
**Introduction:** ISIS (Integrated Software for Image and Spectrometers) is developed and maintained by the U.S. Geological Survey Astrogeology Science Center (ASC) for the cartographic and scientific analysis of planetary image data [1]. The rigorous photogrammetric and radargrammetric control of planetary images is a fundamental capability of ISIS. The control process and its underlying algorithms are inherently complicated and require a reasonable amount of user understanding. In ISIS, particularly for the non-expert user, the complexity is exacerbated because more than twenty standalone applications are required for the creation, editing, adjustment, analysis, and visualization of a control network (Figure 1). The control network is the ISIS data structure that stores image measurements, corresponding ground point coordinates, and additional associated metadata.

![Figure 1: ISIS workflows to create image-to-image (left) and image-to-ground (right) control networks. Each colored box represents a standalone ISIS application.](image1.png)


- “There is a growing need for end-to-end systems. System integration rather than the development of special solutions will become very important in the future.”
- “There is a need from the image understanding community for easy-to-use photogrammetric ‘black boxes’. Along these lines, computer vision and photogrammetry are increasingly working together.”

The notable progress achieved toward these goals in the field of close-range, industrial photogrammetry demonstrates that rigorous, yet user-friendly digital photogrammetric processes can be incorporated into a computational scheme capable of generating quality products while at the same time supporting wider application by non-specialist users [3,4]. This can be accomplished in the processing of planetary images as well.

The ASC is developing in ISIS a fully interactive user interface integrating all aspects of the control process within a single environment. This facilitates a seamless, efficient, more intuitive, and more automated approach to photogrammetric and radargrammetric control. By simplifying data management, implementing rigorous algorithms; providing statistical and graphical data analysis tools; and automating processes and analysis when possible, we reduce effort spent troubleshooting. This makes the process more cost-effective and improves the quality of mapping products. We have creatively named this interface the Integrated Photogrammetric Control Environment (IPCE).

**Photogrammetric and Radargrammetric Control:** The quality of mapping products such as digital image mosaics (DIMs) and digital elevation models (DEMs) -and the geologic maps that use such products as basemaps- depends greatly upon the accurate determination of image position and pointing parameters. Initial estimates for these parameters typically come from spacecraft tracking and attitude data. Some level of uncertainty in these data is unavoidable and will propagate to errors in the final product (Figure 2).

To minimize errors, images are controlled photogrammetrically. Overlapping images are registered to one another through the measurement of common features known as tie points. Images may also be linked to

![Figure 2: Uncontrolled (left) and controlled (right) mosaics of LRO Mini-RF radar images of the 20 km crater Hermite A (87.94°N, 308.98°E), showing the improvement in registration from >3 km to <30 m pixel scale (adapted from [5]).](image2.png)
the ground by identifying corresponding features between them and existing base maps and/or DEMs; human artifacts with otherwise known coordinates such as landers, rovers, or retroreflectors; or locations determined from laser or radar altimetry. These features are called control points. Image measurements then serve as input to the least-squares bundle adjustment [6] which generates improved image position and pointing parameters and the triangulated ground coordinates of tie and control points. The ISIS bundle adjustment module is called jigsaw [7].

**A Single Control Environment:** Slightly more than one year into our 4-year project, we are showing significant progress in the design and implementation of IPCE (Figure 3). As much work remains however, it is not yet available in the public version of ISIS.

Data management is simplified via a project-based approach with the ability to save and restore data and settings. Ongoing efforts are focused on incorporating existing ISIS tools and displays, emphasizing the inter-communication between them. To give but one example, the seemingly mundane (but currently time-consuming) tasks of manually creating, deleting, or editing tie or control points have been greatly streamlined. Changes to a point are immediately reflected in any display showing the point.

A more flexible and intuitive bundle adjustment interface is now in IPCE. Any number of adjustments may be performed with all results saved and available for analysis and comparison (including a graphical representation of the parameter correlation matrix). Images from multiple sensors may now be rigorously adjusted together.

Future work includes improved automated image measurement and matching (e.g. [8]); additional analysis and visualization tools; bundle adjustment improvements such as threading and solving for target body parameters (e.g. pole position, spin offset/rate, and mean radius); and the ability to write updated NAIF (Navigation and Ancillary Information Facility [9]) format image position and pointing kernels.

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**References:**


Figure 3: IPCE interface screen capture showing (from left to right) (a) project tree, (b) images, (c) footprints (with ground points overlaid), and (d) control point editor views. We emphasize that this single interface encompasses functionality of the many standalone applications currently required for photogrammetric and radargrammetric control in ISIS shown in Figure 1.