MRD 127-Pole Location, MRD 128- Wobble, MRD-129 Rotation Period

Improvement to the pole, wobble and rotation period of Bennu will be obtained by the ALTWG during the encounter of Bennu, and will be further updated by Flight Dynamics and the Radio Science Working Group. The project will post documents describing how these data will be produced when they become available. In summary, these are the result of tracking landmarks across the asteroid as it rotates, or by minimizing offsets between altimetric data sets obtained at differing times by varying the orientation of the asteroid's pole, wobble and rotation rate. The result of this analysis are put in a typical NAIF SPICE PCK file, which traditionally capture such data.

Details on how these products will be delivered to the project are provided in the ALTWG SIS: ODOCS 9.4.2 -> SISs -> UA-SIS-9.4.4-307

We summarize what this product looks like in what follows.

Data Product Overview
In the SPICE system, the PC-kernels (PCK) contain orientation and shape information pertaining to extended solar system bodies such as the Sun, the planets, the natural satellites of the planets, comets, and asteroids. The most recent generic PC kernel file can always be obtained from NAIF/JPL.

The purpose of the PCK kernels and associated software is to provide SPICE users with a convenient mechanism for supplying planetary physical constants to application programs. SPICELIB's PCK software is able to read files conforming to the PCK format and return to a calling application program both the data contained in such files and a small number of commonly used numeric quantities derived from the kernel data. Information regarding how to obtain the SPICE Toolkit for a number of languages and computer platforms is located in the ``/software" subdirectory of the main directory of this data set.

Refer to the PCK Required Reading (pck.req) document provided with the toolkit or available from the NAIF Node of PDS if SPICE toolkit is not included with this data set to get more information on how to access PC-kernel data.

Overview

PCK file containing the asteroid Bennu's radii values, body-fixed frame definition and rotation constants (including pole orientation, rotation rate and any wobble) derived by the OSIRIS-REx science team. If the wobble state of Bennu is particularly complicated, the traditional ascii PCK file will be replaced by a binary similar to what used now to describe the details of the Earth's moons libration. Alternatively, the ascii file will be kept, but without the wobble characterized, and the asteroid's wobble will be captured in attitude kernel (also known as a spice CK kernel) for Bennu.

Data Product Structure and Organization

Most likely, a simple ASCII file with NAIF defined values of Bennu's radii, body-fixed frame definition and rotation constants.

Data Format Descriptions
Vintage NAIF SPICE PCK file. See NAIF web site for more information.

Data Type – ASCII file

Fields:

BODY2101955_RADII=vector defining the three longest axis of the asteroid

BODY2101955_POLE_RA = defines the right ascension (RA) of Bennu's pole, and first order and second order time dependence of declination

BODY2101955_POLE_DEC=defines the declination (DEC) of Bennu's pole, and first order and second order time dependence of declination
vector defining the declination (DEC) of Bennu's pole

BODY2101955_PM = values defining the location of Bennu's prime meridian in days past J2000

Additional terms due to librations or wobble which have sinusoidal dependencies are captured in the following fields if necessary:

BODY2101955_NUT_PREC_RA,

BODY2101955_NUT_PREC_DEC,

BODY2101955_NUT_PREC_ANGLES.

2101955 is the NAIF ID assigned for BENNU.

There are instances where a complex rotation such as the lunar libration need to be captured in a binary pck or spice ck file. Our team has several members who know how to generate these files types and will generate them if deemed necessary.

Data Product Generation
This product is updated following the assessment of the location of landmarks while developing a shape model with SPC in the preliminary survey phase. This initial product will then be handed to FDS who will further evaluate the asteroid's wobble and provide an additional updates to the wobble they find as they track surface landmarks on Bennu, or from minimizing cross-overs between OLA scans obtained during Orbital Phase A in Geodyn. The improvements will be returned to ALTWG to update the overall PCK for Bennu. ALTWG will further assessing

which pole and wobble best minimize offset between OLA strips. The new best fits for the pole orientation, wobble and rotation rate will be provided as the mission proceeds.

An excellent first solution for the pole and wobble will be generated by the end of the approach phase when SPC is used to generate a first shape model. A excellent updated solutions will be developed by the end of Orbital A. Only minor improvements are expected later after Orb B, with the extensive OLA data set collected then. All additional updates will be generated for each successive shape model delivered by ALTWG to the SPOC. These changes are likely to be small,especially after Orbital Phase A within the errors of the first results. After introduction of OLA into the solution for wobble, where cross-over errors can be assessed to determine wobble, very small if any changes to the pole are expected from the ALWTG. Only a full dynamical solution output by the RSWG may provide higher fidelity, but this will be provided close to the end of the encounter at Bennu and is likely not required for sampling the asteroid.

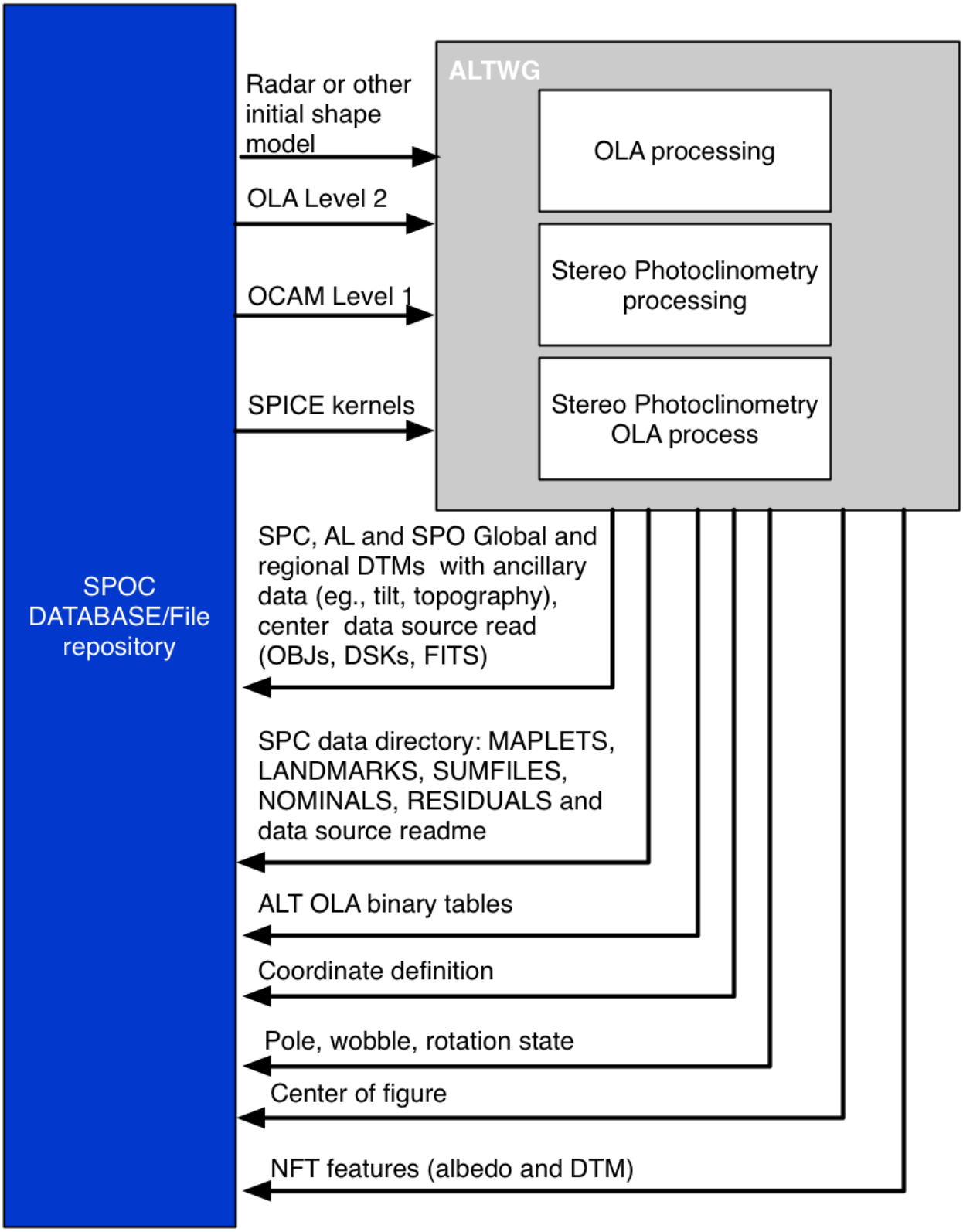
The ALTWG recommends the mission proceed with a wobble and pole value where the uncertainty of these measurements are less than errors that the spacecraft can live with to sample the surface of the asteroid. The approach phase solution may suffice for this purpose, but the final version 3 listed in the table above obtained after detailed survey is likely to be more than sufficient.

Data Product Validation

SPC and OLA process has been validated by using imagery and altimetry data from past mission such Dawn, Hayabusa and MESSENGER, and simulated OSIRIS-REx imagery and altimetry. Various thread tests have been undertaken by the OSIRIS-REx projects. A simple test shows that SPC was able to recover a 10% error in the pole orientation of Bennu within one iteration to better than 1 %. Likewise the rotation period was recovered to much better than 10s, on the order of 1s. More complete tests are planned in the early parts of cruise. These tests will include a full assessment of how well SPC and OLA recover a realistic wobble model for Bennu. The algorithms employed have heritage from Dawn, Hayabusa, MESSENGER, LRO and Rosetta.

Data Flow

For SPC, imagery, spacecraft attitude and trajectories are combined to determine through stereo and photoclinometry the shape of celestial object. This is achieved via a least squares inversion approach, where the topography at each pixel is modeled to match observations. When using OLA data, OLA level 2 data, where the x, y, z position of each return has been derived from OLA ranges, and spacecraft attitude and trajectory are combined together and minimized via least square to make the asteroid shape model, and regional high resolution terrain maps smooth and continuous. The following schematic provides the overall flow of this process.


SPOC DATABASE/File repository
Radar or other initial shape model
OLA Level 2
OCAM Level 1
SPICE kernels
ALTWG
OLA processing
Stereo Photoclinometry processing
Stereo Photoclinometry OLA process
SPC, AL and SPO Global and regional DTMs with ancillary data (eg., tilt, topography), center data source read (OBJs, DSKs, FITS)
SPC data directory: MAPLETS, LANDMARKS, SUMFILES, NOMINALS, RESIDUALS and data source readme
ALT OLA binary tables
Coordinate definition
Pole, wobble, rotation state
Center of figure
NFT features (albedo and DTM)