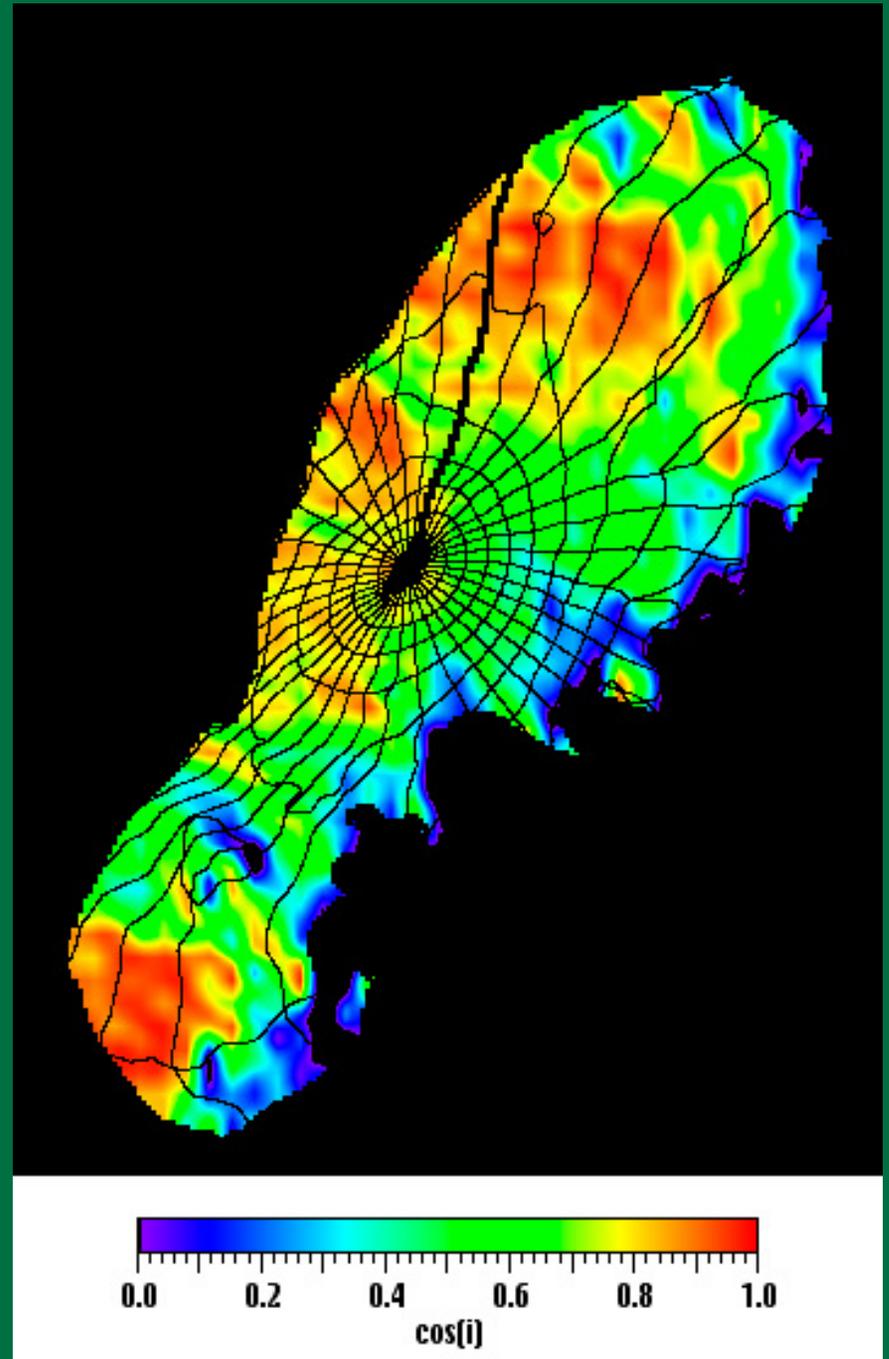


USGS - An Update on Integrated Software for Imagers and Spectrometers (ISIS) as it Applies to Small Bodies and the Need for NASA Cartography Planning

Timothy N. Titus (Chief of Software & Science)
Brent Archinal (Chief of Cartographic Processing)
USGS Astrogeology Science Center

Agenda/Outline

- Motivation
- Capabilities
- Mission Support
- Why use ISIS?
- What is needed to use ISIS.
- Challenges for Small Bodies
- Future Plans
- The Need for Cartography Planning



Motivation for Small Bodies Exploration

Cradle-to-Grave & Beyond

- Part of initial mission planning (e.g. Camera Models)
- Immediate Science Return (from map projected products)
- Data Fusion
- Preserving Data for the Next Generation
 - PDS/Archival

ISIS facilitates the use of:

- SOCET Set
- IDL
- ENVI
- ARCMAP

ISIS Capabilities

- DEM generation from control net generation
- Can help standardize coordinate system.
- Orthorectify images for Mosaic construction
- Band-to-Band Registration for Spectroscopy
- Radiometric Calibration (if you know it)
- Photometric Corrections (if you know it)
- Data Processing Pipeline (THEMIS, HiRISE, LRO, MESSENGER)

Levels of Mission Support for Discovery Class Mission

- Messenger (Platinum - Pipeline)
 - Camera Models
 - Ingestion of Shape Models
 - Additional Software Development
 - Extensive Mission Support
- Dawn @ Vesta (Bronze – Map Projection)
 - Camera Models
 - Ingestion of Shape Models
 - No Radiometric Calibration (within ISIS)
 - No Processing Pipeline (using ISIS)

Other Small Bodies Missions

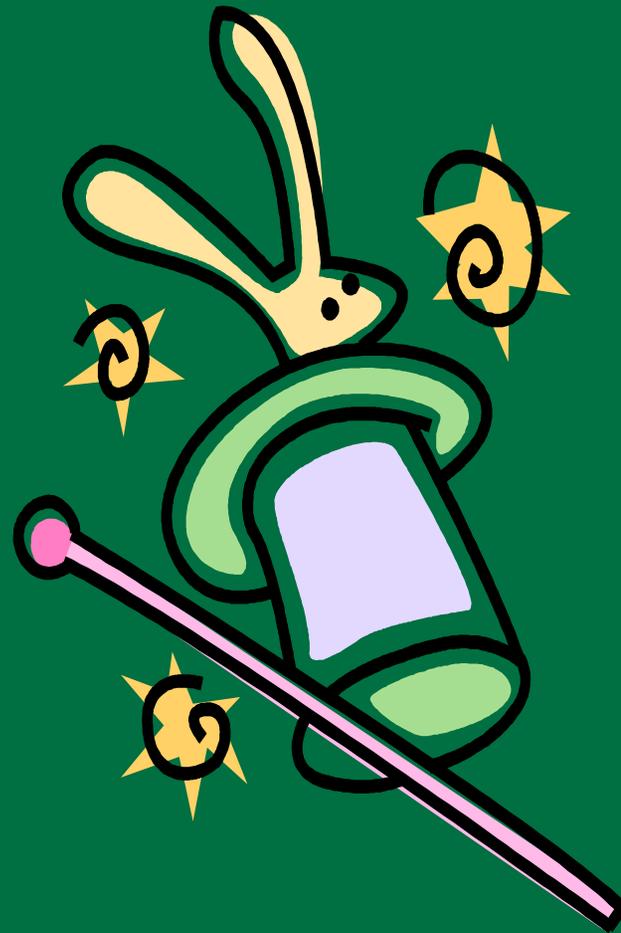
- NEAR – Multispectral Imager (MSI)
- Hayabusa (Funded through PMDAP)
- Rosetta (Funded through PMDAP)
 - OSIRIS
 - VIRTIS
- New Horizons (in negotiations with S/C team)
 - LORRI
 - LEISA
 - Ralph
- OSIRIS-Rex (in discussions with S/C team)

Why use ISIS?

- Mission Pipeline
- Facilitates Data Fusion
- Archival/PDS
- Public & Open Source

What is needed to use ISIS

- Camera Model
- Shape Model
- SPICE (from NAIF)



Challenges of Small Bodies

Asteroids

- Irregular Shapes
- Multivalued DEM
- Possible Changes in Spin States

Comets

- Irregular Shapes
- Multivalued DEM
- Possible Changes in Spin States
- Mapping of Jets

Future Improvements to ISIS

- HST Camera Model Planned to be Added
- ISIS4
 - Why convert to ISIS 4
 - Camera Refactor
 - Enabling New Capabilities
 - Expected Release Date December 2013.
- Improving ISIS requires a strong Foundation of Cartographic Planning.



The Need for NASA Cartography Planning

**Brent Archinal, Tim Titus
and the Astrogeology Science Center
U. S. Geological Survey,
Flagstaff, AZ**

NASA Small Bodies Assessment Group
Marriott Wardman Park Hotel
Washington, D.C.

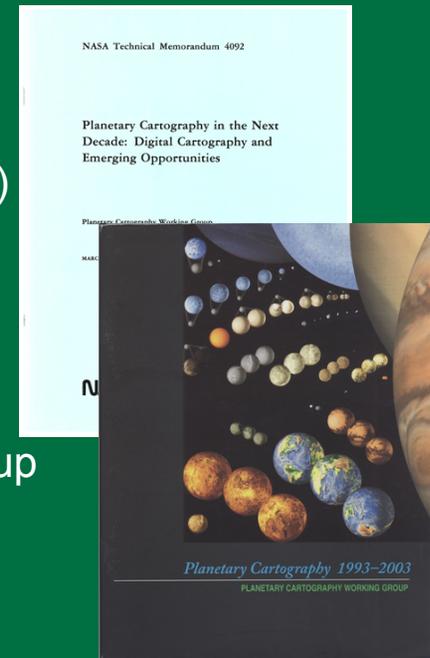
2013 July 10-11

Outline

- Background
- End of the Cartography Working Group (PCGMWG)
- Why continue NASA cartography planning?
 - Algorithms, software, instruments, standards, product development...
- Small body mapping issues
- Other planetary mapping issues
- Recommendations

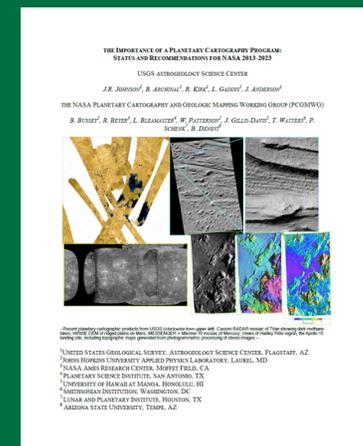
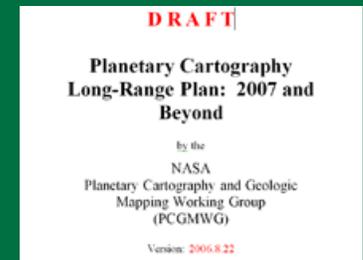
Background

- Global maps & mosaics are an integral part of all planetary missions & instruments, beginning in development stages and continuing through mission operations and data analysis
- Recognizing this, NASA established several committees, working groups, and panels to **plan systematic global data acquisition, data processing and development of cartographic products suitable for planetary exploration**
- From 1974 to 2012:
 - 1974: Lunar Photography and Cartography Committee (LPACC)
 - 1977: Lunar and Planetary Photography and Cartography Committee (LPPACC)
 - 1979: Planetary Cartography Working Group (PCWG)
 - Produced two 10-year plans and supplement (e.g. as at right =>)
 - 1994: Planetary Cartography & Geologic Mapping Working Group (PCGMWG)
 - Included the chair of the NASA Geologic Mapping Subcommittee (GeMS)



End of the PCGMWG

- From 1994 to 2012, PCGMWG made cartography recommendations to NASA
 - Drafted 10 year cartography plan in 2006 =>
 - Main recommendations briefed to NASA PSD >> “wait for Decadal Survey”
- Submitted white paper on cartography to NRC Decadal Survey =>
 - http://www.lpi.usra.edu/decadal/sbag/topical_wp/JeffreyRJohnson.pdf
- Due to FACA issues, the PCGMWG **ceased making cartography recommendations in 2012**
 - Still reviews USGS PG&G Cartography proposal



Why Continue Cartography Planning?

- A wide variety of groups & individuals have pointed to the necessity for planetary cartography planning and development
 - USGS Astrogeology
 - Individual NAC PSS members
 - NAC 2007 recommendation to control all lunar datasets
 - PGCMWG last recommendations
 - IAU WGCCRE, geodetic control recommendations
 - NRC Decadal Survey respondents
 - NASA Ames IRG, small body mapping
 - Various PDS personnel
 - Various NASA HQ personnel

Cartographic Issues Especially Urgent for SBAG

- Technical issues of small body mapping require substantial development
 - “state of the art” of mapping small bodies is uncertain and currently poorly developed
 - Cf. Ames white paper “Human and Robotic Missions to Small Bodies: Mapping, Planning and Exploration”
 - Cf. previous input to SBAG on Skills and Knowledge gaps (SKGs)
 - Require algorithm development for highly irregular bodies
 - Require algorithm and software development for efficient processing of small body data sets (including large numbers of images with complex geometries)
 - Require demonstrations of accuracy of processing methods, applied to the novel image geometries that arise with small bodies
- Better coordination and education is needed to ensure compliance with existing standards for mapping
 - For example, coordinate system and geologic mapping standards
 - Recent experience with the Dawn mission shows how critical this need is
- ***SBAG should be aware of and concerned about these issues***



Carto Issues Broader Than Just SBAG

- Need to control increasingly massive datasets in order to realize their full value for immediate science and future planning...but who pays for this?
 - What should be required from the missions in terms of data calibration, cartographic processing?
 - How can additional processing be prioritized in R&A programs? How to deal with data processing that enables multiple science investigations being costed against pure science?
 - What should be required from Participating Scientists (whose role is somewhere between missions and R&A)?
- Who pays to fill in the strategic knowledge gaps (SKGs) in order to make future processing affordable?
- Who sets the requirements or makes recommendations? (Role of GCWGs and AGs with PCGMWG out of the picture)
- How can standards be coordinated internationally?

Recommendation

- We suggest that the SBAG create a “finding” to the effect that there is a need for a NASA panel or committee to develop a “cartography roadmap”
- Such a panel could be made up of civil servants, bypassing FOIA issues, and yet still gather input from and represent the small body and planetary science community

Backup

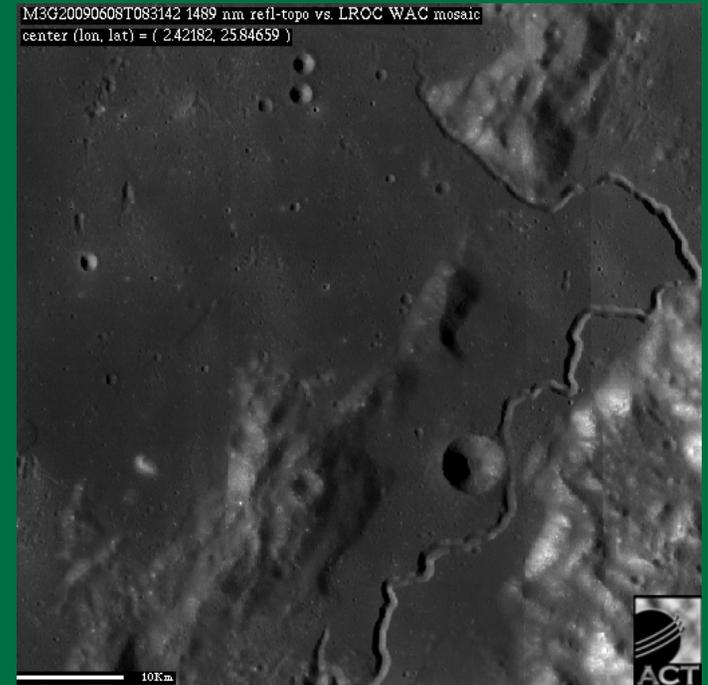


Geodetic Control

- Only way to register data in a common frame
- Yields KNOWN level of accuracy
- Uses: geology, mineralogy (and ISRU), site selection, landing and landed operations
- Other benefits: seam removal, proper orthometric projection of data; registration of multispectral data, proper photometric correction, change detection
- Might have been able to discover non-linear rotation of Titan sooner (internal ocean)
- Might still be able to verify structure of Enceladus, but data not yet controlled



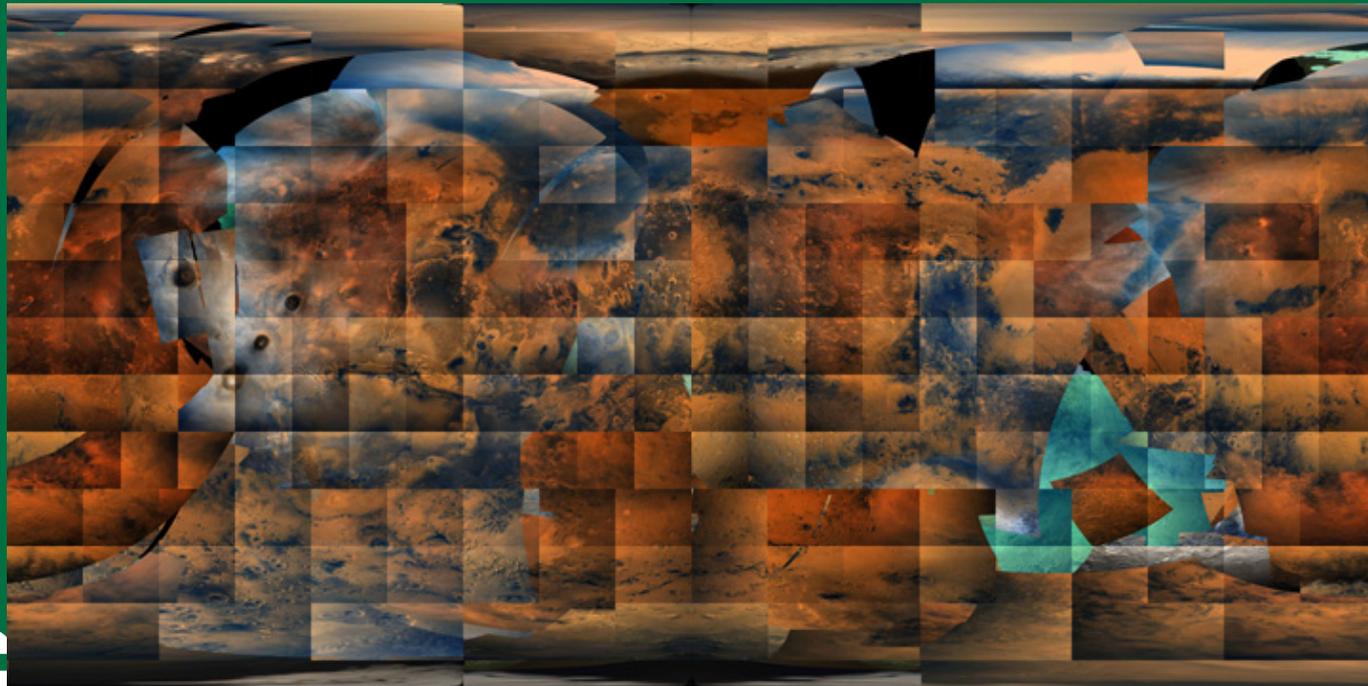
iPhone map without proper control and/or topographic base



Current M³ vs. WAC GLD100 DEM
Apollo 15 and Hadley Rille site
(Courtesy: M³ Team, ACT)

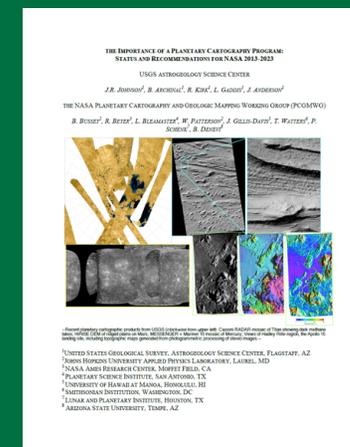
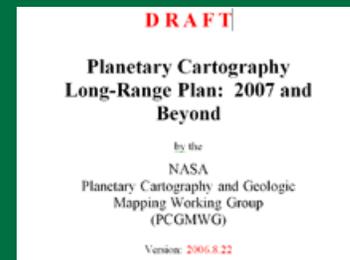
Standards

- Cartographic standards help to avoid confusion in processing and use of datasets
- Need to be considered and understood by missions and instrument teams early on
- Would also help to standardize product formats (further) so as to make usage and understanding easier



End of the PCGMWG (longer version)

- From 1994 to 2012, PCGMWG made cartography recommendations to NASA
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- Due to FACA issues, the PCGMWG **ceased making cartography recommendations in 2012**
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- Groups on mapping standards for Moon & Mars don't make general recommendations on cartography planning (*LGCWG, 2007~2009; MGCWG, mid 1990's to present*)



A Few Examples of Other Planetary Mapping Issues

- How should the current massive planetary datasets be geodetically controlled and integrated to best enable science and operation of science and human missions?
 - Moon, Mars, Mercury, Saturnian satellites, etc.
 - Control and creation of global topographic models
- What are the requirements on missions for mapping standards, instrument calibration, geodetic control (registration and uncertainty) of data & products?
 - Discovery, New Horizons, Flagship
- How can R&A funding – including Participating Scientists – better support development of mapping procedures for large scale and complex products?
 - Previously done by missions
 - Work is often too large and complex (and “not enough science”) for R&A programs
- What are the strategic knowledge gaps (SKGs) related to mapping?
- How should standards groups (LGCWG, MGCWG, others) operate?
- How should NASA interact with international groups on mapping standards and the creation of mapping products?
- When and how should mapping tools be developed and tested for accuracy?

NASA Advisory Council

Short description of the Recommendation

Lunar orbital data sets should be geodetically controlled and accurately co-registered to create cartographic products that will enable fusion, integration, and manipulation of all past and future data relevant to lunar exploration.

Major reasons for the Recommendation

This recommendation results from considering how best to integrate the various data sets (US and international) that will be returned from the Moon in the next 5-8 years as well as those previously obtained. Improved positional accuracy for locations around the globe and for accurate co-registration of all available data sets is needed to maximize safety, reliability and efficiency in lunar human and robotic exploration operations.

- NASA Advisory Council (2007). *Recommendation S-07-C-13 of the NASA Advisory Council to NASA Administrator Griffin*, p. 14, <http://bit.ly/x0HnnM>

IAU Working Group on Cartographic Coordinates and Rotational Elements

The importance of geodetically controlled cartographic products – i.e. derived from least squares photogrammetric, radargrammetric, or altimetric (cross-over) solutions – is well known. These products are valuable since they are precise and cosmetically ideal products at the sub-pixel level of the data, with known or derivable levels of precision and accuracy. In addition global control solutions also provide for improved body pole position, spin, and shape information, with reduced effects of random error and often systematic error. Such solutions would allow for improvements in the recommended models, and more importantly provide for higher (and known) precision and accuracy cartographic products. Although a flood of new planetary datasets is currently arriving, it appears that the production of such products is often not planned for or funded. We strongly recommend that this trend be reversed and that such products be planned for and made as part of the normal mission operations and data analysis process.

- Archinal et al. (2011), *Cel. Mech. Dyn. Ast.*, 109, no. 2, 101-135.

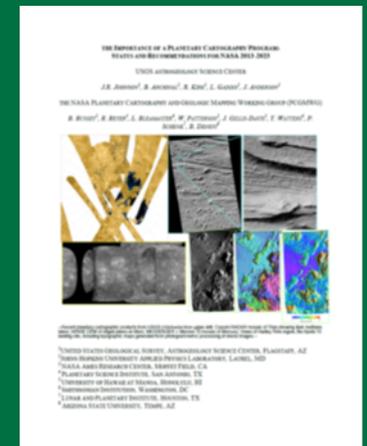
Decadal Survey

Vision and Voyages for Planetary Science in the Decade 2013-2022 (2011), selected quotes on cartography

- ...planetary geologic mapping ... [is one item that is] crucially important to NASA's long-term science goals, and ... require[s] funding. (p. 21)
- R&A programs like planetary cartography are also critical for mission planning, ensuring that (for instance) cartographic and geodetic reference systems are consistent across missions to enable proper analysis of returned data. (p. 126)
- Advancing understanding of the full range of surface processes operative on outer planet satellites requires global reconnaissance with 100-meter scale imaging of key objects, particularly Europa, Titan, and Enceladus as well as topographic data and high-resolution mapping (~10 meters/pixel) of selected targets to understand details of their formation and structure. (p. 227)
- Development of standards for geodetic and cartographic coordinate systems should be encouraged, and these systems should be documented and archived within a NAIF/SPICE framework. (p. 288)
- Geodetic studies of the rotation states of these bodies [Europa, Saturnian satellites, Triton] might provide additional constraints on ocean characteristics. (p. 238)

PCGMWG: Final Recommendation

*“Our key recommendation centers on the need to create a long range planetary mapping and cartography plan. This could be done by the PCGMWG, with advocacy voiced by this Decadal Survey process (or a similar NRC study). With such a plan, cartography can become an integral part of all spacecraft missions and instruments, beginning in the development stages and continuing through mission operations and the data analysis portions of the mission. **Without such a plan, the status quo will remain and the potential utility of the vast amounts of detailed data provided by these missions will remain either delayed or underutilized for the benefit of scientific discovery.**”*



PCGMWG White Paper, J.R. Johnson et al., submitted to the NRC Decadal Survey, 2010

http://www.lpi.usra.edu/decadal/sbag/topical_wp/JeffreyRJohnson.pdf