc

FDS delivery of products used for science planning of the flybys are described here on ODOCS: OSIRIS-REx Mission Operations System 7.0\Science Operations Planning Group (NON-US persons access)\Supporting Material\Detailed Survey Baseball Diamond\ DS_BBD_SOPG.docx

MRD Overview

Baseball Diamond is the Global Imaging Campaign. During this phase MapCam and PolyCam data will be acquired that will ultimately produce Global Pan Image Mosaics, Global Color Maps, and a Global 35cm shape model for SPC. In addition, preliminary NFT features will be identified and built and OLA data will be collected that will help refine the shape and spin state of Bennu. Below is a list of the driving MRDs for Baseball Diamond and those that "fall-out" or are derived from the driving MRDs:

		Derived MRDs														
		MRD-115b	MRD-124	MRD-127	MRD-128	MRD-129	MRD-132	MRD-136	MRD-137	MRD-138	MRD-139	MRD-142	MRD-195a	MRD-542	MRD-608a	MRD-732
Driving MRDs	MRD-121							✓	✓	✓	✓	✓	✓			
	MRD-141													✓		
	MRD-687a														✓	
	MRD-728															✓
	MRD-678b	✓	✓	✓	✓	✓	✓									✓

Observation Plan Summary

The following table maps the 7 Baseball Diamond Flybys (11 stations) to the MRDs they satisfy:

	MRD-121	MRD-141	MRD-687a	MRD-728
FB1			✓	✓
FB2		✓	✓	
FB3	✓			✓
FB4 A	✓			✓
FB4 B	✓			✓
FB5 A			✓	✓
FB5 B	✓			✓
FB6 A			✓	✓
FB6 B	✓			✓
FB7 A		✓	✓	
FB7 B		✓	✓	

The 7 flybys are preceded with six days of MapCam observations made from orbit before beginning the flybys to aid in shape model determination via stereo photoclinometry (SPC). The orbit has the same parameters as the last few days of Orbital-A. At this point in the mission, the

Flight Dynamics team will have collected sufficient data to change to landmark tracking. We will plan on taking images with a 6° off-point from nadir toward the sunlit hemisphere.The MapCam images will be collected every 10 minutes throughout the nominal 16-hour science window using FAST_NADIR_REL targets, for a total of 96 MapCam images and 10 darks per day. Even though images are only needed at high latitudes, we will collect them continuously simply because we do not know where we will be in the orbit at any given time. OTES will be collecting data as a ride along during this orbital phase.

Every 2 hours a set of TAGCAMS OpNav images will need to be taken. Because of anticipated high uncertainty on the evolution of the orbit, a 2x1 mosaic of images with off-nadir pointing will be needed. If the OpNav images making up the mosaic are taken in succession, this may delay the following MapCam observation by a few minutes such that the spacing between MapCam observations could exceed 10 minutes once every 2 hours. If a MapCam observation is instead placed between the two observations making up the OpNav mosaic, the 10 minute cadence can be maintained. This second option would be more slightly more onerous to plan but either option is feasible for science planning.

After leaving the orbital part of Baseball Diamond, the 7 flybys are initiated. The 11 observation stations and 7 flybys are shown schematically in Figure 1. The flybys are spaced on a 7-day cadence. Some flybys have a single observation location near the equator, and others have two observations locations, one in the north and one in the south. To ensure tight targeting constraints, the observations are preceded with 24-hr late-update navigation predictions.

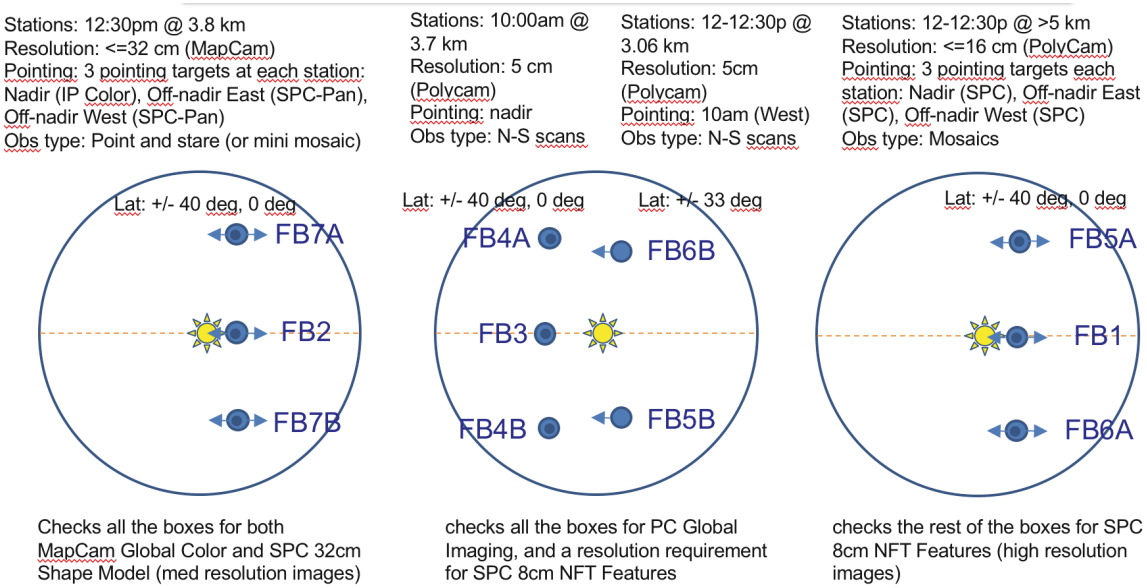

Figure 1. Schematic of the 11 observation locations. Arrows indicate when viewing locations are to also include images to the east or west.

Observation Plans

The equatorial observing stations, 1, 2, and 3, have been successfully planned in J-asteroid. The non-equatorial stations have been successfully modeled in MASC. All plans are based on 2-σ navigational uncertainties and use a 2 mrad/s slew rate. The results are shown in Table1.

Table 1. Observational Parameters for the Baseball Diamond flybys

Observation Station	1	2	3	4A, 4B	5A, 6A	5B, 6B	7A, 7B
Date	2019-03-07	2019-03-14	2019-03-21	2019-03-28,29	2019-04-04,11	2019-04-05,12	2019-04-18,19
Time	18:00	18:00	18:00	18:00	18:00	18:00	18:00
Range to Bennu	5000m	3800m	3700m	3700m	5000m	3060m	3800m
Sub S/C Latitude	0˚	0˚	0˚	±40˚	±40˚	±33˚	±40˚
Solar Local Hour	12:30pm	12:30pm	10:00am	10:00am	12:30pm	12:30pm	12:30pm
Pointing	Nadir East West	Nadir East West	Nadir	Nadir	Nadir East West	West (10:30am)	Nadir East West
Prime Instrument	PolyCam	MapCam	PolyCam	PolyCam	PolyCam	PolyCam	MapCam
Latitude Range Covered	±45˚	±35˚	±45˚	±45˚	±45˚	±35˚	±35˚
Scan Type	Rectangular Raster Scan	Point and Stare	Linear Scan	Linear Scan	Rectangular Raster Scan	Sun Line Scan	Point and Stare
Raster Dimensions/ Number of Images per Slew	3x9	2 pan, 2 color sets, 2 pan 14 frames	16	17	3x10, 3x9	15,21	2 pan, 2 color sets, 2 pan 14 frames
Rotational Resolution	10˚	24˚	4˚	6˚	9.8˚	7.3˚,8˚	24˚
Along-Slew Overlap	34%	50%	30%	30%	30%	30%	30%
Mid-Slew Overlap[1]	49%	58%	72%	58%	50%	31%, 25%	NA
Number of Images	982	230	1450	1000, 1060	1110, 1003	742, 953	230, 230
Data Volume	17398 Mb	3759 Mb	20942 Mb				
MRD(s) Being Satisfied	687a, 728	141, 687a	121, 728	121, 728	687a, 728	121, 728	141, 687a

[1]Mid-Slew Overlap is the overlap between slews at the observation latitude.

It can be seen from the table that linear scans are used for stations 3, 4A, and 4B. These scans are made in a north-south direction and rely on the rotation of Bennu to cover the surface. Sun line scans, which target solar longitude at the two target points, are used for stations 5B and 6B. The rotational resolution, compared to the size of the footprint, determines the amount of overlap between slews. The between-slew overlap increases at higher latitudes because the

linear motion of the surface is smaller at higher latitudes. The table shows the between-slew overlap at the sub-spacecraft location. These overlap values do not take into account the shape of Bennu.

The other six observation stations have multiple pointings, which prohibit use of the linear scan. Figure 2 shows an example of the placement of the PolyCam footprints for station 1, which have additional pointings to the east and west. The observations at this station are made using a 3-line raster scan. Stations 5A and 6A have similar observation requirements, and observations there are similarly made with a 3-line raster scan.

Observations from stations 2, 7A, and 7B collect MapCam images made with a 3x2 point-and-stare scan pattern. Because of the much larger field of view (FOV) of MapCam compared to PolyCam, MapCam images are only needed at the ends of each slew, and there is sufficient time that we pause so that the 5-frame color set can be taken with no slew motion. The overlap between color frames will be determined simply by the rotation of Bennu in the 22.4 seconds needed to take the frames.

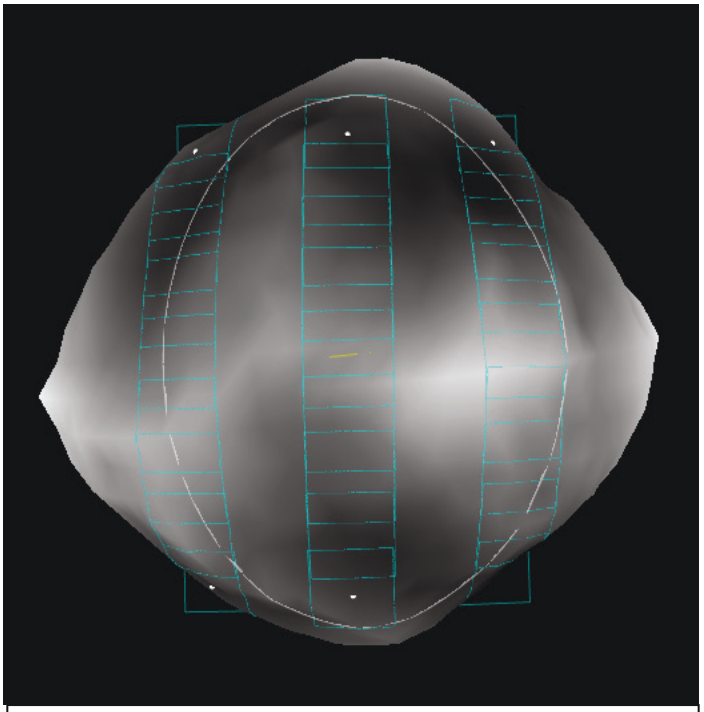

Figure 2 shows the spacing of the PolyCam footprints in an observational set from station 1.

The observational constraints call for the latitude of the observations to typically be within a range of ± 3° (6° full range of latitudes), though one case each of ±1° and ±5°are called out. These constraints cannot be met with the flyby trajectories planned, thus for some of the stations the spacecraft will nominally transit a larger range of latitudes during the 4.3 hour observation period than specified.

The navigational uncertainties contribute to extending the range of latitudes by causing the spacecraft to arrive either early or late to the observation location. Table 2 shows the delivery navigational uncertainties and the amount of time early or late the spacecraft might arrive due to the 2-σ navigational uncertainties. We can compensate for this uncertainty based on late updates to the spacecraft ephemeris by simply shifting the time of day when we begin the observations to the updated arrival time. There is only a ± 90-minute window available for time shifting, and 7 of the observations have timing uncertainties larger than this window. The remaining uncorrected uncertainties in these cases is on the order of 2 degrees or less, which is small compared to the much larger range of latitudes over which the observations are made due to the spacecraft motion during the 4.3-hour observation time as shown in table 2. The wide variations in the latitude ranges are due to different distances from the Bennu center of mass, and there is little that can be done to reduce this range. The delivery longitudinal uncertainties are given in meters because the degrees of longitude decrease with latitude.

Generally they are on the order of a degree or 2 whereas the observation constraints are for +/- 6 degrees or more.

Table 2. Delivery navigational uncertainties and latitude range of observations with nominal trajectory.

Station Number	2-sigma Longitude uncertainty (m)	2-sigma Latitude Uncertainty (deg)	2-sigma Time Correction Needed (minutes)	4.3-hr Latitude Range (deg)
1	113	3.0	134	5.8
2	98	4.4	103	11.1
3	88	4.7	106	11.5
4A	136	4.0	88	12.8
4B	58	9.2	168	12.6
5A	141	2.0	69	7.2
5B	134	7.4	102	18.4
6A	151	2.2	76	7.3
6B	140	7.8	108	18.4
7A	120	3.0	70	12.3
7B	102	7.1	136	11.4

OLA Observations

OLA observations are made at the non-equatorial stations to support the imaging for stereo photoclinometry (SPC). The data will be collected based on the High-Energy Laser Transmitter (HELT) operating at 100 Hz. The scan mirror will be operated in a linear scan in the cross-track direction. For the purposes of this SPP development, the width of the scan was assumed to be 0.0090 rad (80 mrad) with spot spacing of 3.5E-4 rad (0.35mrad).

OVIRS Observations

OVIRS has no requirements for observations in this time period, and the available data volume do not support operating OVIRS as a ride-along instrument.

OTES Observations

OTES data will be collected as a ride-along instrument on all flybys. It will be collecting spectra using its normal 2-second integration time.

L+30 Month Calibrations

Launch+30 month calibrations consist of the routine every-6-months instrument check-out calibrations for all the instruments as well as OCAMS solar analog and star cluster observations for radiometry and geometric distortion trending. The calibrations nominally are to take place during March of 2019. There are no requirements to point toward Bennu during the

calibrations, so they could happen on a transit leg during Baseball Diamond, or at the end of the orbit phase of Detailed Survey.

Operational Considerations:
Fast slew = 5 mrad/s
Slow slew = 2 mrad/s
Slew acceleration = 0.0582 mrad/s/s
All stations are planned with velocity clocking.

All stations require 24-hour late updates, but with relative ATL it is expected that time shifts coupled with the 24 hour ephemeris updates will suffice. As noted above, we cannot satisfy all of the observational constraints on the latitude of observation with only 90 minutes of margin on the SOW. We considered collecting data for a longer period of time to avoid the need for a time shift, as we did for several of the stations in the Equatorial Stations of Detailed Survey, but due to the large amounts of data generated and the likelihood of violating the constraints on the Operational Safe Zone (OSZ), we elected not to collect data for the extended time needed.

Various operational parameters are given in Table 3. OLA is collecting data at the high-latitude stations only (as shown in the table); OVIRS is not collecting data, and OCAMS and OTES are collecting data at all stations. The REXIS team requests that REXIS be on for at least one station. The details of that request are in SOCR-41 and are not considered further here.

We have a risk of lost data from the first observation station of flybys 4, 5, and 6, which have data collections on consecutive days. A significant fraction of the data collected on day 1 needs to be downlinked to make room for the data collected on day 2. If the downlink is lost, i.e. the data are sent but not received, some of the day-1 data will be overwritten with data from the second station. We can eliminate having data at risk by changing the use of memory partitions and making the assignment of some OCAMS data as low priority. Because OVIRS is not collecting data, we can use its partition in addition to the OCAMS and overflow partitions to store OCAMS data. This can be accomplished by configuring the OCAMS low priority data to go into the OVIRS partition. Using all three of these partitions allows us to collect 42.2 Gbits of OCAMS data without a downlink, which corresponds to 2,350 images plus engineering data.

Getting all of these data in the right memory locations is a bit complicated, however. With this new memory management plan, we collect as currently planned on the first day, which puts about 21 Gbits into the normal OCAMS partition leaving room for 7 Gbits of additional data. On the second day we change the OCAMS data to low priority for the first 14 Gbits of the data. The first 8 Gbit of these data go into the OVIRS partition and then the remaining 6 Gbit go into the overflow partition. The OCAMS data priority is then changed back to high priority at the 14-Gbit point on the second day, and the OCAMS data are then added to the empty space in the OCAMS partition. The worst case number of images happens for flyby 5, where we are planning on 2123 images, which gives us a margin of 227 images against the risk of completely losing a downlink between the first and second day.

The six days of orbital imaging at the beginning of Baseball Diamond will be offset 6 degrees sunward from nadir. Instead of redefining nadir as was originally proposed, these observations will be done with FAST_NADIR_REL targets.

Table 3. Operational Parameters for the Baseball Diamond flybys

Observation Station	1	2	3	4A, 4B	5A, 6A	5B, 6B	7A, 7B
Date	2019-03-07	2019-03-14	2019-03-21	2019-03-28,29	2019-04-04,11	2019-04-05,12	2019-04-18,19
Prime Instrument	PolyCam	MapCam	PolyCam	PolyCam	PolyCam	PolyCam	MapCam
Instruments On	PolyCam, OTES	MapCam, OTES	PolyCam, OTES	PolyCam, OLA, OTES	PolyCam, OLA, OTES	PolyCam, OLA, OTES	MapCam, OLA, OTES
Planned with Respect to Reference or Updated Trajectory	Updated	Updated	Updated	Updated	Updated	Updated	Updated
Relative or Absolute (Targets and Time)	Relative	Relative	Relative	Relative	Relative	Relative	Relative
Late Update Time shift	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Shift SOW Center Anchor Point (deg latitude)	0	0	0	+/-40	+/-40	+/-33	+/-40
Wait Time Between Slews/Mosaics	~47 sec.	~548 sec.	~74 sec.	145 sec.	3 sec.	131 sec.	33 sec.
Data Volume (Mb)	17964	4504	26341	18089, 19163	20630, 18715	14043, 17820	4504, 4504
Number of Targets	217	91	92	61, 61	221, 221	50, 46	91
OLA Collection?				Yes	Yes	Yes	Yes
OSZ Excursion on Initial Slew	126.5 sec. (2.11 min.)	NA	600.7 sec. (10.0 min.)				
Total OSZ Excursion	256.8 sec. (4.28 min.)	519 sec. (8.65 min)	2483 sec. (41.39 min.)				
Star Tracker violations		STU 1: 404.8 sec. (6.75 min)					
TSE	orx_tse_190306_190423_BBD-NOM_v1	orx_tse_190313_190423_BBD-NOM_v1	orx_tse_190320_190423_BBD-NOM_v1	orx_tse_1903(27,28)_190423_BBD-NOM_v1	orx_tse_1904(03,10)_190423_BBD-NOM_v1	orx_tse_1904(04,11)_190423_BBD-NOM_v1	orx_tse_1904(17,18)_190423_BBD-NOM_v1
Spacecraft SPK	orx_190220_190608_DS_MPRevB.bsp						
Kernel Set	dev_DS_BBD_V1-SCLK00016						

Requirements

Global Imaging of Bennu (MRD-121)

Requirement:

MRD-121: OSIRIS-REx shall image >80% of the surface of Bennu with <21cm spatial resolution (4-pixel criterion) to produce a global mosaic, stereo images, mosaics of hazards and regions of interest, and image sequences of the asteroid surface.

Observation Constraints:

Blue constraints are requested ride-along observations. Constraints all are being met by this SPP with the caveats MapCam context imagery is not being planned

Instrument		PolyCam	SPP Status	MapCam	SPP Status	Notes
Applicable to ALL Stations				Applicable to ALL Stations		• Observation Constraints are assuming 2-sigma uncertainties. • Need images taken on the same side of sub-solar point. • Need images with some stereo to improve bundle adjustment. • Slew rates must not permit more than 1 pixel of blur. •Request for MapCam context images to accompany nadir PolyCam Images. ▼ There are no ±33˚ lat station, however Flyby 3 compensates for FB4a being at +40˚ lat. as opposed to +33˚ lat. and mitigates resolution degredation due to high emission angles. ▼ Along-slew overlap drops to ~20% in some places for the stero images, however this has been determined ot be acceptable. X Not currently possible to implement context images due to timing and data volume issues. Given these are ride-along observations and not requirements there is no degradation to the associated data products/requirements.
Coverage		≥80% between ±60˚ lat.	✓	≥80% between ±60˚ lat.	X	
Along Slew Overlap		30% (60% desired)	▼	30% (60% desired)	X	
Across Slew Overlap		30% (60% desired)	✓	30% (60% desired)	X	
Range to Bennu		3060m	✓			
Pixel Size		<0.0525	✓			
SNR		≥50	✓			
Incidence Angle		30˚ to 60˚	✓	30˚ to 60˚	X	
Phase Angle		10˚ to 60˚	✓	10˚ to 60˚	X	
Convergence Angle Between Image Sets		Between 20˚ and 50˚	✓			
Stations				Stations		
Sub-Spacecraft Point						
	A	+33˚ lat ±3˚	▼	+33˚ lat ±3˚	X	
	B	+33˚ lat ±3˚	✓			
	C	-33˚ lat ±3˚	▼	-33˚ lat ±3˚	X	
	D	-33˚ lat ±3˚	✓			
Solar Local Hour						
	A	10am (-30˚ lon. ±7.5˚)	✓	10am (-30˚ lon. ±7.5˚)	X	
	B	12pm (0˚ lon. ±7.5˚)	✓			
	C	10am (-30˚ lon. ±7.5˚)	✓	10am (-30˚ lon. ±7.5˚)	X	
	D	12pm (0˚ lon. ±7.5˚)	✓			
Pointing						
	A	Nadir relative scanning ±7.5˚	✓	Nadir relative scanning ±7.5˚	X	
	B	Off-nadir looking at 10am ±30 min. (95% confidence)	✓			
	C	Nadir relative scanning ±7.5˚	✓	Nadir relative scanning ±7.5˚	X	
	D	Off-nadir looking at 10am ±30 min. (95% confidence)	✓			
Emission Angle						
	A	0˚ to 30˚	✓	0˚ to 30˚	X	
	B	20˚ to 50˚	✓			
	C	0˚ to 30˚	✓	0˚ to 30˚	X	
	D	20˚ to 50˚	✓			

Liens:

There is one DRM lien associated with MRD-121 which has been satisfied with the redesign of Baseball Diamond described in this document.

Lien-IP-6-Lien on DRM: The observations acquired to fulfill MRD 121 (e.g. MRD 429) violate the limit on pixel size (≤ 5.25 cm) needed to satisfy the resolution constraint levied by MRD 121. Please refer to Section 6: Resolving this lien will involve re-designing the observations prescribed by MRD 429 so that they are compatible with resolution required by MRD 121

Data Products:

Orange products are those that are derived from observations made for the driving MRD, MRD-121. These observations feed Safety, Sampleability, and Science Value. In addition, these observations will ultimately produce the high resolution global mosaics that will be used as the basemaps to view virtually all other data on top of.

MRD	Name	DP#	Working Group	Consumers
121	Global Pan Image Mosaics	IP-4	IPWG	All products listed here
121	Global Hazard Geodatabase	IP-18	IPWG	Hazard & Geologic Maps
121	Global Hazard Map	IP-2	IPWG	Sampleabilty
136	Crater Distribution	RD-10	RDWG	Science Value
137	>21cm Boulder Distribution	RD-9	RDWG	Long-term science
138	Regolith Distribution	RD-12	RDWG	Long-term science
139	Linear Feature Distribution	RD-11	RDWG	Science Value
142	Global Plume Density Distribution	RD-8	RDWG	Safety and Science Value
195a	Geologic Properties Analysis	N/A	RDWG	Long-term science

Global Color Maps (MRD-141)

Requirement:

MRD-141: OSIRIS-REx shall, for >80% of the asteroid surface, map the surface in a panchromatic filter at < 1m resolution ad map the ECAS b-v color index, v-x color index, and the depth of the 0.7-microns absorption feature, relative to one or more recognized ECAS standard stars, with an accuracy of < 2% in regions where the signal-to-noise ratio is >100 at a spatial resolution of < 2m.

Observation Constraints:

All constraints are being met by the SPP.

Instrument	MapCam	SPP Status	Notes
Applicable to ALL Stations			• Observation constraints are assuming 2-sigma uncertainties.
Filters	Pan, b, v, w, x	✓	• All images should be free of charge smear.
Coverage	≥80%	✓	• Slew rates must NOT permit more than 1 pixel of blur.
Along slew overlap between successive color sets	>30%	✓	• Need nadir pointed imagery at multiple bands of latitude
Along slew overlap between end member color sets	>10%	✓	• If delivery uncertainties are small, would want to be as close to 12:30pm as possible.
Set-to-Set Overlap	55%	✓	• Do NOT want opposition effect (phase angle = 0˚).
Across Slew Overlap	>40%	✓	Need low phase angle and large albedo signal
Station to Station Overlap	30% to 40%	✓	
Color Frame Overlap End-to End	90% (100% desired)	✓	
Pixel Size	≤0.5m	✓	
SNR	≥100	✓	
Emission Angle	<30˚	✓	
Phase Angle	>0˚, but low	✓	
Solar Local Hour	12:45pm ±24 min. (11.25˚ lon. ±6˚)	✓	
Pointing	Nadir ±10˚	✓	
Stations			
Sub-Spacecraft Point			
A	0˚ lat. ±5˚	✓	
B	+40˚ lat ±3˚	✓	
C	-40˚ lat ±3˚	✓	

Liens:
Two DRM liens are associated with MRD-141. Lien-IP-9 has been fully satisfied in the observation plan as described in this document.

Lien-IP-4-Lien on DRM and/or SOPG: If the 2 mrad/sec slew rate used during the Equatorial Stations of Detailed Survey is adopted by the 525m Recon Pass, it will be too rapid for color imaging with multiple filters that must be combined into color cubes. Resolving this lien will involve decreasing the slew rate during color-imaging campaigns to minimize the offset between frames within a color-set.

Lien-IP-9-Lien on DRM: The Equatorial Station imaging only allows for robust imaging at the equatorial latitudes; any pixels above or below ± 40° latitude will suffer from foreshortening, and are not suitable for the mosaicking (the size and position of features will not be accurately conveyed in image-based maps outside of the mid-latitudes). Resolving this lien will involve re-designing the observations intended fulfill MRD 141 so that they are compatible with the requirements of image mosaicking (note: these images will also be used to generate a the global 1064 nm map).

One DRM lien is associated with MRD-542. Lien-SpWe-4 has been fully satisfied in the observation plan as described in this document.

Lien-SpWe-4 MRD 542: Lien on Bill Boynton and the Mission Planning Board to provide a color-optimized observation plan during the 12:30 Equatorial Station of the Detailed Survey at Bennu that meets the color precision and accuracy requirements for the MapCam color ratio imaging

data products. Such accuracy requirements will enable the search for space weathering spectral signatures, which are projected to be very subtle due to the low albedo of Bennu. This lien would be removed if/when the BRM includes these observations in the implementation plan for Detailed Survey.

Data Products:
Orange products are those that are derived from observations made for the driving MRD, MRD-141. This data primarily feeds Safety and Science Value.

MRD	Name	DP#	Working Group	Consumers
141	Global Color-Ratio and True-Color Maps	IP-20	IPWG	Science Value
183a3	Global Photometrically Corrected x-band Image Mosaics	IP-7	IPWG	Safety Map
542	Space Weathering Map	RD-13	RDWG	Science Value

Global 35cm Shapemodel from SPC (MRD-687a)

Requirement:
MRD-687a: The Ground System shall, for >80% of the asteroid surface, produce a set of DTMs at <0.35m in ground sample distance (sample resolution).

Observation Constraints:
All constraints are being met by the SPP with the caveat that end of Orbital A imaging will be required to satisfy northern looks of the northern hemisphere and southern looks of the southern hemisphere.

Instrument		OCAMS or TAGCAMS	SPP Status	Notes
Applicable to ALL Viewing Conditions				• Observationconstraints assume 2-sigma uncertainties. • If TAGCAMS is used to satisfy this requirement, note there are still unknowns pending calibration results. ▼ Constraints for Northern Hemisphere imagery form the North and Southern Hemisphere imagery from the South are NOT being met by any of the 7 flybys (11 stations) in BBD. These constraints are planned to be met during end of Orbital A imaging. ▼ FB1, FB2, FB5a, FB6a, FB7a, & FB7b all contain 3 sets of imagery with s/c pointing nadir, east, and west. The west pointing profile is targeted to ~2pm local solar time on the surface. The combination of all the listed stations provides the necessary N-S-E-W and "albedo" coverage with a variation in local solar time from <10am to >2pm.
Settings		If MapCam, Pan filter only	✓	
Coverage		≥80% (All observation sets should cover the same 80% of Bennu Surface)	✓	
Pixel Size		**The following criteria must be met to satisfy the resolution requirement for SPC:** • Resolution Criteria 1: 2 image stations where pixel size is between 6cm and 32cm • Resolution Criteria 2: 3 image stations where pixel size is between 6cm and 64cm • Resolution Criteria 3: 2 image stations where the minimum pixel size is 15cm	✓	
Viewing Conditions				
Azimuth				
	1	0˚ (±30˚) North	▼	
	2	180˚ (±30˚) South	▼	
	3	90˚ (±30˚) East	✓	
	4	270˚ (±30˚) West	✓	
	5	Albedo: 0˚ (±30˚) North or 180˚ (±30˚) South	✓	
Solar Local Hour				
	A	**Applicable to Veiwing Conditions 1 through 4:** • Between 8:00am & 4:00pm • Required, one set at 10:00am (desired 1 hour, required 2 hour dev) • Required, one set at 2:00pm (desired 1 hour, required 2 hour dev) • Required, three sets must have local time different by one full hour	▼	
	B	**Applicable to Veiwing Condition 5:** •Within 30 min. of noon (11:30am or 12:30 pm is desired)	✓	
Pointing				
	A	**Applicable to Veiwing Conditions 1 through 4:** • At least 3 viewing conditions must be off Nadir (20˚ to 45˚ zenith). 4 viewing condirions would be ideal.	✓	
	B	**Applicable to Veiwing Condition 5:** • Nadir (0˚ to 20˚ zenith) (Further testing could relax this requirement)	✓	

Data Products:
This data will be used to generate a Global 35cm Shapemodel from SPC. The 35cm shapemodel is required to make the transition from Orbital B to Recon, therefore this data must be acquired prior to entering Recon and with sufficient time to generate the shapemodel (2 weeks post data downlink). The primary data product associated with this data is ALT-23 (Local OBJ). Though this shapemodel will provide global coverage, it is categorized as local for the purposes of storage since it will be delivered in local pieces as opposed to one piece as the 75cm shapemodel is delivered. Accompanying the delivery ALT-23 is an entire suite of products including 35cm slope and tilt maps. All products are produced by ALTWG.

NFT Feature Identification and Build by SPC

Requirement:
MRD-728: The ground system shall produce a catalog of up to 300 NFT features consisting of the following for each feature:
1.) A position defined in Asteroid Center of Figure (ACF) coordinates
2.) A 2-D array of displacement (heights) relative to a reference plane above the asteroid surface to represent the shape.
3.) A 2-D array of relative albedo valued to capture variations in how light reflects off the asteroid surface.

Observation Constraints
Note there are two different sets of constraints for identifying and building the NFT features. Apart from resolution, if the constraints for MRD-687a are met the constraints for NFT feature build will be met. The observation constraints for NFT feature identification are more relaxed than those for build, so if the constraints for build are met, the constraints for identification will also be met. **All constraints are being met by the SPP with the caveat that end of Orbital A imaging will be required to satisfy northern looks of the northern hemisphere and southern looks of the southern hemisphere.**

NFT Identification:

Instrument	OCAMS or NavCam	SPP Status	Notes
Hybrid TAG/Orbital B Checkout/Science Phase NFT			• If SPC feature build requirements are met, then NFT feature identification requirements will also be satisfied. • Should get at least 4 images that represent at least two distinct incidence angle groups which are separated in solar azimuth and/or incidence by 20˚.
Settings	If MapCam, Pan filter	✓	
Coverage	Global coverage between ±75˚ (should match SPC capability)	✓	
Pixel Size	Between 8cm and 16cm	✓	
Incidence Angle	20˚ to 60˚	✓	
Emission Angle	0˚ to 30˚	✓	
Full NFT TAG			
Settings	If MapCam, Pan filter		
Coverage	TAG Site Corridor (3-sigma)		
Pixel Size	Between 1cm and 5cm		
Incidence Angle	20˚ to 60˚		
Emission Angle	0˚ to 30˚		

NFT Feature Build by SPC:

Instrument		OCAMS or TAGCAMS	SPP Status	Notes
Applicable to<u>ALL</u> Viewing Conditions				• Observationconstraints assume 2-sigma uncertainties. • If TAGACMS is used to satisfy this requirement, note there are still unknowns pending calibration results. ▼ Constraints for Northern Hemisphere imagery form the North and Southern Hemisphere imagery from the South are NOT being met by any of the 7 flybys (11 stations) in BBD. These constraints are planned to be met during end of Orbital A imaging. ▼ FB1, FB2, FB5a, FB6a, FB7a, & FB7b all contain 3 sets of imagery with s/c pointing nadir, east, and west. The west pointing profile is targeted to ~2pm local solar time on the surface. The combination of all the listed stations provides the necessary N-S-E-W and "albedo" coverage with a variation in local solar time from <10am to >2pm.
Settings		If MapCam, Pan filter only	✓	
Coverage		≥80% (All observation sets should cover the same 80% of Bennu Surface)	✓	
Pixel Size		**The following criteria must be met to satisfy the resolution requirement for building NFT Features:** • Resolution Criteria 1: 2 image stations where pixel size is between 1.6cm and 8cm • Resolution Criteria 2: 3 image stations where pixel size is between 1.6cm and 16cm • Resolution Criteria 3: 2 image stations where the minimum pixel size is 6.4cm.	✓	
Viewing Conditions				
Azimuth				
	1	0˚ (±30˚) North	▼	
	2	180˚ (±30˚) South	▼	
	3	90˚ (±30˚) East	✓	
	4	270˚ (±30˚) West	✓	
	5	Albedo: 0˚ (±30˚) North or 180˚ (±30˚) South	✓	
Solar Local Hour				
	A	**Applicable to Veiwing Conditions 1 through 4:** • Between 8:00am & 4:00pm • Required, one set at 10:00am (desired 1 hour, required 2 hour dev) • Required, one set at 2:00pm (desired 1 hour, required 2 hour dev) • Required, three sets must have local time different by one full hour	▼	
	B	**Applicable to Veiwing Condition 5:** •Within 30 min. of noon (11:30am or 12:30 pm is desired)	✓	
Pointing				
	A	**Applicable to Veiwing Conditions 1 through 4:** • At least 3 viewing conditions must be off Nadir (20˚ to 45˚ zenith). 4 viewing condirions would be ideal.	✓	
	B	**Applicable to Veiwing Condition 5:** • Nadir (0˚ to 20˚ zenith) (Further testing could relax this requirement)	✓	

Data Products:
This data will be used to identify and build 300 NFT features which are necessary for NFT to perform its functions of Checkpoint navigation. The primary data product associated with this data is ALT-18 (NFT feature DTMs). Once the features have been identified by NFT, ALTWG/SPC will build the features.

75cm Shapemodel Data from OLA (MRD-678b)

Requirement:
MRD-678b: The Ground System shall, for >80% of the asteroid surface, produce a set of DTMs at <0.75m in ground sample distance (sample resolution)

Observation Constraints:
All constraints are being met by the SPP with the caveat that polar data is somewhat lacking. Preliminary Survey observations should help fill in these gaps.

Instrument	OLA	SPP Status	Notes
Applicable to ALL Stations			• Observation Constraints are assuming 2-sigma uncertainties. • OLA observations are requires at North and South viewing conditions for SPC/NFT. Other viewing conditions are optional for OLA. ▼ Mid lat. to high lat. data looks good, but Pole data is somewhat lacking. Preliminary Survey data compensates for this.
Settings	<0.7 spot spacing and spot size (equal values)	✓	
Coverage	≥80%	✓	
Pointing	Nadir Relative Scanning ±7.5˚	✓	
Stations			
Azimuth			
A	0˚ (±30˚) North	✓	
B	180˚ (±30˚) South	✓	

Data Products:
There is currently no plan to deliver a 75cm shapemodel from OLA and there are no data products being directly produced from this data. Rather, the data will be used to contribute to refining and validating the products listed below:

- MRD-115b (5cm DTMs from OLA)
- MRD-124 (Shapemodel Center of Figure)
- MRD-127 (Rotation Pole)
- MRD-128 (Wobble of Rotation Pole)
- MRD-129 (Rotation Period)
- MRD-132 (Bennu Volume)
- MRD-732 (NFT TAG Site DEM Accuracy)