

MRD 144- Satellite Images and Proof of Existence

Data Product Overview

Natural Satellite Images and Proof of Existence consists of two ASCII files containing lists of positions (in X,Y image and J2000 RA/DEC sky coordinates) and photometry of any natural satellites of Bennu detected during the Natural Satellite Searches. Three types of satellite searches are to be conducted: a dedicated search for 10-cm or larger satellites within 26 km of Bennu, a dedicated search for 1-m or larger satellites within 36 km of Bennu, and a serendipitous search of all OpNav and science OCAMS imaging of Bennu prior to the dedicated satellite searches for large satellites.

The first file is based on the 80-column file format for astrometry and photometry submitted to the Minor Planet Center. The reason for archiving data in this format is heritage related in that many orbit determination software accept the MPC format. Some of the data columns are not relevant for our purposes but are retained to be consistent with MPC formatting.

The second file contains more information about astrometric positions (higher precision, uncertainties, rms of astrometric fit, XY pixel coordinates, image name) and photometric measurements (higher precision, uncertainties, rms of photometric fit).

Overview

Data type (image, spectrum, data table, map format etc.):

data table

What does it measure at what scale:

unresolved/point source

What observations are required to provide the input data needed to make the data product?:

5 MapCam images per survey field taken at ~45-60 minutes intervals

When in the DRM are the observations that make the data product scheduled to be taken?

serendipitous searches using OpNav and Science OCAMS images will take place between the start of the Approach phase and the start of the 1-m natural satellite search

the 1-m search will occur over 3 consecutive dates (Oct 25-27, 2018 UTC). each date will consist of observations taken within a 4.5 hour window.

the 10-cm search will occur over 3 consecutive dates (Nov 2-4, 2018 UTC). each date will consist of observations taken within a 4.5 hour window.

How long does it take to produce the data product?

resulting data products from data taken during a single 4.5 hour window will be reduced within 24 hours of data downlink

Is this product used of sample site selection, science value, or long-term science?

mission safety

Data Product Structure and Organization

What is the structure of the data product (e.g. FITS file with 4 extensions):

ASCII

How is the product organized (e.g. one data set per mission phase, one file per Earth Day, etc.):

two files per natural satellite search (or per contingency follow-up observation per detected satellite)

Data Format Descriptions

Minor Planet Center astrometry form

Header information (metadata) included with data product. For example:

ASCII table including the following: object ID, type of detector (set to 'C', not relevant), mid-time of observation, J2000 Right Ascension coordinate, J2000 Declination coordinate, magnitude, filter, observatory code (set to 'XXX', not relevant).

Detailed Description of data format. For example:

Table

Data Type

ASCII

Field name, Field Description, Field Length, Field Format:

Example format:

```
    natsat1  C2015 01 01.04172 03 51 56.17 +24 45 25.7          6.2
V          XXX
```

Fortran format:

```
A7, 2X, A1, I4, 1X, I2, 1X, F8.5, 1X, I2, 1X, I2, 1X, F5.2, 1X, I2, 1X, I2, 1X, F4.1, 10X, F4.1, 1X, A1, 5X, A3
```

Astrometrica photometry file

Header information (metadata) included with data product. For example:

ASCII table including the following: J2000 Right Ascension coordinate, J2000 Declination coordinate, magnitude, X pixel coordinate, Y pixel coordinate, photometric flux, FWHM (full width half maximum), signal-to-noise, rms fit, Right Ascension error, Declination error, photometric magnitude error, name of image, object ID, astrometry type code (set to 'C'), observations mid-time UT year, observations mid-time UT month, observations mid-time UT day (in decimal days), J2000 Right Ascension coordinate, J2000 Declination coordinate, magnitude, observatory code (set to 'XXX').

Detailed Description of data format. For example:

Table

Data Type

ASCII

Field name, Field Description, Field Length, Field Format:

Line 1:

I2,1X,I2,1X,F6.3,11X,+/-
,I2,1X,I2,1X,F5.2,11X,F5.2,11X,F7.2,2X,F7.2,2X,I6,1X,F6.1,1X,F6.1,2X,F5.3

Line 2:

17X,+/-,F4.2,18X,+/-,F4.2,11X,+/-,F4.2,1X,A27

Line 3:

A7,2X,A1,I4,1X,I2,1X,F8.5,1X,I2,1X,I2,1X,F5.2,1X,I2,1X,I2,1X,F4.1,10X,F4.1,1X
,A1,5X,A3

Example format:

```
03 51 56.171          +24 45
25.75                6.21          179.01   379.01   14518   41.5    37.9   0.004
                   ±0.63                ±0.67                ±0.01
Bennu_natsat_1.fits
      natsat1 C2015 01 01.04172 03 51 56.17 +24 45 25.7          6.2
V      XXX
```

Data Product Generation

How and by whom is the product generated?

Astrometry and Photometry

What are the input products needed to produce the product?

MapCam images of Natural Satellite Search fields, astrometric/photometric star catalogs, s/c ephemeris position, Bennu ephemeris position, MapCam image filter, MapCam image exposure time, MapCam image exposure duration, MapCam pointing (RA/DEC)

Are there format expectations for the input products?

Yes, though the fortran programs being used can be easily modified to accommodate any input formats. The MapCam image headers need to be in the standard FITS header format. A list of FITS header keywords and their meanings are required.

What algorithms and/or calibration data is used to generate products?

Are there format expectations for the inputs?

Has a specific Science Team Member been assigned to produce this product?

Carl Hergenrother

Will multiple versions of the product be generated?

If natural satellites are found, additional astrometry and photometry will be produced.

How will they differ?

The formats will remain the same, the data will be different due to occurring at different epochs.

On what cadence will they be delivered?

TBD, depending on the contingency plan. Cadence for astrometry will depend on the orbit of the satellite.

Data Product Validation

How will the product be vetted to ensure contents and format are correct?

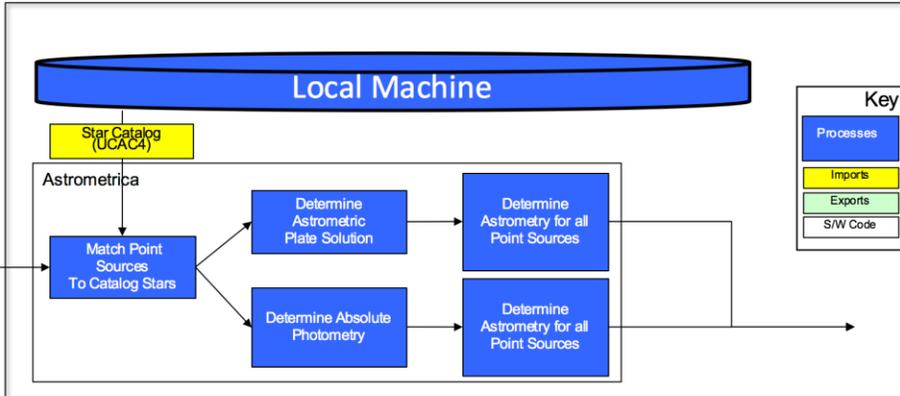
Creation of synthetic image data (with synthetic satellites) will be run through the detection software. Astrometry produced from the synthetic image data will be compared with expected results.



Astrometry & Photometry Generation

List functions of Astrometry Generation:

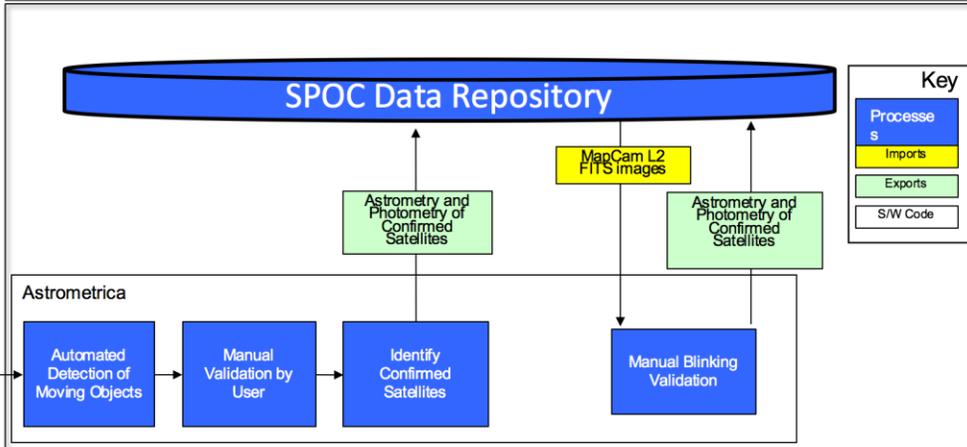
1. Read astrometric star catalogs from Local Machine
2. Read list of detected point sources from Source Extraction algorithm within Astrometrica
3. Match catalog stars to detected point sources
4. Determine the astrometric plate solution in J2000 coordinates
5. Determine the astrometry of all point sources in J2000 coordinates
6. Determine photometric solution
7. Determine photometry for all point sources
8. Transfer astrometry and photometry for all point sources to Moving Object algorithm in Astrometrica



Moving Object Detection and Validation

List functions of Moving Object Detection and Validation:

1. Automatic detecting of objects moving in a consistent linear motion
2. Manually validate automatically detected candidate satellites to identify real detections
3. Identify real satellites
4. Archive list of confirmed satellites to SPOC Data Repository
5. Read OCAMS MapCam L2 FITS data back into software tool
6. Manually blink images to search for satellites not detected by automated detection routine
7. Archive list of additional confirmed satellites to SPOC Data Repository



Describe the sources, destinations, and transfer procedures for data products.

State the size of an individual data product and the total size of all the data products generated over the course of each mission phase.

ASCII files will be very small (<1 MB). If natural satellites are found and warrant further following, astrometry and photometry may be produced throughout any of the encounter phases.

State the time span covered by a product, if applicable, and the rate at which products are generated and delivered.

The natural satellite searches will occur throughout the Approach phase. If no satellites are found, this data product will not be produced. If satellites are found, additional astrometry and photometry files may be produced throughout the rest of the encounter.

Standards used to generate data product

Time (e.g. times are all converted to UTC)

UTC

Coordinate System

J2000 celestial coordinate system
astronomical photometric system (b,v,w,x,monochrome v)

Data Storage Conventions (i.e. byte order, compression, machine dependence)

Natural satellite astrometry file to be saved to SPOC repository
Product to be retrieved via WebQuery based on data product type (name) or name of satellite
(provisional natural satellite identifier, for example, sat001, sat002, etc.).
There is no need to search

Relevant ICD Data Products:

- Astrometry of Confirmed Satellites (AP-8)
- Photometry of Confirmed Satellites (AP-9)
- Map of Region around Bennu with faint detectable satellites (AP-11)