A COMPLETE, COREGISTERED, AND SEARCHABLE COLLECTION OF PHOBOS AND DEIMOS IMAGES FROM 1975–2016. Carolyn M. Ernst[1], Robert W. Gaskell[2], Olivier S. Barnouin[1], and R. Terik Daly[1], [1]Johns Hopkins Applied Physics Laboratory, Laurel, MD 20723, USA (carolyn.ernst@jhuapl.edu); [2]Planetary Science Institute, Tucson, AZ 85719, USA.

Introduction: Over the past four decades, an armada of spacecraft have imaged Phobos and Deimos, thereby providing rich datasets of these bodies. There are thousands of images of the moons, however, the irregular shapes of Phobos and Deimos pose challenges for analyzing their surfaces. The synthesis of datasets from multiple spacecraft and instruments also poses a challenge. The Small Body Mapping Tool (SBMT; http://sbmt.jhuapl.edu) overcomes these challenges. The SBMT lets users search for and visualize data of irregularly shaped bodies [1, 2]. Within the Tool, we have created a complete, coregistered, and searchable collection of Phobos and Deimos images from the Viking Orbiter, Phobos 2, Mars Global Surveyor (MGS), Mars Reconnaissance Orbiter (MRO), and Mars Express (MEX) missions. These images can be projected onto updated stereophotoclinometry (SPC) [3] shape models of Phobos and Deimos [4] (e.g., Figure 1).

Spacecraft Data: We classified ~7000 publically available images of Phobos and Deimos according to whether they were sufficient for coregistration, inclusion in our shape modeling effort, and inclusion in the Small Body Mapping Tool. To be included, images had to contain Phobos or Deimos with at least 10 pixels across the body and not be completely saturated. In total, 3,402 images of Phobos and 951 of Deimos were classified for inclusion. The images came from the Viking Orbiter 1 and 2 Visible Imaging Subsystem (VIS) cameras, the Phobos 2 VSK, the MGS Mars Orbiter Camera (MOC), the MRO High Resolution Imaging Science Experiment (HiRISE) and Compact Reconnaissance Imaging Spectrometer for Mars (CRISM), and the MEX High Resolution Stereo Camera (HRSC). Table 1 summarizes these datasets, which were coregistered as a part of the shape modeling process.

Two altimetry tracks taken during one Phobos flyby were also included from the MGS Mars Orbital Laser Altimeter (MOLA). Major errors in the groundtrack location were corrected by adjusting the relative positions of the MGS spacecraft and Phobos and recomputing the locations of the ranging measurements [5], but the correction was limited by the quality of the images and shape model at that time. The RMS difference between the corrected tracks and our updated SPC Phobos shape model is ~67 m. We improved the correction using this shape model, decreasing the RMS difference to ~26 m.

Shape Models: The previous best shape models of Phobos [6] and Deimos [7] were constructed primarily

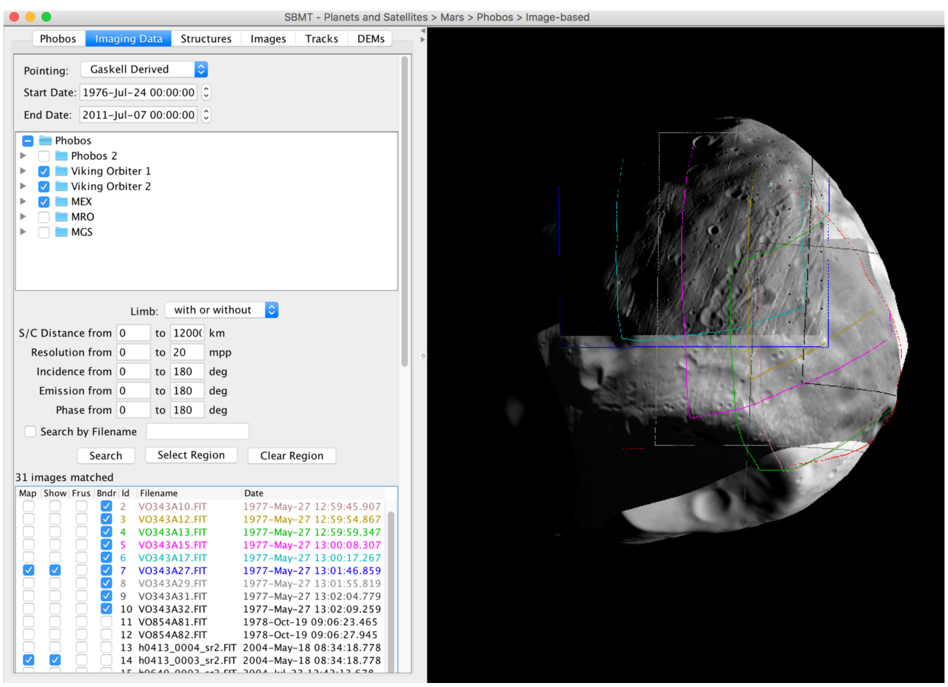

Figure 1. The SPC Phobos model in the Small Body Mapping Tool. An HRSC image (bottom) and a Viking Orbiter image (top) are overlain on the shape model, with lighting simulated to match the Viking image. Colored boundaries indicate a subset of additional images not mapped on the body.

using Viking Orbiter images. We created high-resolution shape models of Phobos and Deimos using stereophotoclinometry (SPC) with images from Viking, Phobos 2, MOC, HiRISE, and HRSC (Figures 1, 2).

The global SPC shape models consist of over 3 million plates. This is the first time that the shape of Deimos has been modeled using SPC. None of the spacecraft performed close flybys of Deimos, but incorporating newer images helped to better constrain the overall shape. However, the anti-Mars side remains constrained by limbs only. The additional Phobos coverage markedly improved the shape model, especially due to the global coverage from HRSC. Global (Phobos) and hemispherical (Deimos) high-resolution maplets (20-m ground sample distance for Phobos, 25-m for Deimos) were produced as part of the shape modeling effort. The previous Phobos and Deimos shape models had effective ground sample distances of 60 m ([6], constructed using 232 images) and 600 m at the equator ([7], constructed using 12 images), respectively. The new SPC models are a factor of 3 and 24 higher in resolution. Global maps of elevation, slope, gravitational potential, and gravitational acceleration have been calculated based on the updated models, and include the gravitational effects of Mars.

Phobos and Deimos in the SBMT: The SBMT now has enhanced Phobos- and Deimos-specific functionality. The updated SPC shape models are available for viewing, in addition to ~3500 images of the two moons from the aforementioned missions and the two corrected MOLA altimetry tracks. The data are all coregistered to the shape models, and are searchable by location, pixel scale, observation time, filter, and viewing geometry. The data can be projected on to the shape model, and the lighting can be set to simulate the conditions under which the data were acquired. The geophysical maps can be used to color the plate model, and backplanes for each image, calculated from high-resolution maplets, are available. Three CRISM disk-resolved hyperspectral images each of Phobos and of Deimos are also available, and can be viewed in any channel or as a complete spectrum. Structures (e.g., polygons, circles) can be mapped directly onto the shape using the images. A searchable web gallery of available images has also been created.

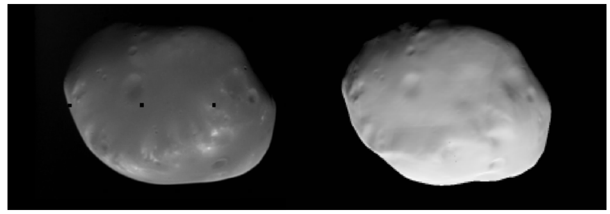

Figure 2. Comparison between Viking Orbiter image f428b22 of Deimos (left) and a simulated image based upon the SPC Deimos model (right).

Regional DTMs can be generated at higher resolution than the global shape model, where the data permit. The observing conditions tab lets users visualize the relative positions of a given spacecraft and moon through time, including simulations of the lighting conditions and the sub-Earth, sub-spacecraft, and sub-solar points. Customized data, including basemaps and mosaics, can be imported and visualized on the shape model. A more detailed description of functionality within the SBMT is available here [2].

The SBMT framework makes it possible to maintain a single repository for most of the images ever acquired of Phobos and Deimos, which is readily available online and can be used by anyone to investigate these satellites. The images are available in a searchable database and can be projected on the most up-to-date shape models made from the best images available. This repository is also a valuable resource for future missions to Phobos or Deimos, including JAXA's planned MMX mission. Download the SBMT at sbmt.jhuapl.edu to explore Phobos and Deimos in detail!

References: [1] Kahn, E.G. et al. (2011) *LPS*, *42*, abstract 1618. [2] Ernst, C.M. et al. (2018) *LPS*, *49*, abstract 1043. [3] Gaskell, R.W. et al. (2008) *MAPS*, *43*, 1049–1061. [4] Ernst, C.M. et al. (2015) *LPS*, *46*, abstract 2753. [5] Banerdt, W.B. and Neumann, G.A. (1999) *LPS*, *30*, abstract 2021. [6] Gaskell, R.W. (2011) *NASA PDS.* [7] Thomas, P.C. et al. (2000) *NASA PDS.*

Table 1. Phobos and Deimos Data Used in this Project

Years	Mission	Agency	Instrument	Phobos Images in SBMT (total available)	Deimos Images in SBMT (total available)
1975–1980	Viking Orbiter	NASA	Camera	315 (391)	133 (164)
1989	Phobos 2	USSR	VSK	37 (38)	n/a
1998	MGS	NASA	MOC	6 (16)	1 (2)
1998			MOLA	2 tracks (2)	n/a
2004–2016	MEX	ESA	HRSC	3020 (4779)	805 (1435)
2008–2009	MRO	NASA	HiRISE	21 (56)	9 (76)
2007			CRISM	3 (3)	3 (3)