THE USER EXPERIENCE: DEVELOPING AN INTEGRATED PHOTOGRAMMETRIC CONTROL ENVIRONMENT (IPCE) FOR PLANETARY MAPPING. Kenneth L. Edmundson[1], B.A. Archinal[1], J.C. Backer[1], J.M. Barrett[2], K.J. Becker[1], T.L. Becker[1], J.P. Bonn[1], D.A. Cook[1], M.A. Hahn[1], I.R. Humphrey[1], S. Lambright[3], E.M. Lee[2], J.A. Mapel[1], K.A. Oyama[4], A.C. Paquette[1], M.R. Shepherd[1], S.C. Sides[1], T.L. Sucharski[1], and L.A. Weller[1], [1]Astrogeology Science Center, U.S. Geological Survey, Flagstaff, AZ, USA, 86001, (kedmundson@usgs.gov), [2]USGS Retired, [3]Tableau, Seattle, WA, USA, 98103, [4]Naval Surface Warfare Center, Port Hueneme, CA, USA, 93043

Introduction: The photogrammetric control process consists of two basic steps: image measurement of tie and control points followed by the least-squares bundle adjustment (BA). The BA improves image position and pointing parameters and generates the triangulated ground coordinates of tie and control points [1]. The accurate determination of image position and pointing is essential to create mapping products such as digital image mosaics (DIMs) and digital elevation models (DEMs).

Describing the control process in two steps is a gross oversimplification. In practice one measures images; bundle adjusts; analyzes results; fixes errors; adds/removes images, image measurements, or ground points; fine-tunes settings; re-measures; re-adjusts; and repeats as necessary. The workflow is complicated and the tasks complex. It is not trivial to produce intuitive, user friendly software for photogrammetric control.

The Integrated Software for Imagers and Spectrometers (ISIS3) is developed and maintained by the U.S. Geological Survey Astrogeology Science Center (ASC) for the cartographic and scientific analysis of planetary image data [2]. The rigorous photogrammetric control of planetary images is fundamental to ISIS3. Many standalone applications are required. Repeatedly opening and closing these applications, storing and re-loading data all the while, can be error-prone, inefficient, and costly.

The User Experience (UX): The ASC is developing in ISIS3 an interface offering a seamless, efficient, more intuitive, and cost-effective approach to the photogrammetric process by integrating all aspects of the process into a single environment [3]. It is called the *Integrated Photogrammetric Control Environment* (IPCE). The risk of user error is reduced through simplified data management and the ability to interact with multiple, integrated windows into the data and processing results (Figure 1).

The ISIS3 Bundle Adjustment: The ISIS3 BA runs both in IPCE and as a standalone application called *jigsaw* [4]. A number of improvements to the BA have recently been implemented. Images from different sensor types can be adjusted together and images can be weighted differently. The BA runs in a separate thread from the IPCE GUI, allowing the user to continue working during the run. We can now solve for target body parameters (e.g. pole position, spin rate, radii) and have published preliminary results ob-

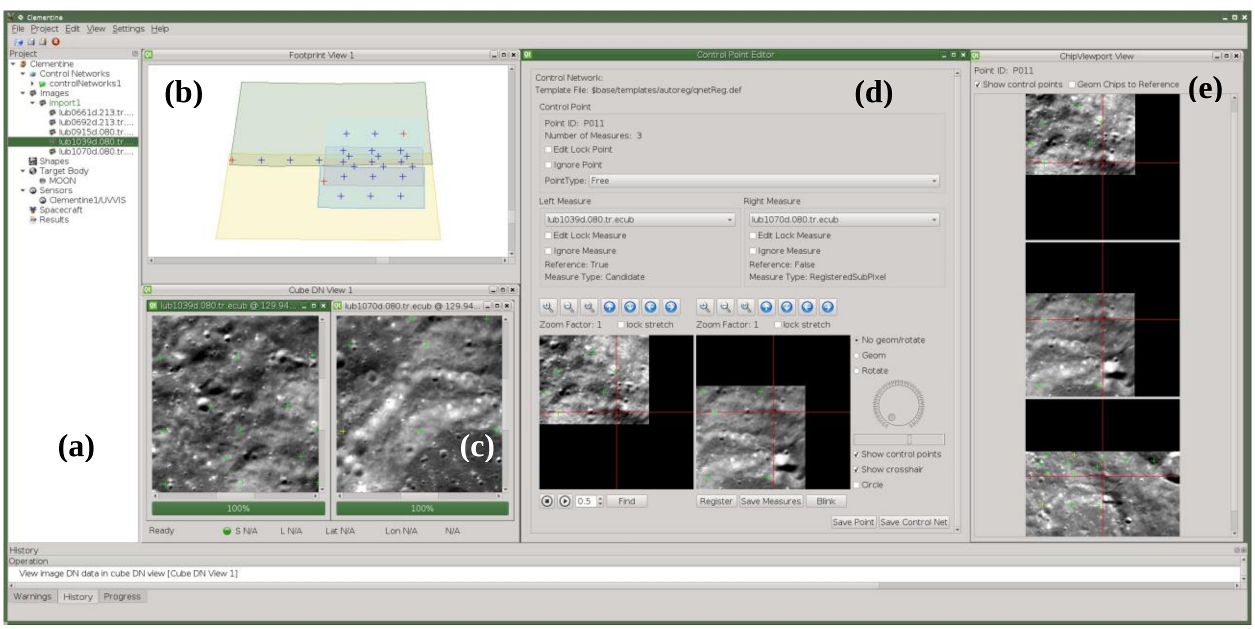

Figure 1: IPCE interface screen capture showing (a) *project tree*, (b) *footprints* (with tie and ground control points overlaid), (c) *image display*, (d) *control point editor*, and (e) *image measurement thumbnails*.

tained in processing a global network of Enceladus consisting of Cassini ISS images [5].

We are implementing piecewise polynomials in ISIS3 and the BA to represent the position and attitude of images from time dependent sensors (e.g. line scanners, radar). Currently position and attitude are modeled as single polynomial functions of time. Low-order polynomials cannot accurately represent complex spacecraft motions induced by, e.g., thruster firings, operation of other instruments, or anomalous events. Modeling such motion requires high-order polynomials, but these can cause instability in the BA. A piecewise polynomial model in which the image is divided into segments, each with a low-order polynomial, offers a better approach (Figure 2) [6].

Future Work: General plans include incorporating improved automated image measurement and matching methods into IPCE (e.g. [8]); adding further analysis and visualization; and adding the ability to write updated NAIF (Navigation and Ancillary Information Facility [9]) format image position and pointing kernels. BA plans include sensor self-calibration, free network adjustment, imposition of conditions between sensor parameters, variance component estimation, improved outlier detection, sequential estimation, and solving for target body libration. We plan to implement the rigorous adjustment of laser altimeter (LA) and image data within the BA (e.g. [10]). This will make possible the generation of improved sensor models, image position and pointing information, and LA data sets. It enables production of higher quality digital terrain models that will facilitate landing site mapping, providing a greater margin of safety for surface operations on manned and robotic missions.

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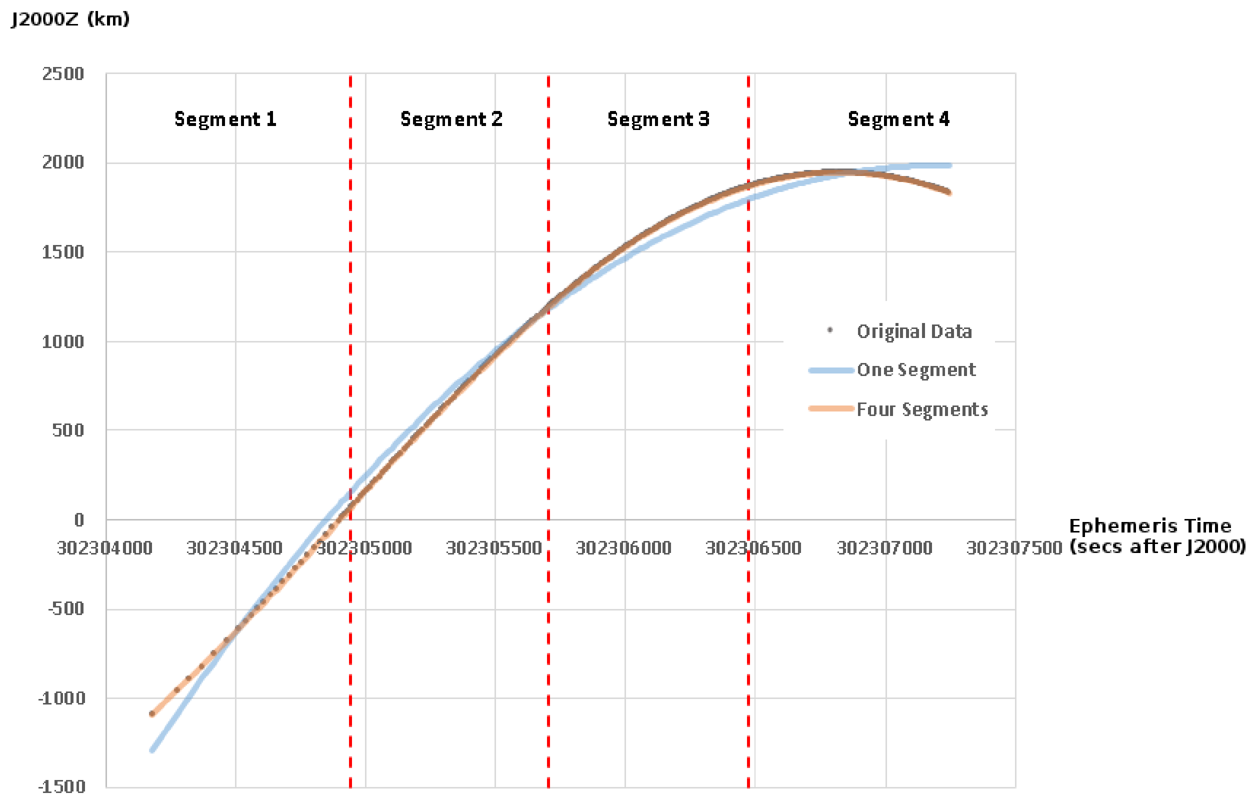

Figure 2: Lunar mean Earth/polar axis system Z-coordinate of spacecraft position for Chandrayan-1 M^3 image M3G20090731T092152 [7]. This image has 30,154 lines and extends from latitude ~56°S to ~87°N, crossing the 0°/360° longitude boundary near the pole. The blue curve is a single quadratic polynomial. The brown curve is piecewise continuous with four segments. Each segment is a quadratic polynomial. Continuity constraints are imposed at segment boundaries. The RMS errors of fit are ~91 km and ~2.8 km for the single and piecewise continuous curves respectively. These fits were performed after BA.