CARTOGRAPHIC PLANNING FOR THE OSIRIS-REX ASTEROID SAMPLE RETURN MISSION. D. N. DellaGiustina[1], O. S. Barnouin[2], M. C. Nolan[1], C. A. Johnson[1], L. Le Corre[3] and D. S. Lauretta[1] , [1]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721, [2]The Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, [3]Planetary Science Institute, Tucson, AZ 85719. Email: danidg@orex.lpl.arizona.edu

Introduction: The primary objective of the Origins, Spectral Interpretation, Resource Identification, and Security-Regolith Explorer (OSIRIS-REx) mission is to return a pristine sample of carbonaceous material from the surface of primitive asteroid (101955) Bennu. Understanding the spatial context of this sample is critical to linking the geological nature of the sample to the global properties of Bennu and the broader asteroid population [1]. This abstract presents the cartographic planning being conducted to support the primary objective of the OSIRIS-REx mission. Cartography is the science and practice of placing information in a standards-compliant spatial framework [2]. For OSIRIS-REx, this framework is essential for mission planning, data analysis, and visualization of results.

Motivation: OSIRIS-REx is unique among planetary missions in that all remote sensing is performed to support the sample return objective. Prior to the sampling event, OSIRIS-REx will survey Bennu for approximately one year to select and document the most eminent candidate sample site. During this period, the mission will combine coordinated observations from the OSIRIS-REx Laser Altimeter (OLA), OSIRIS-REx CAMera Suite (OCAMS), OSIRIS-REx Visible and InfraRed Spectrometer (OVIRS), OSIRIS-REx Thermal Emission Spectrometer (OTES), and the OSIRIS-REx radio communication system into four thematic maps of decision-making properties: deliverability, safety, sampleability, and scientific value [1]. The deliverability map maximizes the probability that the OSIRIS-REx flight dynamics team can deliver the spacecraft to a desired location. The safety map minimizes the probability that physical hazards are present at a location. The sampleability map quantifies the probability that a sample can be successfully collected from a given point on the surface. Finally, the scientific value map illustrates the presence of organics and volatiles within a geological context that is definitive enough to determine sample history.

Bennu Coordinate System: The ability to combine multiple data sets into decision-making maps hinges on the use of a single standard coordinate system for Bennu. There are two aspects of the coordinate system definition: the location of the origin and the definition of the prime meridian. Early in the mission planning a preliminary coordinate system was established using the Nolan et al. radar shape model of Bennu [3], along with a plan to refine the coordinate system during asteroid encounter. As the first images of Bennu are acquired, the established prime meridian (PM) on the current shape model will be reassigned to a nearby geological feature. To preserve the location of the PM as image resolution improves, the particular element of the feature that defines the PM, or the feature itself, will be re-specified. This allows the position of the PM to remain static throughout operations. In the initial phases of encounter, the origin of Bennu will be defined by the center of figure (COF) of the asteroid shape model. As the mission progresses, however, the center of mass (COM) will be determined to within a few meters. When this occurs, the origin will be adjusted from the COF to the COM. The position of the COM will be assessed throughout the mission; however, the origin of the coordinate system will only be updated if the COM deviates significantly from the initial determination. The right hand rule for defining the positive pole and latitudes of Bennu has been adopted despite the retrograde nature of Bennu's rotation, as recommended by the IAU [4].

Data products created by the OSIRIS-REx team must be submitted to the OSIRIS-REx Science Processing and Operations Center (SPOC) in a formal Map Interchange Format (MIF). The MIF enforces use of the standard coordinate system and ensures that all data sets are registered to a common shape model of Bennu. The SPOC will redistribute the properly formatted data products to other science team members using a central repository.

Cartographic Products: Geodesy is primarily conducted by the OSIRIS-REx radio science and altimetry teams, who are responsible for determining the coordinate system, mass, gravity field, rotational elements, shape model and local terrain models (via stereophotoclinometry) of Bennu. Once these products are developed, photogrammetric mapping is performed by the OSIRIS-REx image processing team.

Using the Integrated Software for Imagers and Spectrometers (ISIS) [5], the image processing team will develop global and site-specific controlled mosaics using photometrically corrected panchromatic and color images of Bennu. These mosaics will serve as base maps for several derived thematic maps. The results of stereophotoclinometry may be recycled to control the subset of images used to create the shape model of Bennu; otherwise ISIS bundle adjustment routines will generate and apply a control network. Using SOCET SET in conjunction with ISIS [6], digital terrain models and orthoimages of the sampling site will be derived from OCAMS stereo images and controlled to OLA data.

It is worth noting that additional software development must take place in both ISIS3 and SOCET SET prior to use by a planetary mission. Each program requires that mission specific camera models, translations, and coordinate transformation routines are implemented before they can be used with data from that mission. A mission wishing to use either software package for image processing and photogrammetry should consult the USGS Astrogeology Science Center early in the planning stages.

3D Support and Visualization: The longitude-latitude-radius system is suitable for larger planetary bodies with sufficient convexity. Small bodies, however, are often irregularly shaped with regions that cannot be uniquely addressed using the longitude-latitude-radius system [7]. For such bodies a pure Cartesian system might be considered more useful during data processing and visualization. To prepare for this possibility, the OSIRIS-REx mission will use 3D shape model capabilities that support both the longitude-latitude-radius system and Cartesian point clouds to create and visualize data products. During operations data visualization will take place using the Small Body Mapping Tool (SBMT) [8] and JAsteroid, a 3D version of the Java Mission-planning and Analysis for Remote Sensing (JMARS) [9]. JAsteroid is capable of displaying data in a traditional 2D view using geographic coordinates, as well as a full 3D view that will illustrate data sets projected onto a tessellated shape model of Bennu in Digital Shape Kernel (DSK) format [10].

OCAMS imagery will be projected onto the Bennu shape model in DSK format using ISIS before being mosaicked and transformed to a cartographic projection [5]. Map-projection standards have not yet been defined for small bodies [7], perhaps due to the diversity and irregularity of their shapes. To determine an appropriate set of map-projections for Bennu, simulations are being conducted by the image processing team. Using the Nolan et al. shape model of Bennu and predicted SPICE kernels, simulated images of Bennu have been created to mimic the set of observations OSIRIS-REx will acquire for mapping purposes. Sample mosaics are then created to determine an appropriate set of map-projections (Figures 1-2) using ISIS. These simulations also allow the performance of image processing pipelines to be determined.

Future Work: An assessment of the work needed to implement additional Cartesian point cloud support in ISIS is presently being conducted, to ensure that all of the required photogrammetry tools are developed before encounter with Bennu. Because few cartographic standards have been defined for small bodies, the OSIRIS-REx mission must also develop internal guidelines to ensure that map-projections, conventions, and symbology are consistent with existing standards for other planetary bodies, where applicable.

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Fig. 1 – Simulated images from the first pass of the OSIRIS-REx “baseball diamond” mapping survey mosaicked using an equirectangular map-projection centered at 0° latitude, 0° longitude. Distortion seen at equatorial latitudes is likely due to Bennu’s distinct equatorial ridge [3].

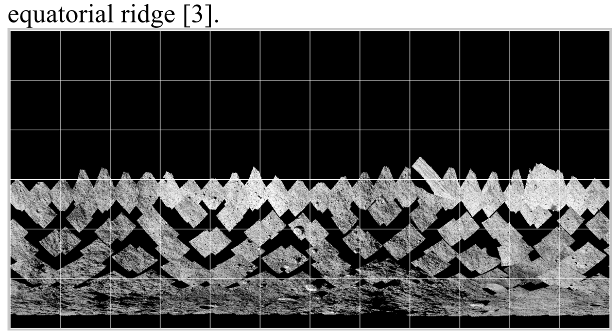

Fig. 2 – The same set of simulated images as Fig.1, mosaicked using a polar stereographic map-projection and centered at -90° latitude.