J-ASTEROID: JMARS FOR ASTEROIDS AND OTHER SMALL BODIES

P. R. Christensen, S. Anwar, M. E. Burris, S. R. Carter, S. L. Dickenshied, D. D. Noss, W. R. Hagee, K. J. Rios, and P. F. Wren, Arizona State University School of Earth and Space Exploration – Mars Space Flight Facility, Moeur Building, 201 E. Orange Mall, Tempe, AZ 85287-6305, help@jmars.asu.edu

Background: JMARS (Java Mission-planning and Analysis for Remote Sensing) [1] is an open source, cross-platform, geospatial information system developed by ASU's Mars Space Flight Facility to provide mission planning and data-analysis tools for NASA orbiters, instrument team members, students of all ages, and the general public. Originally developed as a mission planning tool for the THEMIS instrument onboard Mars Odyssey, JMARS was released publicly to the science community for free in 2003. It has a proven track record in mission planning on multiple NASA missions.

JMARS provides functionality to quickly locate and view 2D planetary data for Mars, the Moon, Vesta, Ceres, Mercury, Earth, and many of the outer planet moons. Data from any number of instruments can be simultaneously displayed in a co-registered manner. Traditionally supported datasets include thousands of global maps and millions of individual images collected from various NASA instruments including THEMIS, HiRISE, CTX, CRISM, and SHARAD. Access to TES spectral data has also long been available in JMARS to members of the TES science team.

In addition to graphic data, JMARS also provides access to underlying numeric data whenever possible, allowing for the quick and easy plotting of elevation data, mineral abundances, or temperatures, just to name a few. This numeric data can also be used to project any user selected scene over available topography to create a 3D image.

J-Asteroid for OSIRIS-Rex visualizations: When JMARS first expanded to support a range of planetary bodies, it was sufficient to model various planets and planetary moons as spheres with differing radius values. Recent missions to asteroids and comets have clearly shown that such models are insufficient for visualizing data for smaller bodies.

J-Asteroid was created as an extension of JMARS with support for true 3D visualization of arbitrarily shaped planetary bodies. In addition to the previously supported functionality, J-Asteroid for OSIRIS-REx [3] allows draping mission data onto any shape model supported by the NASA NAIF [2] team's Digital Shape Kernel (DSK) functionality.

Any global or regional map available in J-Asteroid can be draped onto a selected DSK shape model and compared to other global maps by adjusting transparency or adjusting layer stacking order. Individual instrument footprints for the OCAMS, OTES, and OVIRS instruments can also be draped onto the 3D model and compared against other spatial datasets.

J-Asteroid also has the ability to load FITS files that define numeric values for each triangular facet in a shape model, and shade or colorize the entire 3D display according to those values. This allows for the science analysis teams to create, share, and visualize datasets among themselves without any additional interpolation of the data's spatial extent.

The spectral functionality in J-Asteroid has been rewritten and extended in support of the OTES and OVIRS instruments, so that it functions similar to other layers. This allows queries on spatial, temporal, and other metadata, as well as easy searches for overlapping data from other instruments. Spots representing the instrument field of view are displayed on the 3D body and can be colorized dynamically based on any values collected by the instrument, or by a dynamic user-defined formula operating on instrument metadata or spectral indices. Spectra for the spots can be easily viewed within J-Asteroid or exported to files for analysis in external tools.

J-Asteroid for OSIRIS-REx mission planning: JMARS was originally written in 2001 as a mission planning tool for NASA's THEMIS instrument on board Mars Odyssey. In 2006, JMARS began to be used as a mission planning tool for NASA's HiRISE instrument on the Mars Reconnaissance Orbiter. In 2009, JMARS was extended to support mission planning for NASA's Lunar Reconnaissance Orbiter Camera (LROC) orbiting the moon. Although these cameras fly on different NASA spacecraft, they each completed their primary missions in roughly circular polar orbits with the camera nominally pointed towards the planet's surface and limited slewing around one axis.

In contrast, the OSIRIS-REx mission will virtually never orbit Bennu. Instead, the spacecraft will frequently fly near or past the asteroid at varying speeds and distances. To allow for all of the on-board instruments to collect asteroid science data during any phase of the mission, J-Asteroid was enhanced to allow full targeting of the spacecraft, which has 3-axis freedom of rotation. Much of the data collected for the mission will be done while slewing back and forth across the desired area, so the J-Asteroid software is able to model pointing locations, spacecraft rotational acceleration and velocity, and the relative positions of the spacecraft and asteroid to one another.

The relatively small size of Bennu (about 250 meter radius) means that for much of the mission the asteroid is smaller than a single field of view for many of the mission's instruments, and even when the spacecraft is closer, it is still common to plan images that span the asteroid's limb, including both on body and outer space data. Visualization of these plans requires that instrument fields of view not only be shown upon the same 3D model mentioned previously, but that portions of the field of view that are off-body still be displayed appropriately in 3D (See Figure 1)

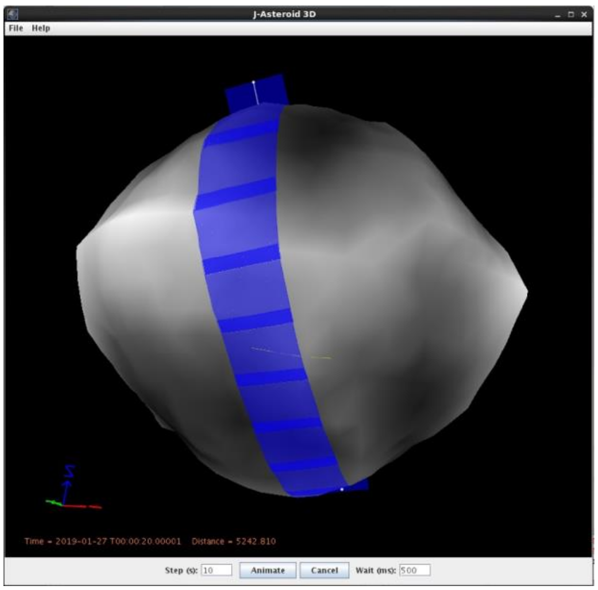

Figure 1: Instrument FOVs depicted both on and off the body.

Approximately one year after launch, the OSIRIS-REx spacecraft performed an Earth Gravity Assist (EGA) in September of 2017. Although originally designed just to target Bennu, J-Asteroid was enhanced to target the Earth and the Moon in support of the EGA activity and was successfully used to collect data from many of the instruments in the weeks following the closest approach.

Because OSIRIS-REx is a sample return mission, many phases of the mission have to be completed on tight schedules, so everything in J-Asteroid has been designed for fast development of mission plans and quick visualization of instrument and derived data as it becomes available. As new information is discovered, plans can be quickly modified and evaluated as necessary. Throughout all of these activities, J-Asteroid checks for compliance with mission and instrument flight rules, warning the user if any planned activity has the potential to cause harm to the spacecraft or a loss of critical data.

Long term benefits to JMARS: Although much of the work done for J-Asteroid for OSIRIS-REx has been driven by mission specific requirements, one goal of the development team has always been to allow for much of the newly developed functionality to be integrated back into the core JMARS software for the benefit of the planetary community at large.

Along these lines, some initial support for 3D models has already made its way into JMARS, with smaller bodies such as Itokawa, Eros, and Phobos already available in the public tool, including support for draping any low-resolution dataset over the 3D model. Plans are underway to include support for arbitrary resolution data on a 3D shape model for all supported planetary bodies, no matter their size or shape.

Improved spectra functionality has already been made available in a revised TES spectra layer in the public JMARS. This will allow easy deployment of layers with spectral data from other point spectrometers. This functionality is expected to continue to evolve and improve as OTES and OVIRS use in J-Asteroid drives new feature enhancements.

The 3D targeting capability in J-Asteroid has already been used to validate and adjust strategies for data collection for upcoming Mars missions by visualizing the planned data acquisition. The ability to support multiple planetary bodies in one mission planning tool will help future missions easily collect and visualize data for targets of opportunity as well as primary and secondary targets of interest.

References: [1] Christensen P. R. et al. (2009) Eos Trans. AGU, 90(52), Fall Meet. Suppl., Abstract #IN22A-06. [2] Acton, C. H. et al. (2018) Planet. Space Sci. 150(1). [3] Gal-Edd, J., and Cheuvront, A. (2015) IEEE Aerospace Conference, 2015 (pp. 1-9).

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