PROGRESS IN IMPROVEMENT OF GEODETIC CONTROL AND PRODUCTION OF FINAL IMAGE MOSAICS FOR CALLISTO AND GANYMEDE.

T. Becker[1], T. Rosanova[1], D. Cook[1], M. Davies[2], T. Colvin[2], C. Acton[3], N. Bachman[3], R. Kirk[1], and L. Gaddis[1], [1]USGS, Astrogeology Program, Flagstaff, AZ (tbecker@flagmail.wr.usgs.gov); [2]RAND, Santa Monica, CA; [3]JPL, Pasadena, CA.

Introduction: The Astrogeology Team of the U.S. Geological Survey and RAND are continuing to provide cartographic and image processing support for the Galileo Mission and the NASA science community. This report summarizes our recent efforts toward improved geodetic solutions for the Galilean moons Callisto and Ganymede. USGS uses ISIS (Integrated Software for Imagers and Spectrometers) [1], [2], [3] software and the updated geodetic information to generate digital map mosaics containing the best coverage of Voyager I, Voyager II, and Galileo SSI data.

Background: Following the Voyager flybys of Jupiter in 1979, control networks of the four Galilean satellites were computed at RAND [4]. This involved selecting control points on images, making pixel measurements of their locations, using reseau locations to correct measurements for geometric distortions, and converting the measurements to millimeters in the focal plane. These data are combined with the camera focal lengths and navigation solutions as input to a photogrammetric triangulation program to solve for the best-fit sphere, the coordinates of the control points, and the three orientation angles of the camera at each exposure (right ascension, declination, and twist). These data were then furnished to USGS and maps were produced [e.g., 5].

After the original release, RAND continued to improve the control networks. In preparation for the Galileo encounters, Voyager-only global digital maps of all four Galilean satellites were prepared using available geodetic data and released by USGS in 1995-1996 [7]. Although the best available data were used, it was recognized that the control had limitations due to data gaps, low spatial resolution coverage in large regions, limited overlap between some images, and inherent problems with the Voyager vidicon imaging system (i.e., geometric camera distortions). The Galileo SSI experiment, imaging with a fixed-raster, charge-couple device (CCD) sensor with a higher signal-to-noise ratio than the Voyager vidicon provided an excellent opportunity to acquire higher quality data with greater geometric stability and more complete coverage. As SSI data have become available since 1995, RAND has continued to incorporate additional images and control points to improve global control [6].

Evaluation of Input Parameters: With the most complete Galileo datasets in-hand for Callisto and Ganymede, improvement in control and final production of refined, global digital base maps could proceed. To establish consistency between RAND, USGS, and NAIF (Navigation Ancillary Information Facility) on input data, several key aspects of the data and software were examined. These activities benefit processing and analyses of Galileo, Voyager, Cassini and Viking data. Specifically, we reviewed time tags, spacecraft vectors, planet constants (rotation axes, prime meridian), focal lengths, spacecraft trajectories, ephemeris values, reseaus, and distortion correction routines. In a coordinated effort, RAND, NAIF and USGS examined and compared the input data and made adjustments where necessary. The following items were confirmed and validated:

1) Voyager data time stamp. It was determined that the Flight Data Subsystem (FDS) count retrieved from the Greenwich Mean Time (GMT) fields in the Supplementary Experimental Data Record (SEDR) supplied by JPL is the most accurate time stamp for the Voyager data. This was confirmed by Voyager team members Candy Hanson and Andy Collins.

2) Time system conversions. The accuracy of USGS software using NAIF routines for time system conversions was examined. To conform to the NAIF kernel time unit, a conversion is required from the Coordinated Universal Time (UTC) calendar system to Ephemeris Time (ET) seconds past J2000. For transfer of data to RAND, the UTC time units are converted to ET Julian date format.

3) Camera parameters. Modifications to ISIS were made to adjust the Voyager shutter close-times to shutter center-time to improve accuracy and to be consistent with Galileo SSI parameters.

Control Point Networks: With confirmed input parameters for data processing, an intensive effort was begun to establish the best control point network using combined Voyager I and II and Galileo SSI data to maximize coverage at moderate resolution. USGS selected images on the basis of resolution, coverage, filter and image quality. Images were eliminated from the USGS data set if they exceeded 10 km/pixel resolution, were redundant in coverage, and/or had extreme viewing and sun angles. Control points were then selected manually between all overlapping images. In Voyager data, points were not selected in the frame corners to minimize camera distortion effects. Areas of limb coverage were avoided to minimize viewing angle distortion. Very high resolution images (greater than 0.5 kilometers/pixel) were eliminated because their limited spatial coverage would not substantially improve the global geodetic solution.

Although it was thought that summation-mode images could not be included because of loss of resolution due to compression [7], a quantitative comparison by one of us (Kirk) of their image quality versus a full-frame image from the same sequence indicated that resolution was not substantially degraded by summation (beyond the factor of 2, which would be expected). This process involved comparing the autocovariance curves of a full-frame and a summation frame with and without magnification. The size of the smallest features resolved in each image could be identified by the location of a band in the autocovariance curves. The relative resolutions of the images were also compared by blurring the full-frame image with Gaussian filters of various sizes and then computing its correlation with magnified versions of both the summation frame and the full-frame 2x2 averaged on the ground. RAND currently includes the summation frames in their triangulation calculations. Including the summation frames in the control network increases the SSI coverage, which improves the ratio of SSI frames to Voyager frames and increases their influence on the geometric control. Comparison of the autocovariances of Voyager and SSI images of the same regions also showed that the effective resolution of the latter is about a factor of 1.6 better at the same pixel scale. Because of this, and because of the need to correct Voyager camera distortions based on reseau measurements, SSI images are greatly preferred even at the same nominal pixel scale and are given more weight (by a factor of 2) than Voyager images in geodetic calculations.

As a result of these efforts, USGS supplied RAND with a complete network of control points for Callisto and Ganymede. These new data supplement the existing RAND control network. Although SSI coverage is complete for Callisto, it was recognized that an additional SSI frame of Ganymede could further improve the control for that satellite. After careful deliberation, the Galileo SSI team plans an additional medium-low resolution frame of Ganymede to be collected during the C20 encounter. This image will complete the SSI global coverage for Ganymede along the equatorial region, giving RAND the opportunity to perform a triangulation using global coverage based on SSI data alone.

Preparation of global digital mosaics: The final global digital mosaics of Callisto and Ganymede are prepared as follows. The images are radiometrically calibrated, photometrically normalized applying the Lunar-Lambert function with values that have been derived from empirical fits to Hapke functions [8], and corrected for anomalies and blemishes. Geometric control for each image is applied as they are projected to a sinusoidal map projection in ISIS. Three mosaics are generated at high (0.5 – 2 km/px), medium (3 – 9 km/px), and low resolution (> 10 km/px). These separate mosaics are then digitally rescaled and merged to one final mosaic. High resolution takes precedence in overlapping areas.

For a comparison base for the new solution, we measured areas of misregistration within the separate Voyager-only Callisto resolution mosaics generated in 1996 by comparing coordinates of features in overlapping areas. We further measured the coordinates of the same features on the published I-Maps [5]. An example of an offset discovered using this method (holding the medium-resolution mosaic as reference) is near Asgard, where Voyager I and Voyager II overlap with one another. Misregistrations in this area are ~7 to 8 km in the digital mosaics and up to ~44 km in the I-map (Table 1). The offsets in Table 1 vary in latitude and longitude direction.

Table 1. Historic Voyager-only offsets.

Nearest Named Feature or Region	Lat Range In Degrees	Lon Range In Degrees	I-Map Series offset Km Lat. Lon.	1996 Low Res. Mosaic offset Km Lat. Lon.	1996 Hi Res. Mosaic offset Km Lat. Lon.	1996 Med Res. Mosaic offset Km Lat. Lon.
HOGNI	-10~-20	10~20	15.9 4.6	18.0 13.0	15.9 3.8	****
VALHALLA	10~20	50~60	10.9 2.1	0.8 7.6	3.4 7.2	****
NJORD	10~20	120~130	0.4 5.9	12.6 34.0	****	N/A
ASGARD*	30~35	140~150	44.1 5.0	8.0 6.7	N/A	****
BRAN	-20~-30	200~210	12.2 8.0	2.9 4.6	N/A	****
IGALUK	0~10	310~320	13.0 12.1	8.0 11.8	N/A	****
TINDR	0~-10	350~360	9.6 7.6	2.1 8.4	2.1 2.5	****

****** = Medium resolution held as reference.**

References: [1] Torson, J. and K. Becker (1997), *LPS XXVIII*, 1443. [2] Eliason, E. (1997), *LPS XXVIII*, 331. [3] Gaddis et al. (1997), *LPS XXVIII*, 387. [4] Davies and Katayama, (1981), *JGR*, 8635. [5] *USGS I-1888, I-2069, I-2073, I-2074, I-2075, I-2076*, 1:5M, (1990). [6] Davies, M, et al. (1998), *Icarus*, v. 135, 372. [7] Becker, T. et al., *LPS XXIX*, 1892. [8] McEwen, A.S., (1991), *Icarus*, v. 92, 298.