Initial Global Control Network and Mosaicking Of ISS Images Of Titan

Brent Archinal, Tammy Becker, Ella Lee, and Ken Edmundson, Astrogeology Science Center, U. S. Geological Survey (2255 N. Gemini Drive, Flagstaff, AZ 86001, USA, barchinal@usgs.gov)

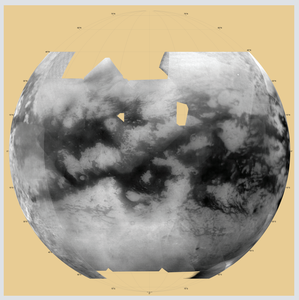


Figure 1: Initial near-global controlled ISS mosaic of Titan, orthographic projection of the Saturn facing hemisphere. For details, see the text and Figure 3 caption.

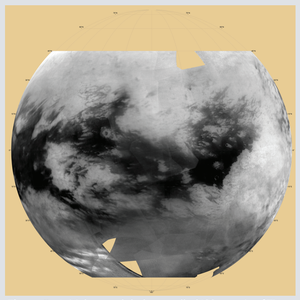


Figure 2: Initial near-global controlled ISS mosaic of Titan, orthographic projection of the "far side" hemisphere. For details, see the text and Figure 3 caption. Clouds (white streaks) are visible at lower left.

Figure 3 (below): Initial (near-global, complete longitude coverage) controlled ISS mosaic of Titan, Equirectangular projection, covering +45° to -65° latitude and longitude from 360° to 0° W (left to right). North is up and east is to the right. This mosaic is generated from averaged images, which would not be possible at such resolution had the images not been controlled. Images are included from Titan flybys and Cassini Saturn orbits: S08, S15, S17, S18, S25, S27, S28, S29, S30, S31 (T32/T33), S32, S34, S38, S39, S43, S49, S50, S51, S55, and S56. While waiting for additional funding opportunities, not all available data has been used, resulting in some holes and lower resolution areas. For the same reason, no cosmetic improvements (filtering, sharpening, etc.) have been attempted. This version, printed at 180 dpi, is shown at 19x lower resolution than the full resolution controlled mosaic, which was produced at 350 m/pixel. Map scale (at the equator) is ~1:16.8M. Clouds (white streaks) are visible at lower left center.

Introduction: The Cassini mission has returned an abundance of data about the surface of Titan. To maximize the science return from these data and to assist with planning for Cassini and future missions, we have begun the process of rigorously registering images and ancillary data from Cassini's ISS and RADAR instruments into a single, consistent, precise global Titan reference frame and have created the first controlled near global (all longitudes, +45° to -65° latitude) ISS mosaic of Titan (Figures 1 to 3). This has been done via a controlled, photogrammetric least squares bundle adjustment.

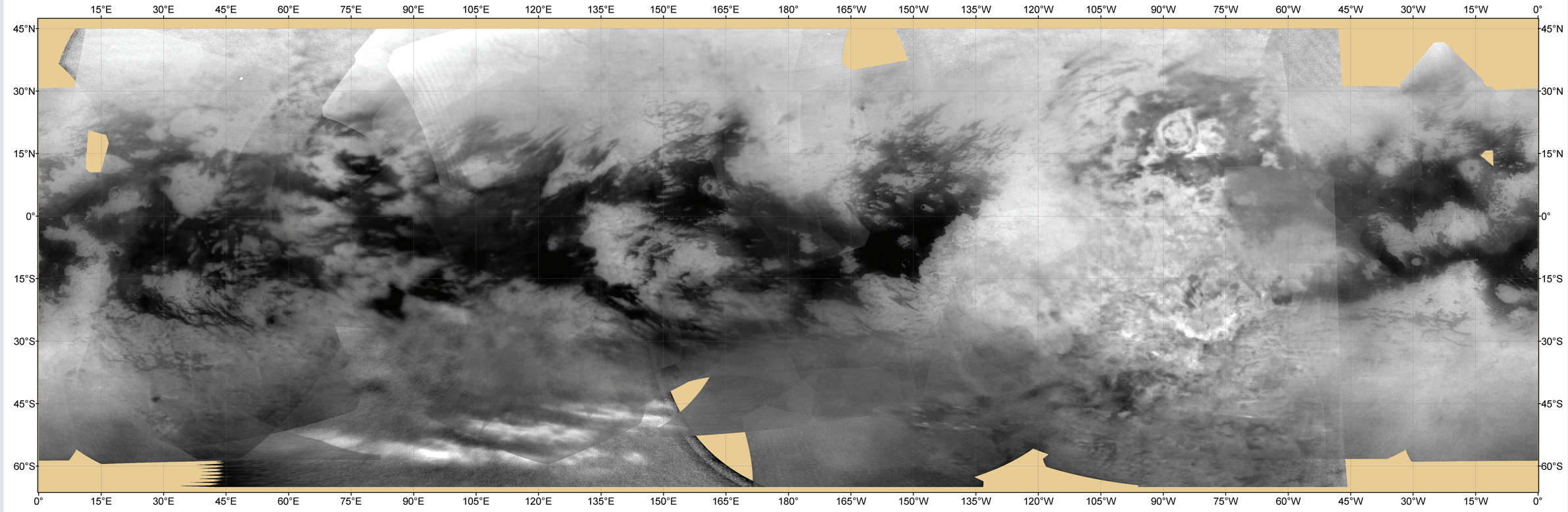
Methods: ISS images (938 nm and MT1 filters) have been chosen based on those used for existing uncontrolled mosaics [1]. Processing is done with ISIS3 [2]. Images are radiometrically calibrated (cisscal), surface features enhanced using MT1 images (Figure 4) [1], and image tie points seeded and measured (pointreg) (Figure 5). Manual tie points are measured between ISS and RADAR images, since RADAR images currently have higher resolution and (likely) accuracy, given they are unaffected by spacecraft pointing errors. Bundle adjustment solutions are then done (*jigsaw*) [3] using fixed locations for the RADAR points, and solving for lat/long of other points as well as spacecraft orientation and position. A spherical model with radius 2575 km is used for Titan's shape and an updated RADAR derived model for orientation [4]. Improvements have been made in the preprocessing of images (compared to [1]), e.g., rather than independently registering successive flyby images to each other and updating SPICE only for the "master" image, all images are included in the solution process and are updated.

Intermediate solutions are performed and improved by remeasuring outlier points, flyby by flyby. These already show substantial improvements in the relative positioning of the images, and can also be used to substantially improve the visibility of features by averaging overlapping data (Figure 6). Eventually data from all flybys are combined and overall solutions done. The results of our best global solution so far are shown in Figures 1 to 3 and Table 1. Figures 7 to 9 show the distribution of images and tie points used. Figures 10-13 show various comparisons of all and portions of the mosaic to other products.

Relevance: Geodetically controlling the Titan datasets together enables the intercomparison and analysis of Cassini data and thus directly supports the best and intended use of these data. The creation of coordinate systems, coordinate frames, and controlled mapping products is strongly supported via a number of advisory groups in a variety of contexts [14]. To our knowledge, this is the first publication describing such work for Titan.

Future Work: This controlled network and mosaic can be further improved and additional data added, so it can be used for specialized investigations in the exploration of Titan, including retargeting features for change detection or to acquire higher resolution data. Among many possible uses are the investigation of two key scientific issues: 1) Searching for and documenting changes on Titan's surface, including lake margins [6, 7] and dark and bright surface patterns thought to signal precipitation, drying, and evaporite formation [8-11]; and 2) Solving for pole position, spin rate and changes in spin rate to constrain Titan's internal structure and lay a foundation to document evidence of an internal ocean [12-14]. The current results and any future processing will also facilitate investigations on: a) the global shape of Titan; b) surface albedo changes; c) determining or setting limits on the size of topographic features; d) improving the efficiency of image targeting; e) improving the registration of any co-acquired VIMS images; and f) improving photometric correction of ISS and VIMS images.

We are seeking funding to continue to expand this network, by including ISS and RADAR images from all relevant flybys, and in particular extending coverage to higher latitudes. Further improvements can also be made to improve the efficiency of processing and to optimize the statistical weighting of parameters to produce the most accurate geodetic solutions. The resulting image mosaics will contribute fundamentally to many of the important science investigations noted above. The RADAR-ISS control network and associated mosaics will provide a solid reference frame for the current Cassini mission and future exploration of Titan.



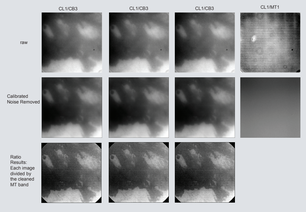


Figure 4: Calibration steps. Row 1 shows the raw images used; Row 2 shows the images after radiometric calibration (with noise removed); Row 3 shows the results of ratioing the three image with the cleaned MT band image.

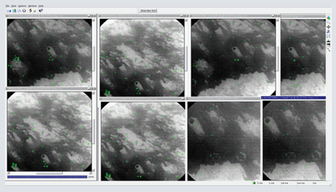


Figure 5: Tie-pointing example. Snapshot of the ISIS 3 control point network tool, *qnet*, with multiple overlapping T8 images displayed. Green plus marks are locations of multiple shared tie point measurements.

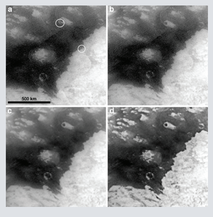


Figure 6: Example of improvements from control and filtering. a) Uncontrolled mosaic, with mis-registered images (offsets circled); b) Controlled mosaic with the best images on top; c) Controlled mosaic with image averaging, and; d) High pass filtered version of the latter. From S15 (T8) flyby, showing the boundary between the dune field Shangri-La (dark) and Xanadu (bright).

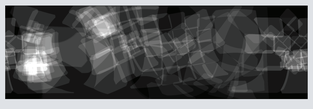


Figure 7: Titan Image-Sum band mosaic, for the average mosaic computation. Minimum of 3 (or 0) images (dark) to a maximum of 53 (bright).

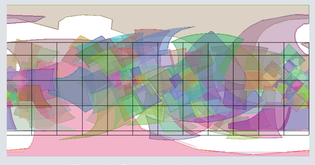


Figure 8: Footprints of all images (702) included in global network. Grid outline shows output mosaic [lat=65°S to 45°N; lon=0° to 360°].

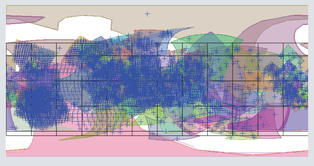


Figure 9: Footprints & Control Points of all images included in global network. Grid output as in Figure 8. Ground Points tied to RADAR are shown in bright green ("+").

Table 1: Control Network Solution Statistics

Number images	702
Number flybys	21 (full and partial)
Number points	7848
Number fixed points	50 (to RADAR positions)
Number measures (X&Y)	48542
Global solution RMS	1.25 pixels
Mean square positional error	1.6 km (on points)
Maximum residual	16.5 pixels

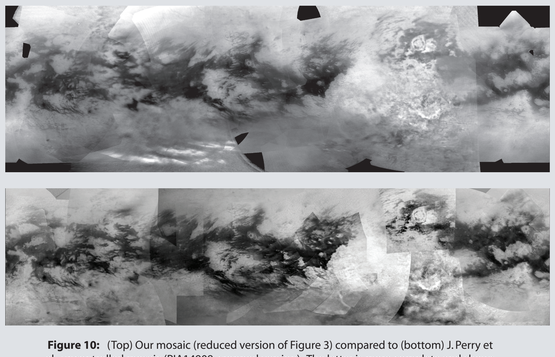


Figure 10: (Top) Our mosaic (reduced version of Figure 3) compared to (bottom) J. Perry et al. uncontrolled mosaic (PIA14908, cropped version). The latter is more complete and shows more detail in some areas and includes the poles (not included here), while the former shows more detail in other areas and less obvious seams due to the image averaging.

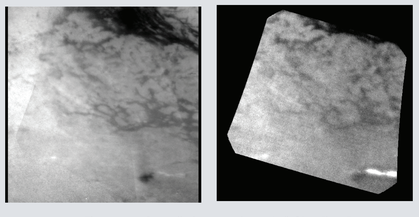


Figure 11: Controlled averaged mosaic (left) vs. "best" image (right, N1563524438 (S32)) example (2/2). Examples are from an area east of Tseghi.

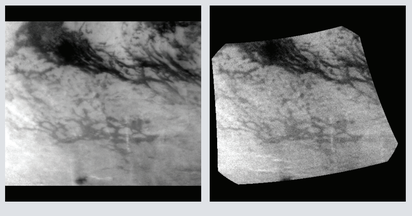


Figure 12: Controlled averaged mosaic (left) vs. "best" image (right, N1624422569 (S51)) example (2/2).

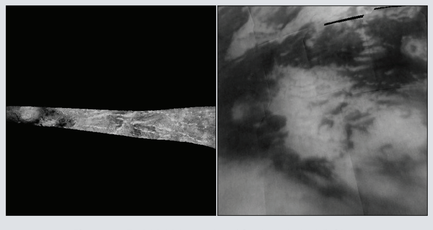


Figure 13: T8 RADAR image (used for tie-pointing) (left) vs. controlled averaged mosaic (right).

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References: [1] Perry et al. (2005) *LPS* XXXVI, #2312; J. Perry, per. comm. [2] Anderson et al. (2004) *LPS* XXXV, #2039. [3] Edmundson et al. (2012) I*SPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci.*, I-4, 203, doi:10.5194/isprsannals-I-4-203-2012. [4] ftp://naif.jpl.nasa.gov/pub/naif/CASSINI/kernels/pck/cpck07Dec2012.tpc. [5] Johnson et al. (2010) http://www.lpi.usra.edu/decadal/sbag/topical_wp/JeffreyRJohnson.pdf; NASA Advisory Council (2007) http://bit.ly/x0HnnM; Archinal et al. (2011) *Cel. Mech. & Dyn. Ast.*, 109, 101. [6] Hayes et al. (2010) *JGR*, 115, E09009. [7] Turtle et al. (2011) *Icarus*, 212, 957. [8] Turtle et al. (2011) *Science*, 331, 1414; (2012) *LPS* XXXXIII, #2555. [9] Lorenz & Turtle (2012) *LPS* XXXXIII, #2472. [10] Barnes et al. (2012) *LPS* XXXXIII, #2762. [11] Vixie et al. (2012) *LPS* XXXXIII, #2766. [12] Stiles et al. (2008) *Astron. J.*, 135, 1669. [13] Lorenz et al. (2008) *Science*, 319, 1649. [14] Bills and Nimmo (2011) *Icarus*, 214, 351.