THE SMALL BODY MAPPING TOOL (SBMT) FOR ACCESSING, VISUALIZING, AND ANALYZING SPACECRAFT DATA IN THREE DIMENSIONS: 2019 UPDATE. R. J. Steele[1], C. M. Ernst[1], O. S. Barnouin[1], R. T. Daly[1], and the Small Body Mapping Tool Team[1]. [1]The Johns Hopkins University Applied Physics Laboratory, 11101 Johns Hopkins Road, Laurel, MD, 20723, USA (sbmt@jhuapl.edu).

Introduction: Spacecraft missions return massive amounts of valuable data, but those data can be hard to access, visualize, and analyze. Most asteroids, comets, Kuiper belt objects, and small moons present additional challenges because two-dimensional map projections severely distort features on irregularly shaped bodies. The Small Body Mapping Tool (SBMT) developed at the Johns Hopkins University Applied Physics Laboratory addresses these challenges [1].

The SBMT lets users search for spacecraft data and project it onto shape models of small bodies. As a result, users can quickly find the data they need, look at the data in context, and do their science in three dimensions, without worrying about map projection issues or wading through Planetary Data System (PDS) archives. Alternatively, the SBMT can be a starting point: users can pinpoint the data they need using the SBMT and then download the raw data from the PDS. The Tool includes a diverse suite of bodies and data types (images, spectra, altimetry data, see "Available Data") and supports co-registration of these data products. It has been or is being used by multiple mission teams, including Dawn, Rosetta, OSIRIS-REx, and Hayabusa2.

The Small Body Mapping Tool is publicly available as a free download at sbmt.jhuapl.edu. It works on Mac, Linux, and Windows operating systems and has an easy-to-use graphical user interface that has been refined and improved over the last year. The SBMT is written in Java and uses the Visualization Toolkit (VTK), an open-source, freely available software system for 3D computer graphics, rendering, and visualization [2]. Although datasets and functionality specific to active missions (e.g., OSIRIS-REx) are currently restricted to team members, such features go public once the data have been archived with the PDS.

Features: The SBMT facilitates interactive searches for spacecraft data. This capability allows users to quickly and easily identify the images, spectra, or altimetry data that will help them achieve their science or engineering objectives. Once selected, data can be projected onto the shape model and analyzed using the SBMT's built-in analysis tools, thereby integrating data discovery and data analysis. Alternatively, users can export data for use in analysis tools of their choice.

The Tool's graphical user interface includes several tabs next to a large viewing area. Once users choose a body from a menu, each tab provides access to a different dataset. Users can set shape model illumination and simulate camera pointing. In the viewing area, users can interactively manipulate the shape (rotate, zoom, etc.).

Body tab: The body tab allows users to visualize a shape model at a variety of resolutions, view a basemap (where available), and overlay color maps of elevation, slopes, gravitational potential, and gravitational acceleration onto the shape. Such geophysical maps have proven useful in studies of asteroids [3–5]. Newer bodies in the SBMT have additional plate colorings, including uncertainty planes. These additional colorings will be added to legacy bodies in the coming year.

Data tabs: Once users choose a body, the SBMT interface populates tabs based on the available data. Once a particular data tab is selected, users can search based on many parameters, including emission, incidence, and phase angles; pixel scale; data acquisition time; and wavelength. Users can also search for data by location by selecting a region of interest on the shape. Search capabilities for lidar datasets have been enhanced over the past year to take advantage of hypertrees to improve search results. The SBMT displays the footprints of images, spectra, and altimetry data found by the search so that users can decide which to load (Fig. 1). Users can simulate lighting to match the conditions when the data were acquired. The ability to view off-limb images (e.g., jets on comets) has also been implemented.

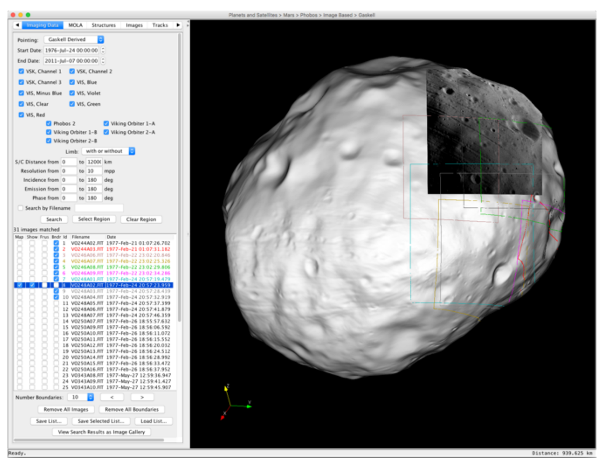

Figure 1. The SBMT lets users easily search for data. Here, available data footprints are shown (colored squares), and one image has been projected directly onto the shape model of Phobos.

The data tabs include several analysis tools. The functionality depends on data type (e.g., images vs. lidar tracks). For images, the SBMT can generate image cubes for overlapping images. These cubes can then be used to make RGB composites or be exported (e.g., to

ENVI). The custom bands feature for spectral data allows users to do band math [e.g., 6]. For lidar data, transects can be used to measure topography (Fig. 2).

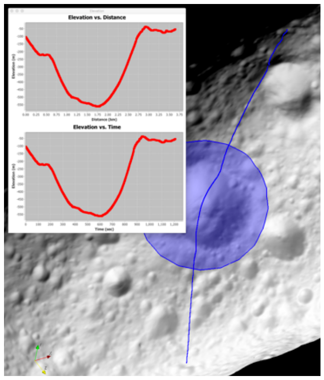

Figure 2. Topographic profiles can be extracted from lidar tracks and DTMs, such as this example from Eros.

Structures tab: The structures tab lets users map features on the shape model while viewing images or other data. Paths and polygons can be used to map lineaments, regions, and geologic units [e.g., 7–10]. Craters and blocks can be mapped with circles or ellipses [e.g., 11, 12] (Fig. 3). Points can be used to mark the locations of features. The data are saved as XML (paths, polygons) or ASCII (circles, ellipses, points) files that can be easily imported into other tools or codes. The files contain both the measurements (e.g., polygon area, crater diameter) and regional geophysical data (e.g., elevation, slope). The structures panel has undergone several changes recently, including UI improvements and the ability to import/export certain structures as ESRI shapefiles.

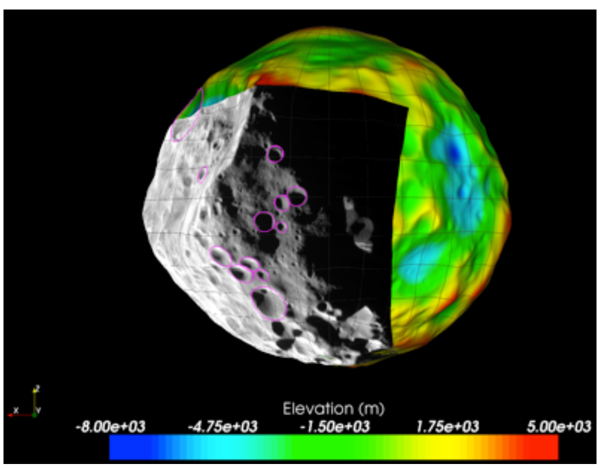

Figure 3. The SBMT lets users map craters, blocks, and other features directly on the shape. Here the user is mapping craters (magenta circles) on Phoebe. The shape is colored by elevation; a Cassini ISS image is draped on the shape.

Regional DTMs tab: For shape models generated using stereophotoclinometry [13], global shape models have lower resolution than the maplets on which the models are based. The regional DTMs (Digital Terrain Models) tab contains a database that allows users to construct higher-resolution regional DTMs, which can be overlain on the shape model or visualized independently in the SBMT. We are in the process of migrating regional DTM generation from a user's local machine to a server-side process to improve the user experience.

Observing conditions tab: The observing conditions tab lets users visualize the relative positions of the spacecraft and the target body through time, including simulations of the lighting conditions and the sub-Earth, sub-spacecraft, and sub-solar points. Future enhancements to this tab will provide a way to link ground-based observations made at known times to specific parts of the object.

Custom data import: Each data tab allows users to import customized data and visualize it on the shape model. Users can apply pointing information from the SBMT to display imported data, as long as the files retain their original dimensions. Simple cylindrical global or regional basemaps can also be imported.

Available data: As of early 2019, the public version of the SBMT includes spacecraft data for several asteroids (Ceres, Vesta, Lutetia, Eros, Itokawa) and moons (Phobos, Dione, Mimas, Phoebe, Tethys). Currently funded NASA grants will enable us to add 9P/Tempel 1, 81P/Wild 2, 103P/Hartley 2, and the saturnian moons Atlas, Calypso, Epimetheus, Helene, Hyperion, Janus, Pan, Pandora, Prometheus, Rhea and Telesto. The SBMT can also be used for large, spherical bodies like the Moon and Mercury [9, 14].

Conclusion: The Small Body Mapping Tool is a powerful, easy-to-use tool for accessing and analyzing data from small bodies. We will continue to release new datasets and functionality. Visit sbmt.jhuapl.edu to subscribe to the SBMT mailing list. We invite everyone in the community to reach out and discuss collaborations.

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