**THE SMALL BODY MAPPING TOOL (SBMT) FOR ACCESSING, VISUALIZING, AND ANALYZING SPACECRAFT DATA IN THREE DIMENSIONS: 2020 UPDATE.** A. C. Martin[1], C. M. Ernst[1], O. S. Barnouin[1], R. T. Daly[1], R. J. Steele[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 [1,2].

The SBMT allows users to find, access, and analyze spacecraft data in a contextual way for small bodies. It lets users search for spacecraft data and project it onto the small body shape models to help users quickly find data they need and do their science in three dimensions without worrying about map projection issues or sorting through Planetary Data System (PDS) archives. Alternatively, users can use the SBMT as a starting point to pinpoint the data they need and then download the raw data from the PDS. The Tool includes a diverse suite of bodies and data types (images, spectra, altimetry data) and supports co-registration of these data products.

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 a user-friendly graphical interface that has been 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 [3]. Anyone can access datasets for 11 asteroids, 4 comets, and 16 satellites. Datasets and added features for active missions (e.g. OSIRIS-REx) are currently restricted to team members, but will be made public once all data products in the SBMT have been archived with the PDS.

**Features:** The SBMT's interactive search capabilities for spacecraft data allow users to quickly and easily identify data that will help them achieve their science or engineering objectives. In the viewing area, users can interactively manipulate shape models (rotate, zoom, etc.). The Tool's graphical user interface includes several tabs next to a large viewing area that provides access to different datasets. Select a region, click "Search", and the Tool will return a list of available images, spectra, or altimetry data products that cover the region of interest. The data can be draped onto the shape model and analyzed using the SBMT's built-in analysis tools. Alternatively, users can export data for use in analysis tools of their choice.

**Updates, Improvement, and New Features:** Here, we focus on the substantial updates that have been implemented over the past two years. Additionally, several behind-the-scenes updates have been made to improve efficiency and the user experience. See Ernst et al. [2] for a general description of the SBMT's capabilities.

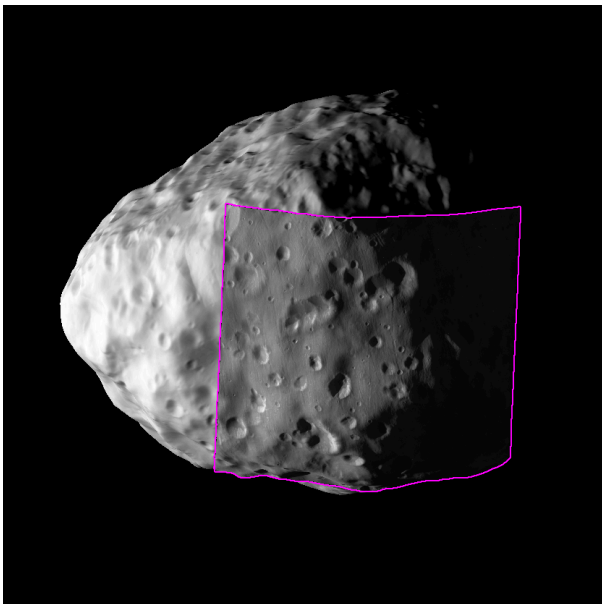

**Figure 1.** Saturn's moon Epimetheus viewed using the SBMT. A high- resolution SPC shape model of Epimetheus has been overlain by Cassini ISS image number N1866366029 and is outlined in pink. Cassini image credit: NASA/JPL-Caltech/Space Science Institute.

*General features:* Most of the SBMT's tabs have been updated to use a more advanced table-client code. This change makes it possible to sort a list of data file or structures by any attribute shown in a table (e.g., whether or not it's visible, name, feature size), as well as an improved stability for the various checkboxes that help the user to visualize data. The tables for the image and observing condition tabs will be updated soon.

*Save state*: Users can now save the current state of the SBMT. This capability means that a user could have multiple datasets displayed, be mapping craters on an asteroid, close the SBMT, shut down their computer, and later pick up right where they left off. Features currently being saved by this ability include saving existing structures, mapped images, and the orientation of/distance to the body in the renderer. Additional components are being made to save state incrementally.

*Image tab:* The SBMT now will automatically save any user-generated custom stretches made to an image. This means that the time and care a user takes to customize a view of an image will be retained after the tool is restarted. The code that handles the visualization of

images in the SBMT is complex and is due for a major update in the coming year.

*Spectra tab:* The entire spectra tab has been updated, both in terms of the graphical user interface (GUI), as well as the features that allow users to color spectral footprints by various attributes (including the use of custom formulas). Built-in spectra capabilities are publicly available for Eros and Itokawa. Spectra can now be exported in both SBMT- and human-readable formats, and read back into the SBMT via the custom data tab.

*Lidar tab:* The entire lidar tab has also been updated to improve both the GUI and the functionality. Separate browse and search tabs allow the user to access public data for Eros, Itokawa, and Phobos. Additional options for colorizing the lidar data on the body have been added.

*Structures tab:* The behind-the-scenes functionality of the structures tab has been vastly improved, particularly when displaying a large number of structures at one time. The user will notice the ability to see more attributes in the table, add header comments to structures files, and manipulate the 3D view while in edit mode.

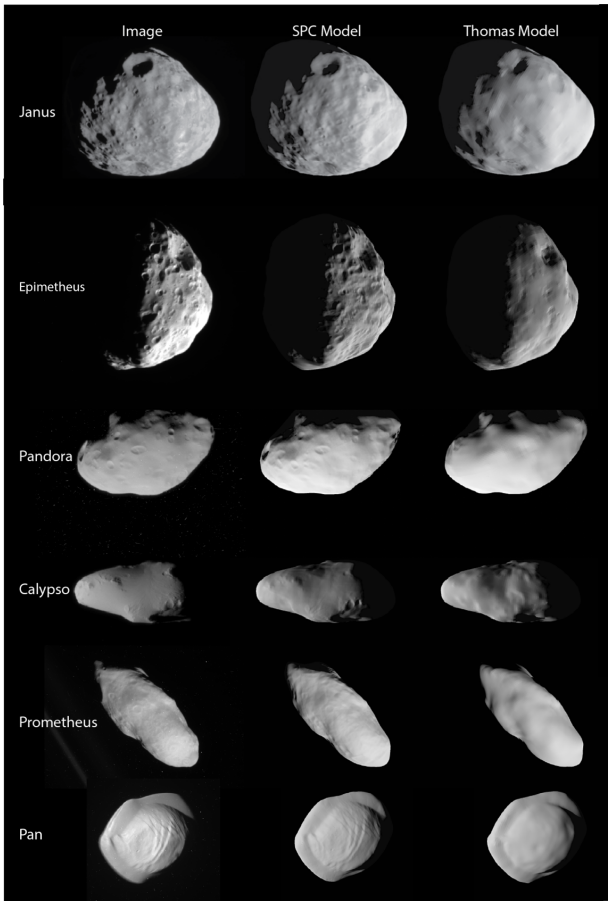


**Figure 2.** Comparison among Cassini ISS images (left), new SPC models (center), and the current best Peter Thomas models (right). Geologic features are visible on these bodies for the first time, and match well with the actual images.

*Regional DTMs tab:* DTMs (Digital Terrain Models) loaded into or found via the DTM tab can now be exported as custom models. When exported in this manner, these custom DTMs retain knowledge of their associated planetary body, and any SBMT datasets are accessible for search and display.

*Observing conditions tab:* The observing conditions tab is currently undergoing a complete overhaul to improve the GUI, add features, and provide compatibility with SBMT mission-planning visualization features. This tab now allows users to create and save movies.

*Custom data import:* Custom data tabs for spectra and lidar have been upgraded to match their corresponding main tabs, as described above.

**Newly available data:** New in the SBMT for this LPSC are several models of irregularly shaped saturnian satellites. We have made available new stereophotoclinometry-based models and registered Cassini ISS images of Janus, Epimetheus, Pandora, Calypso, Prometheus, and Pan. A description of these models can be found in [4]. Updated shape models from Thomas [5] are also now available, including the ability to map Cassini ISS images based on the pointing knowledge gained by the aforementioned SPC models. Figure 2 compares Cassini ISS images to the new SPC models and Thomas [5] models.

**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 and stay up-to-date with the latest developments. We invite everyone in the community to reach out and discuss collaborations.

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**References:** [1] Kahn et al., 2011, *LPS 42*, abs. 1618. [2] Ernst et al., 2018, *LPS 49*, abs. 1043. [3] Schroeder et al., 2006, *The Visualization Toolkit: An object-oriented approach to 3D graphics*, Kitware, Inc. [4] Daly et al., 2018, LPS 49, abs. 1053. [5] Thomas et al., 2019, Icarus, doi.org/10.1016/j.icarus.2019.06.016.