MRD- 119 (Site-specific color-ratio maps)

1. Requirement Summary:

MRD-119: For ≥80% of a 2-sigma TAG delivery error ellipse around at least the prime sampling site, map the surface in a panchromatic filter at ≤25 cm resolution and map the ECAS b-v color index, v-x color index, and the relative depth of the 0.7-micron 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 ≤50 cm (Site-Specific Color Ratio Maps)

Primary Co-I(s): Daniella DellaGiustina

Working Group(s): Image Processing

2. Key Associated Data Products:

The data product associated with MRD-119 is the global MapCam color ratio map, described as follows:

Site-specific Color-ratio maps: False-color image mosaics that highlight spectral variations across the surface of Bennu. They satisfy MRDs 119 and 141 and are produced from MapCam images in the b, v, w and x filters (the central wavelengths for these filters are 450, 550, 700 and 850 nanometers respectively). After a photometric correction is performed for images in each color filter, ratios in I/F are used to create false-color images. The main color ratios are expected to be b/v to characterize the UV slope, the v/x to characterize the visible slope, and a combination of the v, w and x images to characterize the presence and depth of any 0.7-micron (i.e. 700 nm absorption feature). Other ratios may be deemed diagnostic and also used. The color ratios can be represented as RGB color maps.

Although MRD-119 also specifies mapping in the panchromatic filter, the products generated from MRD 121 and MRD 116 will satisfy (and exceed) the panchromatic mapping needs outlined by MRD 119.

To explain the concepts relevant to this MRD, we will use the following nomenclature:

"Frame" refers to an individual filter image within a color-set (e.g. a single v-image)

A "color-set" is defined as b, v, w, and x frames of the same target that are acquired successively at nearly the same time. These images should overlap to the greatest extent possible.

A "color-cube" is defined as a color-set where all of the frames have been co-registered to each other and the edges of each frame have been "band-trimmed" to remove any non-overlapping pixels. Color cubes represent and "single" multi-band image that will be mosaicked with other color-cubes to generate the color-ratio map.

"Domain" refers to the projected spatial extent (in terms or line and sample) of a single image.

"Line" and "Sample" are used to refer to the "rows" and "columns", respectively, of an image.

3. System to Generate Sufficient Observations:

The mission does not have the ability to satisfy MRD 119 until MapCam images are acquired in the b, v, w, and x filters during the 525 m Reconnaissance (Recon) pass . Fulfilling MRD 119 requires that a color mosaic is generated at sufficient quality to allow for identification and interpretation of color units on the surface of Bennu. To ensure success, these images must have the following characteristics:

The images should be taken of the surface at Bennu at low phase (but not zero phase). This ensures the best possible signal-to-noise ratio at the shortest possible exposure time.

The total overlap of all frames included in a color-set should be as close to 100% as feasible. This will minimize the presence of seams in the mosaic, and minimize differences in phase angle between frames in a color-set (to avoid phase reddening). At a minimum, the color frames (b, v, w, x) should have a total overlap of 90% from end-to-end.

The number of color-sets acquired along a single slew should provide 80% coverage of the 2-sigma TAG delivery error ellipse to fulfill MRD 119.

All images should be acquired at low emission angles (< 30 degrees) to minimize distortion, foreshortening, and other projection effects for 80% coverage.

Blur should be minimized to the greatest extent possible, and should not exceed 1 pixel in the blue filter (where the longest exposure time is anticipated).

The overlap between successive color-sets (i.e. the first and second) of a single slew should be > 30%.

The overlap between color sets across longitude-band slews should be > 40%.

4. Minimum Success of Criteria:

For the 525 m Recon flyby, we must:

Acquire MapCam image coverage of ≥80% of the 2-sigma TAG delivery error ellipse in color-sets (b, v, w, and x filters).

Acquire MapCam images that are ≤ 12 cm in pixel size over than required area.

Acquire MapCam images that have a SNR ≥100.

Acquire MapCam images that have the required amount of overlap, both within and between color-sets (as addressed in Section 3. "System to Generate Sufficient Observations").

Generate color-cubes for each color-set acquired from by MapCam.

Generate the following "ratio" images using frames within the color cubes:

the b/v slope,

the v/x slope

depth of the 700 nm absorption feature (if it is present).

Map each color-ratio to an RGB color channel to generate false-color composite products that highlight the signal associated with each of the above "ratios".

The requirements for achieving appropriate image-to-image overlap is well described in the MRD verification page for MRD-141.

5. Dependencies per Mission Phase:

Detailed constraints for creating the products associated with MRD 119 are addressed in Section 3. "System to Generate Sufficient Observations" of this page. Detailed constraints for dependencies from prior mission phases are addressed in Section 3 for each of the corresponding MRDs: 123, and 149.

Dependencies from the relevant mission phases are as follows, according to dates within DRM Rev C:

- Image data (L2 OCAMS images in the b, v, w, and x filters):

Detailed Survey Equatorial Station (MRD 149) MapCam Images:

A photometric model for MapCam color filters will be developed and can be applied to a color mosaic by 4/02/2019.

525 m Recon Pass (MRD 119) MapCam Images:

A site-specific uncontrolled color-ratio mosaic will be generated within 10 days of each 525 m Recon pass

A site-specific, controlled, and photometrically corrected color-ratio image mosaic of the sample-site will be generated within ~2 weeks of each 525 m Recon pass (by 8/05/2019 and 8/19/2019 for the prime and backup sample sites, respectively.)

- Altimetry data (including the Bennu shape model, site-specific terrain models):

Preliminary Survey (MRD 123): The Bennu shape model will be generated from OCAMS images and OLA data acquired during Preliminary Survey. The global shape model is required to generate the global panchromatic mosaics and must be generated by 1/09/2019 (e.g. by Baseball Diamond).

6. Adequacy of the DRM:

This section cannot be completed until trajectory and attitude kernels for the 525 m Recon Pass have been generated.

7. Data Products per Mission Phase:

Timeline of data products:

The relevant Mission Phase for MRD 119 is the 525 m Recon fly-by. During the 525 m Recon pass approximately L2 color MapCam images will be acquired. The first fly-by occurs on

7/20/2019 for the prime candidate sample site and on 8/3/2019 for backup candidate sample site, according to the DRM. The data processing timeline occurs in the following stages:

1. Image Mosaicking: Image mosaicking can begin once the following inputs are made available:

L2 MapCam b, v, w, and x images in units of I/F from the 525 m Recon Pass.

Reconstructed attitude and trajectory kernels from the 525 m Recon Pass.

Other inputs to this process include the OCAMS photometric model, (generated during the same time frame as the color-ratio products from Equatorial Station MapCam images) and the Bennu shape model (produced during Preliminary Survey).

It is anticipated that the first uncontrolled global color-ratio mosaic will be completed within 14-20 days after necessary inputs are received by the IPWG.

8. Overview of Processing:

Tools/Techniques used to satisfy MRD

In proximity operations the minimum tools/techniques will be used to meet MRD 119:

Color image mosaicking pipeline using ISIS3 for OSIRIS-REx

Software Status

Color image mosaicking pipeline: The color image mosaicking pipeline is presently in development, although the architecture of this pipeline will be similar to the completed panchromatic image mosaicking pipeline. The color image mosaicking pipeline is based on the Dawn FC color image mosaicking pipeline developed by OSIRIS-REx collaborator Lucille Le Corre.

9. Provenance of Algorithms, Software, and Techniques

Relevant information relating to the history and utility of selected software packages can be found using in the following data product descriptions:

Color-Ratio Mosaic data product description

10. Expected Results & Simulated Data

Using simulated SPICE kernels for two distinct 525 m Recon passes, with the 85 cm shape model of Bennu (generated from the Nolan radar shape model) and a MapCam camera model implemented in ISIS3 for OSIRIS-REx, the following simulated data was generated for each observation. Imaging times were taken every 60 seconds throughout the observation window.

The coverage of MapCam images across each 525 m Recon pass, as a percentage of its 2-sigma TAG error ellipse (Figure 1 and Table 1).

The emission angles, relative to the 85 cm shape model, of MapCam images across each 525 m Recon pass (Figure 1).

The incidence angles, relative to the 85 cm shape model, of MapCam images across each 525 m Recon pass (Figure 2).

The phase angles of MapCam images across each 525 m Recon pass (Figure 3).

The pixel size of MapCam images across each 525 m Recon pass (Figure 4).

Histograms depicting the distribution of each of these four parameters (Figures 5-8).

Because these values are calculated with respect to the terrain of the Bennu shape model, it is important to note that incidence and emission angles may exceed the required thresholds over small spatial scales (due to crater walls, boulders, etc.); this should not be used to interpret a violation of any requirement. Requirements should be verified using the average values for emission and incidence angles over the desired area. A complete set of plots (Figures 1 - 8) and statistics (Table 2) are given for Case 02. Summarized results are given for both observations in Table 1, which demonstrates that both meet the requirements.

Table 1. Summary of Two Recon 525m Observations

| Observation | Target Lat, Lon | 2-Sigma Radius (°) | Coverage (ISIS3, Terrain) | Coverage (STK, Sphere) | Mean phase angle (°) | Mean emission angle (°) | Mean incidence angle (°) | Mean pixel size (cm) |
|---|---|---|---|---|---|---|---|---|
| Case 02 | 0°, 319.7° | 1.003 | 100% | 100% | 34.7 | 21.6 | 29.0 | 3.47 |
| Case 05 | -20°, 319.7° | 0.9531 | 100% | 100% | 36.1 | 18.6 | 40.1 | 3.49 |

Table 2. Statistics for Each Quantity in Observation "Case 02"

| | Phase Angle (deg) | Emission Angle (deg) | Incidence Angle (deg) | Pixel Resolution (cm) |
|---|---|---|---|---|
| Mean | 34.7 | 21.6 | 29.0 | 3.47 |
| Median | 35.0 | 20.3 | 28.0 | 3.47 |
| Mode | 35.7 | 21.7 | 27.6 | 3.47 |
| Max | 37.9 | 93.8 | 102 | 3.57 |
| Min | 30.2 | 0 | 0 | 3.38 |

Figure 1. Emission Angles and Coverage of MapCam Images for 525 m Recon Pass "Case 02"

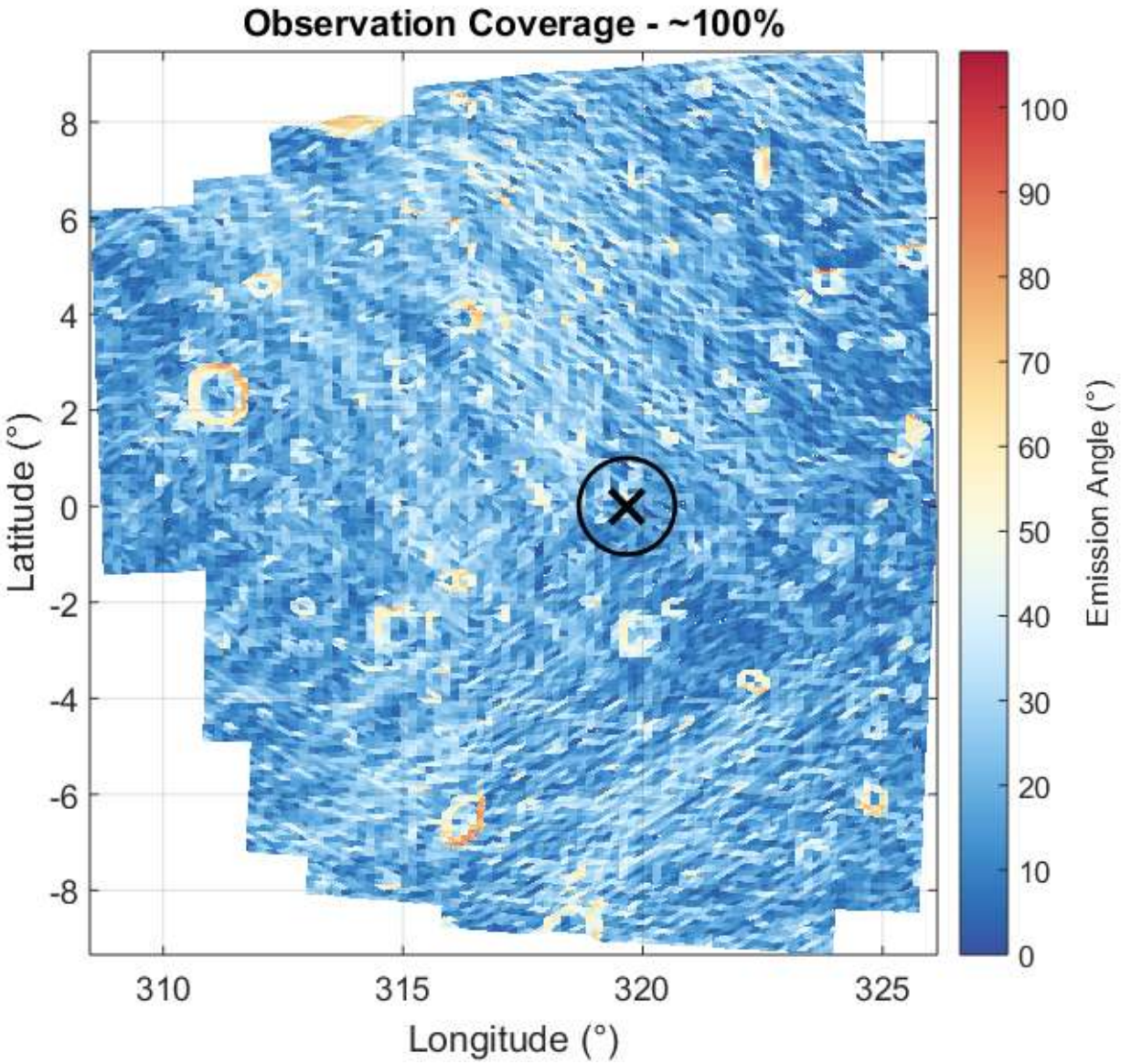



Figure 2. Incidence Angles of MapCam Images for 525 m Recon Pass "Case 02"

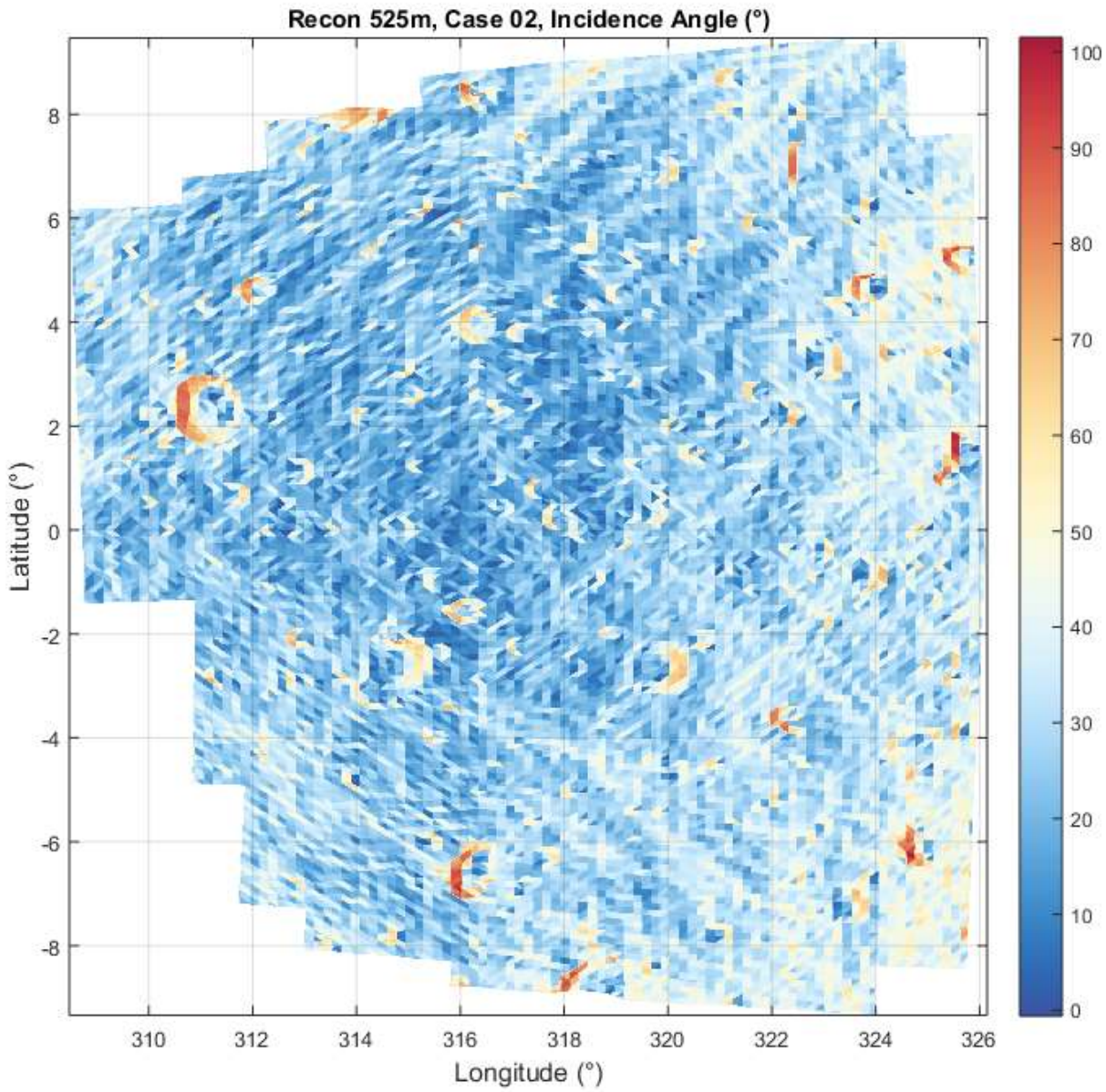



Figure 3. Phase Angles of MapCam Images for 525 m Recon Pass "Case 02"

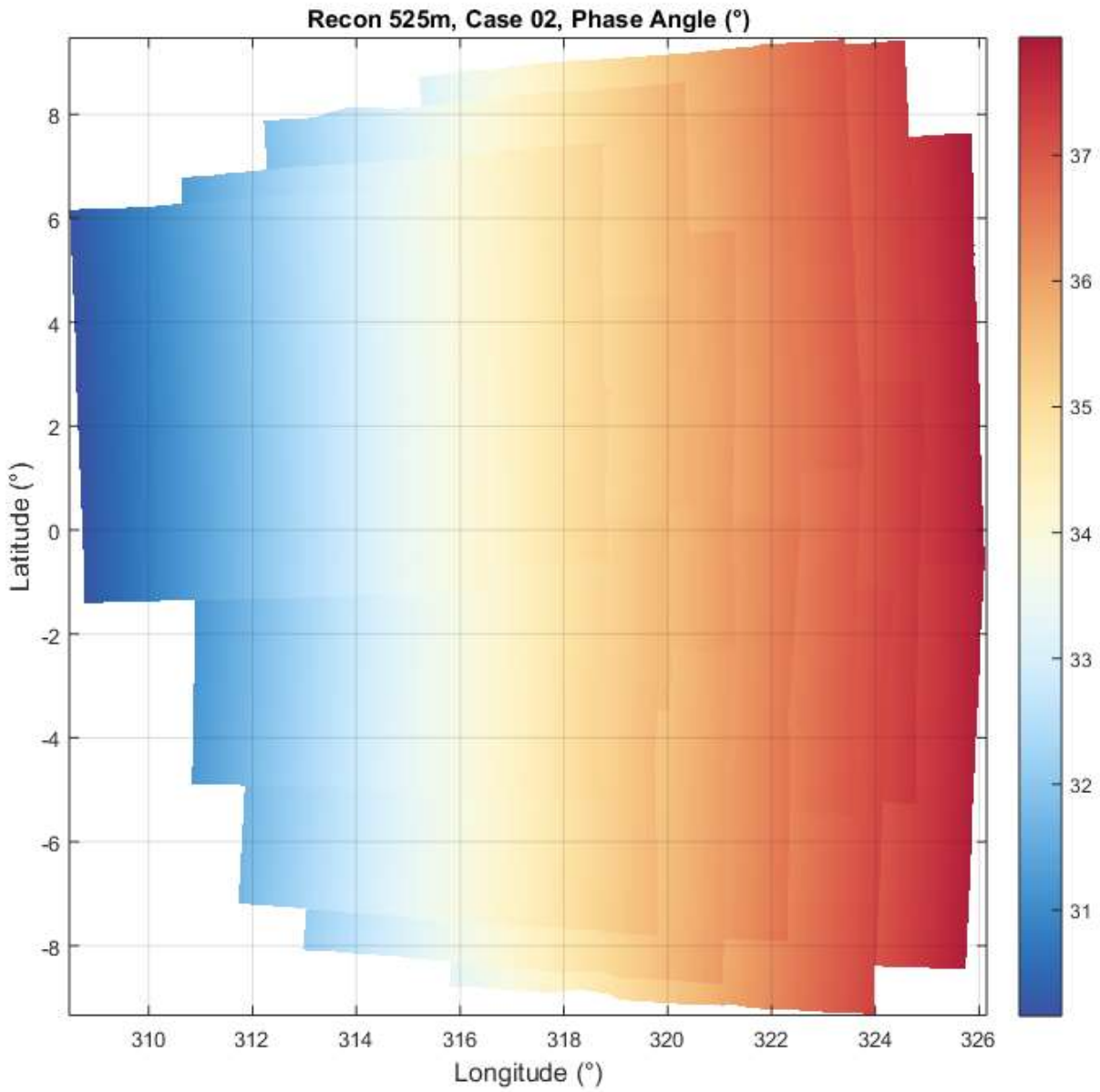



Figure 4. Pixel Sizes of MapCam Images for 525 m Recon Pass "Case 02"

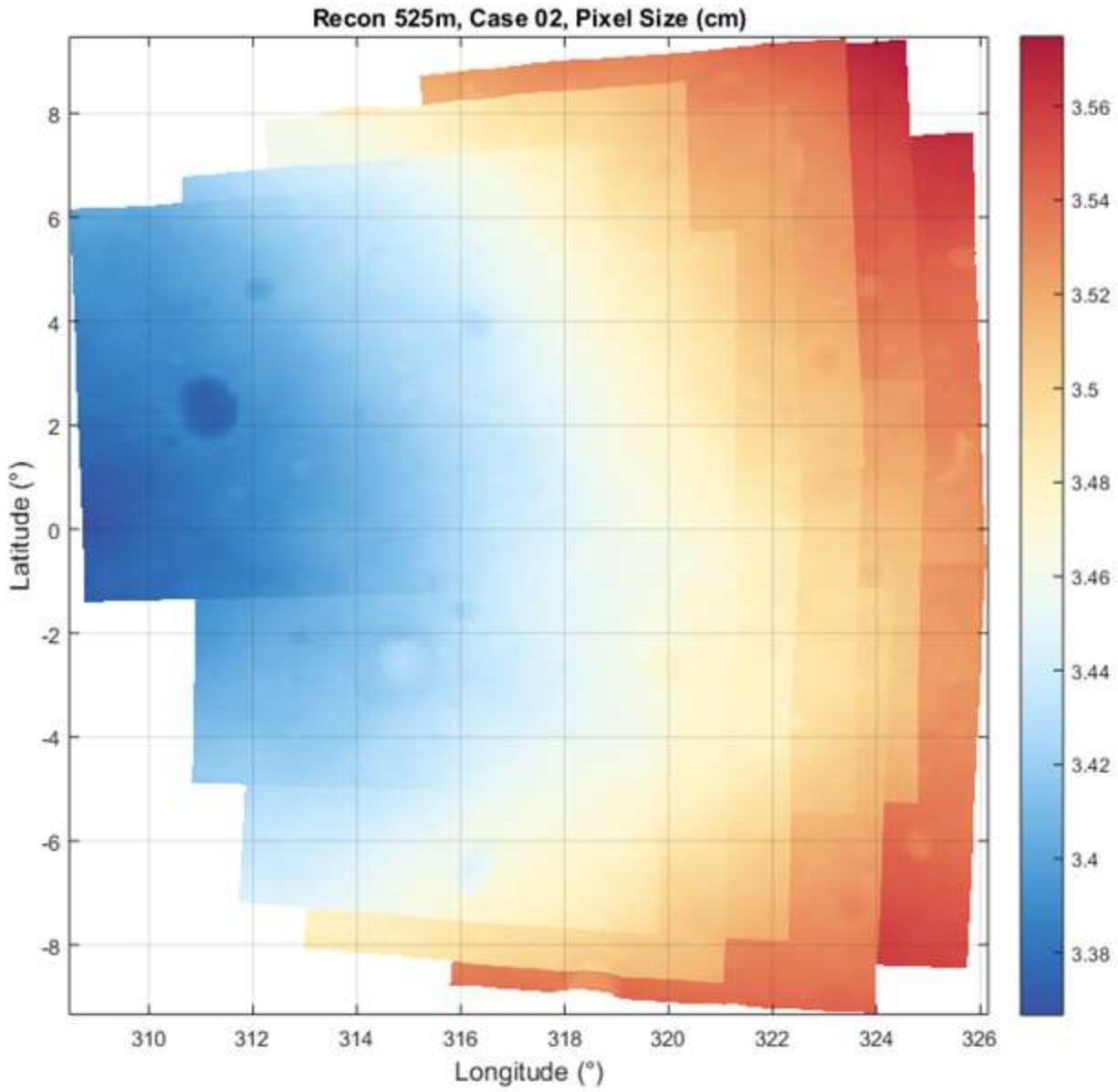



Figure 5. Histogram of Emission Angles of MapCam Images for 525 m Recon Pass "Case 02"

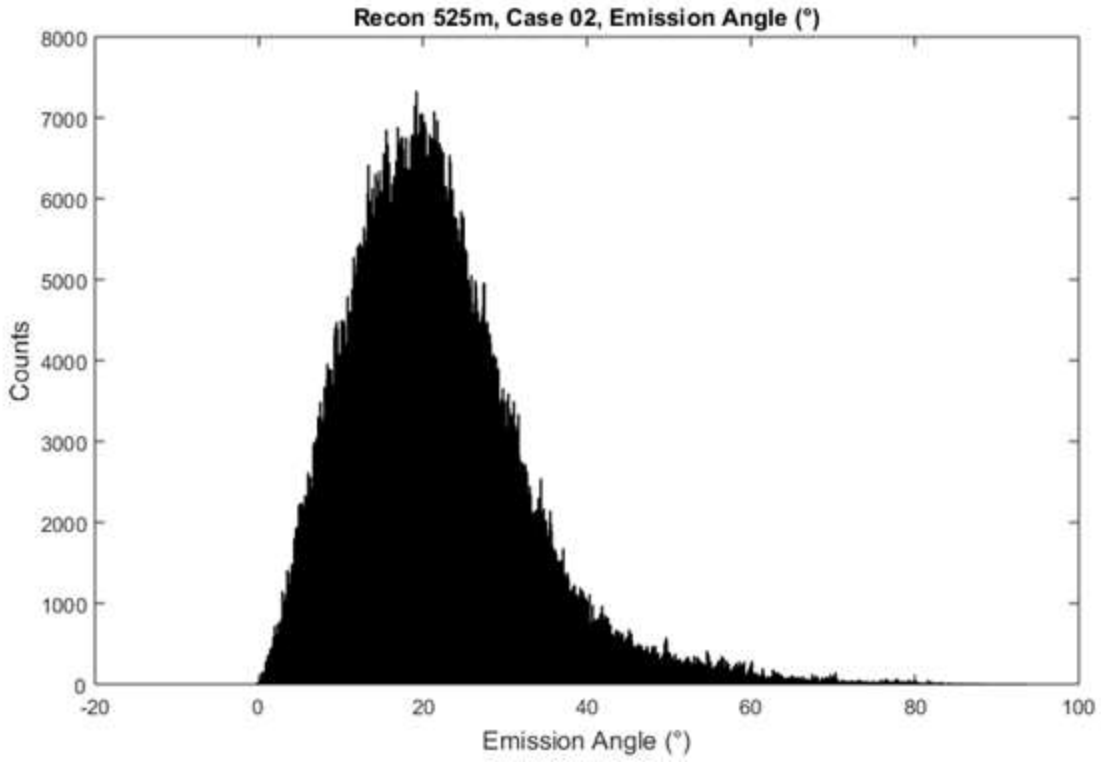



Figure 6. Histogram of Incidence Angles of MapCam Images for 525 m Recon Pass "Case 02"

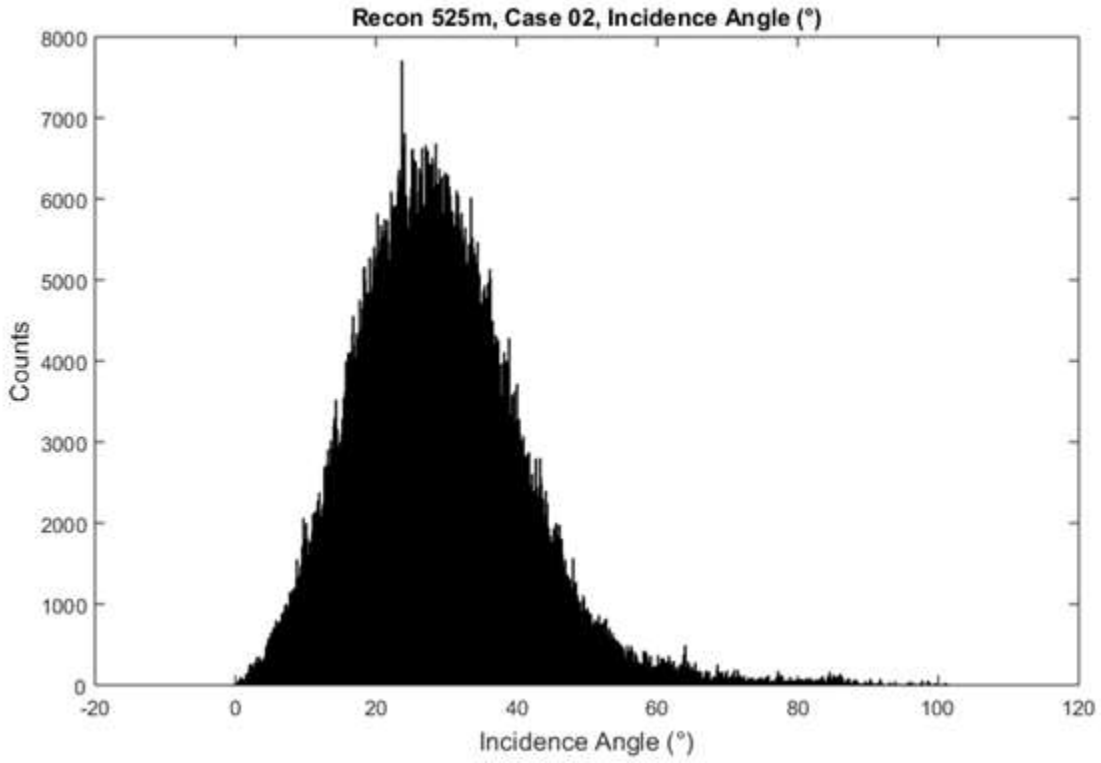



Figure 7. Histogram of Phase Angles of MapCam Images for 525 m Recon Pass "Case 02"

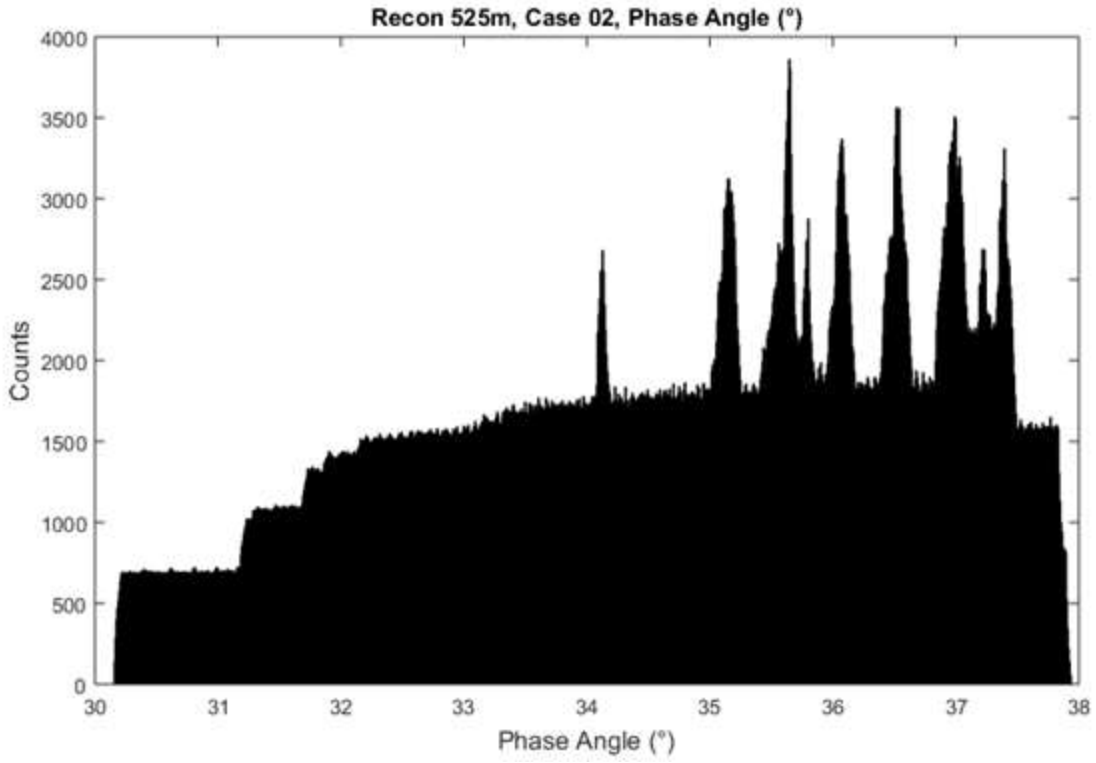
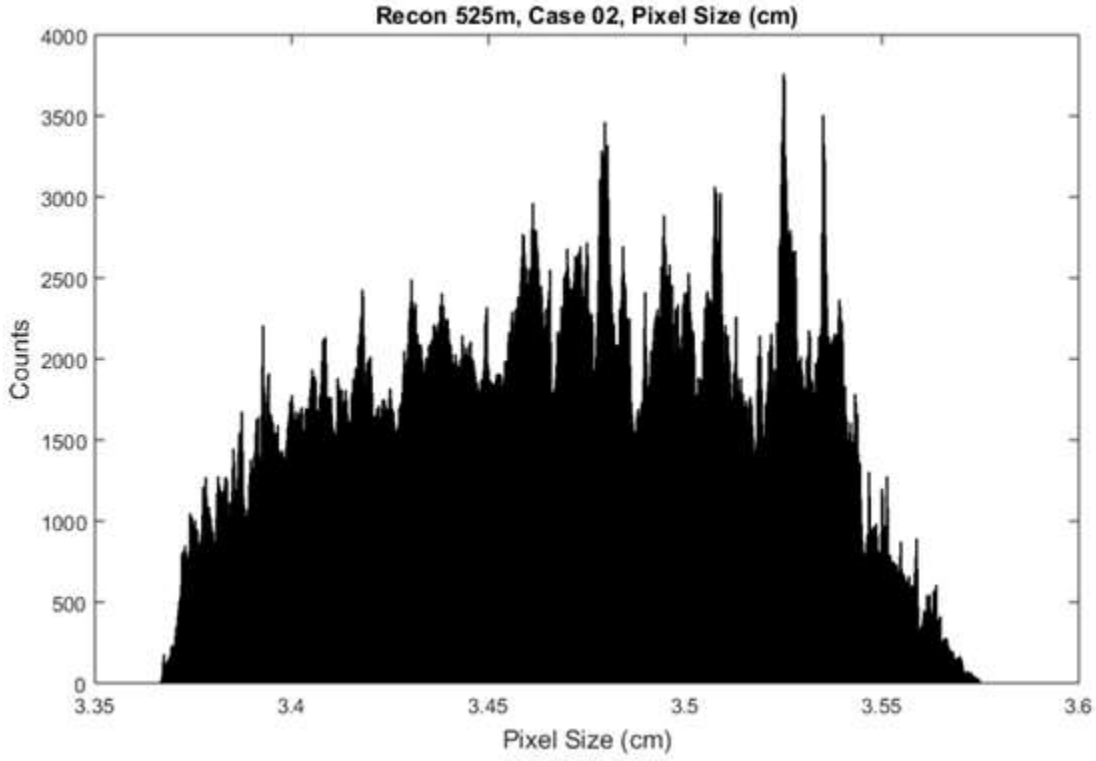



Figure 8. Histogram of Pixel Sizes of MapCam Images for 525 m Recon Pass "Case 02"




11. Analysis and verification methods

Verification documentation on the OSIRIS-REx ISIS3 version, which implements OCAMS camera models into ISIS3 and handles DSK shape models of asteroid Bennu, can be found here.

12. Existing or Potential Liens

MRD 119 has the following potential liens:

Lien-IP-3 has closed with the July 2017 OCAMS pipeline review. The IPWG agrees that OCAMS is presently implementing appropriate calculations to determine the spectral radiance and I/F for OCAMS Level 2 images, and their technique has been reviewed and signed off on by several IPWG members.

Lien-IP-3-Lien on OCAMS: The OCAMS pipeline does not currently calculate spectral radiance and I/F for color filters as advocated by the science team. Resolving this lien will involve a modification of the OCAMS pipeline to calculate spectral radiance, and subsequently I/F, for MapCam filter images.

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-5 on SPOC and/or FDS has closed with the delivery of the kernels and the analysis completed by John Kidd.

Lien-IP-5-Lien on SPOC and/or FDS: There currently are no 525 m Recon SPICE kernels that are complaint with the Level 2 Requirements. Accordingly, no analysis can be done to determine the geometric quality of images generated to fulfill MRD 119. Resolving this lien involves generating new SPICE kernels for the 525 m Recon Pass.

13. SPOC Requirements

The requirements that the SPOC must fulfill in order for all relevant parties to access the necessary information to fulfill MRD 119 are cited/described within the documents listed in the "14. External Interfaces" section of this page.

14. External Interfaces

The following ICDs describe the external interfaces relevant to MRD 119:

OCAMS-SPOC ICD

FDS-SPOC ICD

ALTWG-SPOC ICD

RADF SIS

IPWG-SPOC ICD