AMMOS PLANETARY ORBITAL MOSAICKING AND MAPPING (POMM) TOOLSET.

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Introduction: POMM is a set of software tools supporting the automation of Planetary Orbital Mosaicking and Mapping requirements. POMM is designed to provide the planetary scientist, student, and enthusiast with easy-to-use workstation tools that perform the basic functions necessary for many satellite mapping and analysis studies. These capabilities include:

1) The ability to co-register (stack) multiple orbital map images over the same location for time series analysis;

2) Mosaic multiple adjacent overlapping orbital map images to create large-area basemap coverages and regional overviews; and

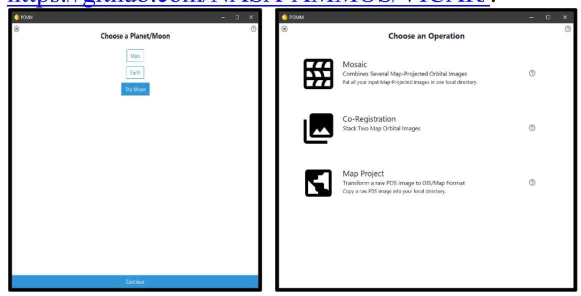
3) Create map-projected orbital satellite images from selected sensors and bands provided in PDS [1] format.

POMM (v1) supports the co-registration and mosaicking of single-band *map-projected* orbital images of Mars, Earth, and Earth's Moon. However, if map-projected images are not available, POMM can create them from their EDR PDS format for the following mission sensors:

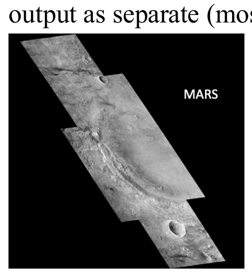
- Mars Reconnaissance Orbiter (MRO) Context Camera (CTX);
- MRO High Resolution Imaging Science Experiment (HiRISE) Red-band;
- Mars Express (MEX) High Resolution Stereo Camera (HRSC) "nd2" format;
- Lunar Reconnaissance Orbiter (LRO) Narrow Angle Camera (NAC "LE/RE" format); and
- LRO Wide Angle Camera (WAC "CC" format) COLOR VIS bands

POMM simplifies basic planetary mapping by providing user-friendly scripts that integrate complex processing functions provided by a variety of bundled Open Source software packages including VICAR/AFIDS [2/3], ISIS3 [4], and GDAL [5]. The POMM scripts are operated by a simple user interface which guides the user in providing the required input datasets and parameters. A command-line interface is also available that allows individual POMM, VICAR, ISIS3, and GDAL commands to be executed directly.

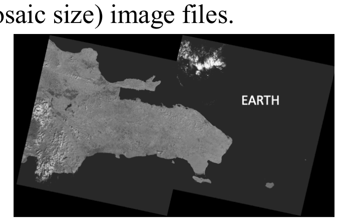
POMM was funded by the Advanced Multi-Mission Operations System (AMMOS) which supports NASA robotic missions with tools for planetary exploration, including Earth and space science. AMMOS is managed by the Multi-Mission Ground Systems (MGSS), a division of the NASA Interplanetary Network Directorate. Information concerning the availability of AMMOS POMM Open Source tools can be found at: https://github.com/NASA-AMMOS/VICAR/.



Mosaicking Orbital Map Images: POMM mosaics two or more adjacent map-projected images. The inputs can be from different satellite sensors and resolutions (e.g., CTX and HRSC) as long as they are map-projected and overlap. POMM employs automated mosaicking techniques for near-seamless geometric edge matching, brightness feathering and block adjustment between and across images. However, best results are obtained with inputs having similar resolutions, viewing and sun angles, and brightness histograms. Some custom pre-processing may be desired or necessary. There is no specific limit to the number of input images to mosaic, but available cpu performance and disk space resources should be considered. 100% overlapping images will not be "blended" in the output mosaic, but co-registered and output as separate (mosaic size) image files.

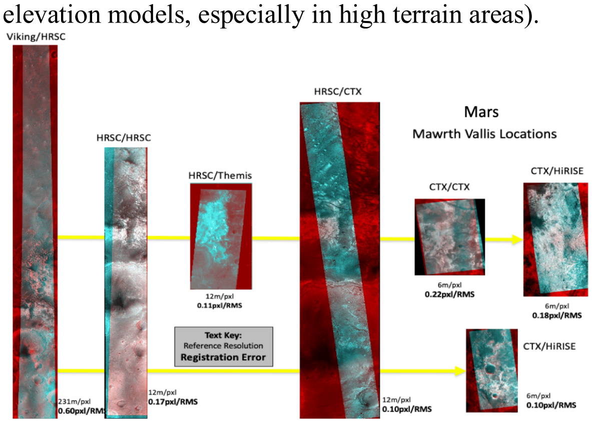


Jezero Crater *Sinusoidal* Projection
Three Image Mosaic

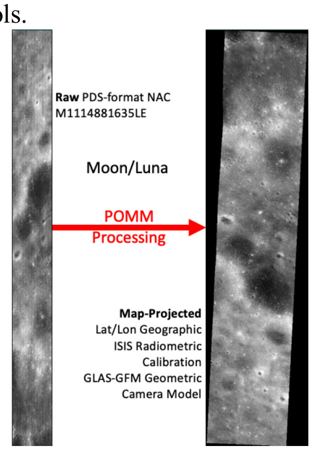


Dominican Republic *Lat/Lon* Projection
Two Image Mosaic

Co-Registering Orbital Map Images: This tool is used to co-register and stack time-series satellite images that may have large positional offsets (100+ meters) relative to each other [6,7]. The inputs can be from different satellite sensors and resolutions as long as they are map-projected and have a large overlap. The software co-registers the "Second" map image to the "Reference/Master" map image. The Reference image should be similar or lower resolution than the Second image. With the default option (1), the two registered images are output to the dimensions and projection of the Reference image. With option 2, both (master and the secondary image) are trimmed to the size of the secondary image (with added padding). A gridded tiepoint file is output, but is relative to the master image and an "intermediate" projected version of the second image (also output). The tiepoint file (csv/text format) contains six columns: Latitude, Longitude, Reference Image Line, Reference Image Sample, Second Image Line, and Second Image Sample. Note that co-registration accuracy will be proportional to the quality of the input imagery's map projection (and underlying elevation models, especially in high terrain areas).



Map Projecting PDS Orbital Images: When pre-existing map projected images are not readily available, POMM provides tools to map-project selected EDR images from PDS format [1]. POMM uses the GLAS-GFM [8] replacement sensor camera model for geometric map projection, and ISIS3 [4] software for radiometric calibration. An optional user-provided DEM model can be provided for terrain correction (or a standard global DEM model provided by default). Three output map projection choices are currently available (Geographic; Equidistant; Sinusoidal). Note that NAIF SPICE kernels [9] are required for ephemeris processing and are automatically downloaded using ISIS tools.



GLAS-GFM Camera Model. POMM geometric focal plane mapping is performed using the Generic Linear Array Scanner – Generic Frame-Camera Model [8]. GLAS is a next-generation U.S. Government multi-instrument camera model standard replacing legacy RPC and RSM designs, and supports a number of pushbroom, frame, and hybrid sensor designs, as well as supporting bundle adjustments and tiepoint corrections. Standardized GLAS camera model software also simplifies development of downstream common POMM software processing scripts.

Requirements and Features: Among the several POMM system design requirements, the two most important are Extensibility and Software Reuse.

Extensibility. The software design must be sufficiently generic to allow the easy adaption of future moderate-to-large size spherical moons and planets (no asteroids). This in-turn means that POMM orbital image inputs must be *map projected* (to avoid mission-specific custom processing software). POMM generally expects input images to be map-projected products created by a planetary science mission (although five mission sensors are directly supported).

Software Reuse. With the exception of the GLAS-GFM camera model software, most of POMM utilizes custom scripts incorporating VICAR/AFIDS, ISIS, and GDAL application programs. This provides a significant reduction in costs and software reliability risk. POMM also leverages the early "AFIDS-MOS" mosaicking designs developed by Drs. Albert Zobrist and Nevin Bryant for edge matching, brightness block adjustment and feathering.

GeoTIFF Standard. POMM uses the GeoTIFF georeference standard widely supported in the planetary community. To simplify georeference exchange, POMM has a special "vicarGT" GDAL-compatible plug-in that will convert most external georeferenced formats (e.g., jpeg2000; ENVI) to the internal "vicarGT" format which uses GeoTIFF Geokeys. Accepted georeferenced input file formats include: .tif (geotiff); .jp2 (jpeg2000); .img (PDS); and .vic (vicarGT; vicar format with geotiff property label).

References: [1] PDS3 (Planetary Data System) data format. https://pds.nasa.gov. [2] VICAR (Video Image Communication and Retrieval) https://www-mipl.jpl.nasa.gov/vicar.html. [3] AFIDS (Automated Fusion of Image Data System) https://ui.adsabs.harvard.edu/abs/2004AGUFMSF51A..05B/abstract. [4] ISIS3 (Integrated Software for Imagers and Spectrometers) https://isis.astrogeology.usgs.gov/7.0.0/index.html [5] GDAL (Geospatial Data Abstraction Library) https://gdal.org/. [6] Logan, T. L., et al. (2018) *LPS XLIX,* Abstract #1178. [7] Trautman, M. R., et al. (2018) *LPS XLIX*, Abstract #7032. [8] Theiss, H. J. (2020) *XXIV ISPRS Congress 2020*. V-1, 49-56. [9] NAIF SPICE https://naif.jpl.nasa.gov/naif/.