

Introduction

Since 1971, the U.S. Geological Survey (USGS) has developed cartographic and scientific software systems used to process and analyze NASA planetary image data. Current active NASA planetary spacecraft instrument teams are using Integrated Software for Imagers and Spectrometers (ISIS) to support ground data processing (GDP) operations. Instrument team and mission scientists use ISIS for analysis and research conducted during the active mission to provide insights and guidance that influence mission planning. With support for over fifty NASA and ESA instruments, scientists routinely integrate current and past data in their research activities. ISIS has proven to be a valuable asset for NASA scientists for systematic data processing, planning, research and analysis operations for active and past missions.

Missions	Instruments	Sensor/Camera Type
Mars Express*	(1) HRSC	Pushbroom
Mars Odyssey*	(2) THEMIS IR, THEMIS VIS	Pushbroom, Pushframe
Mars Global Surveyor	(3) NAC, WAC-R, WAC-B	Pushbroom, Pushbroom, Pushbroom
Mars Reconnaissance Orbiter*	(4) HiRISE, CTX, CRISM, MARCI	Pushbroom, Pushbroom, Pushbroom Spectrometer, Pushframe
Viking Orbiter 1 & 2	(4) VIS A&B	Frame (vidicon)
Cassini*	(3) ISS WAC, ISS NAC, VIMS	Frame, Frame, Point Spectrometer
Galileo	(1) SSI	Frame
Voyager 1 & 2	(4) ISS NAC, ISS WAC	Frame (vidicon), Frame (vidicon)
Apollo 15, 16, 17	(6) Metric, Panoramic	Frame (film), Pushbroom (film)
Clementine	(4) UVVIS, NIR, LWIR, HIRES	Frame, Frame, Frame, Frame
Chandrayaan-1	(1) Mini-SAR	Radar
Lunar Orbiter 3, 4, 5	(6) HR, MR	Frame (film), Frame (film)
Lunar Reconnaissance Orbiter*	(4) NAC-L, NAC-R, WAC, MiniRF	Pushbroom, Pushbroom, Pushframe, Radar
Kaguya	(2) MI VIS, MI NIR	Pushbroom, Pushbroom
Mariner 10	(2) TPE A&B	Frame (vidicon)
MESSENGER*	(2) MDIS NAC & WAC	Frame, Frame
Dawn*	(3) FC1, FC2, VIR	Frame, Frame, Pushbroom Spectrometer

Table 1. This table shows the variety of instruments currently supported by ISIS3. Missions with an asterisk indicate they are currently active (7 total).

Discussion

With fifty years of involvement in NASA planetary missions, Astrogeology Science Center (ASC) planetary scientists, cartographers and computer scientists have applied their combined experience and expertise in developing software systems and applications to support space exploration mission activities. ISIS3, written in C++, employs a plugin architecture that allows rapid and efficient development of instrument camera models. Camera models provide fundamental geometric capabilities enabling highly precise cartographic mapping capabilities. Table 1 shows the current list of supported camera models in ISIS3 including those that are still actively collecting data.

In addition to the instrument camera model, there are only a few software application/components required to support ingestion of raw instrument data products (usually PDS EDRs), radiometric calibration (optional) and application spacecraft attitude and pointing ephemerides (SPICE). Once these minimal requirements are met, ISIS3 provides over 300 applications that support increasing specialization in processing techniques and procedures.

Figure 1 shows the GDP systems for three current NASA missions. The HiRISE mission was one of the first to adopt ISIS3 as its primary cartographic GDP system. The LROC and MESSENGER missions are also using ISIS3 in their GDP. Each of these collaborations has proved mutually beneficial to help keep mission costs lower and improve ISIS3 functionality.

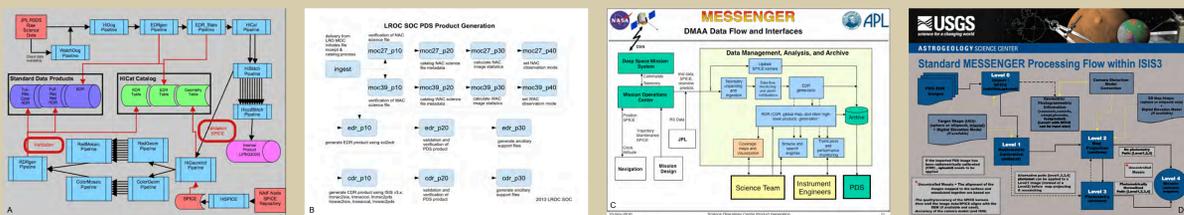


Figure 1. These charts show the data flow pipelines for the GDPs of the HiRISE (A), LROC (B) and MESSENGER (C) missions. Figure 1.D shows standard ISIS3 processing flow for individual MESSENGER PDS EDR products.

Results

Figure 2 shows a very recently completed global map of the lunar surface produced by the LROC team using ISIS3. The LROC and USGS teams have worked together to create a very sophisticated and highly precise camera model of the LROC WAC instrument. What makes this product unique is that the mosaic, comprised of thousands of small images acquired over the course of ~20 months, is *uncontrolled*. Results of this quality from data that is not subjected to labor intensive photogrammetric control processes, which are also available in ISIS3, are not common and typically require a great deal of hard work and dedication in all aspects affecting cartographic accuracy.

Figure 3 provides an illustration of an inherent ISIS3 feature – data fusion. This product combines earth-based Arecibo Observatory radar data of Mercury's North Pole and recent MESSENGER WAC and NAC images into a single cartographic map product. This is made possible in ISIS3 with its ability to accurately produce high level cartographic products originating from different data sets. This ISIS3 feature provides research and mission scientists the opportunity to conduct analysis with datasets from multiple instruments on the same spacecraft, from past missions and other sources.

Conclusion

ISIS3 continues to provide a highly sophisticated and comprehensive cartographic image processing system capable of support for integration and analysis of NASA mission data. Its powerful yet flexible processing capabilities create a suitable framework to develop ground data processing systems for spacecraft instrument packages. With these components in place, research and analysis is conducted in a consistent image data processing environment at reduced costs and greater adaptability.



Figure 2. This seamless mosaic of Normalized Reflectance at 643 nm wavelength of the lunar surface was produced from thousands of images obtained by Lunar Reconnaissance Orbiter Camera Wide Angle Camera (LROC WAC) over the course of ~20 months of operation. Each image was processed and projected orthorectified onto the WAC GLD100 digital elevation model (DEM) to this Orthographic view at 500 meters/pixel using ISIS3.

Image Credit: NASA/GSFC/Arizona State University

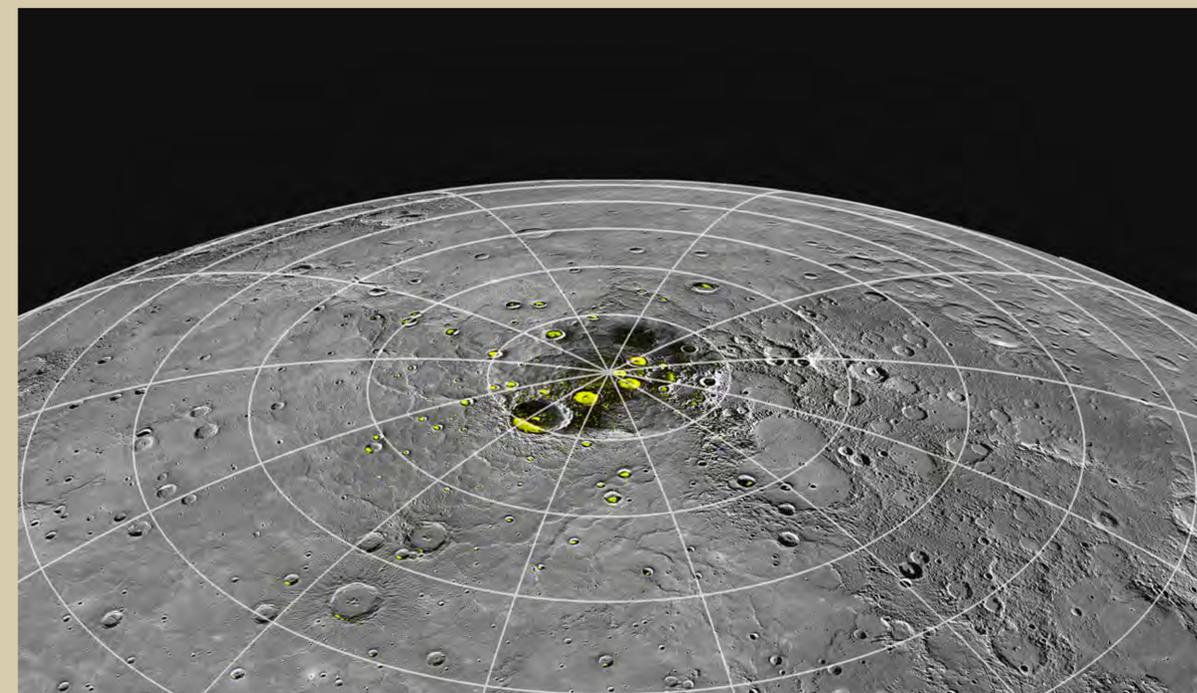


Figure 3. This composite image mosaic, prepared using ISIS3, demonstrates data fusion capabilities within ISIS3. This image was part of a NASA MESSENGER press conference on November 29, 2012 (http://messenger.jhuapl.edu/news_room/presscon12.html), detailing radar bright areas of Mercury's North Pole.

Image Credit: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institute of Washington