The Need For NASA Planetary Cartography Planning

by

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With contributions from:

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Cartography Research Assessment Group Informational Meeting
LPSC, The Woodlands, Texas
2015 March 22

Outline

- What this is about
- Needs for NASA planetary cartography planning
  - Much-needed improvements in algorithms, software, instruments, standards, product development…
  - Geodetic control and coregistered data
  - Adherence to standards
- Outstanding planetary mapping issues
- Recommendations

This *is not* just about:

- USGS (or anyone else's) funding
- Geologic mapping
- R&A reorganization
- Senior reviews of cartography related resources (USGS, RPIF, PDS)
- Coordinate systems
- One planetary body or type of body

But these are related issues

This *is* about:

- Enabling the best possible science return from missions
- Enabling exploration
- Lowering costs or at least economy of scale

- The best outcome for NASA, science, exploration, and the taxpayer

Two Levels of Cartography Planning Needed

- Long-term cartographic planning for missions
  - Instrument design, calibration, data acquisition strategies, standards, etc.
  - Ensures that usable data are returned
  - Must be defended as much as other costs such as mission development and operations, science, etc.

- Infrastructure support for product development
  - Capabilities must be anticipated, developed and maintained
    - Technology development: Specialized hardware, algorithms, software, data access & storage, etc.
    - Personnel support and expertise
  - Status must be monitored & prioritized continuously

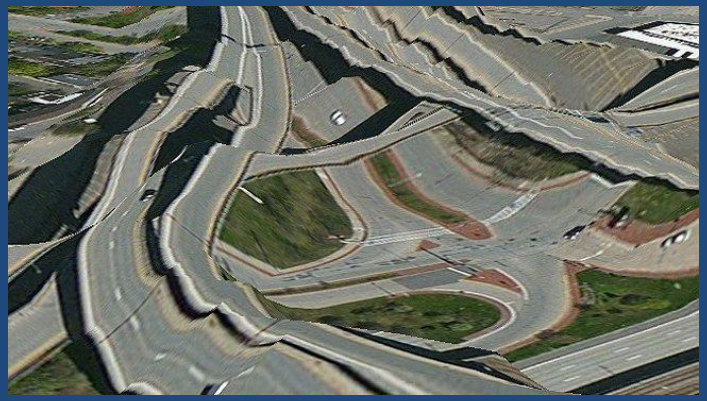
A Few Examples of Needs

- Geodetic control and coregistered data
- Adherence to standards
- Development & Technology needs
- Terrestrial planets & satellites mapping
- Small bodies mapping
- Many other lessor issues not covered here…

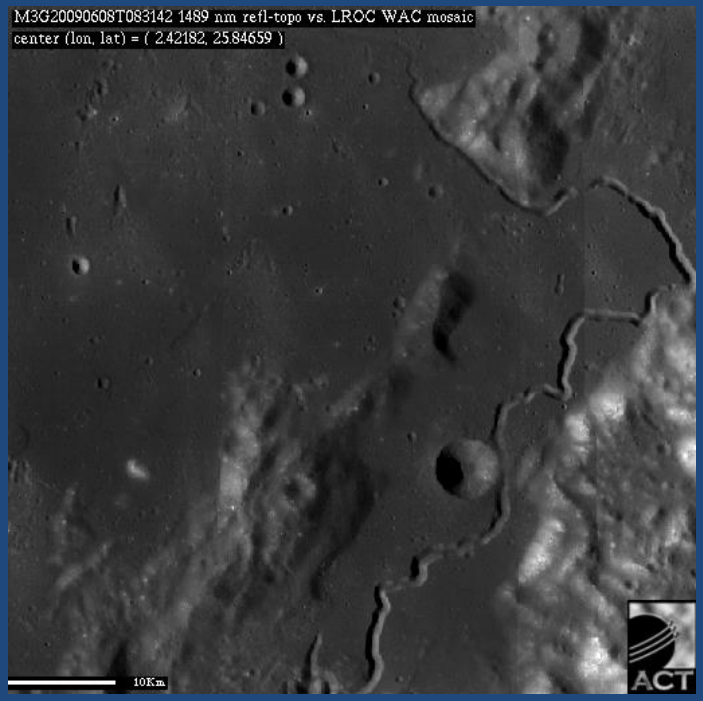
- All these problems are exacerbated by the exponential increase of returned data volume. The problem is not solved by mere increases in computing power. Significant advances in automating processing that currently relies on expert supervision are required.

Examples: Geodetic Control

- Only way to register data in a common frame
- Yields KNOWN level of accuracy
- ***Applications:*** geology, mineralogy, 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, comparison of multiple instrument and mission datasets
- Might have been able to derive internal structure of ***Titan*** and ***Mimas*** – sooner & collect more appropriate data
- Might still be able to verify structure of ***Enceladus***, *but data not yet controlled for that purpose*



iPhone map without proper control and/or topographic base



Current M^3 vs. WAC GLD100 DEM
Apollo 15 and Hadley Rille site
(Courtesy: M^3 Team, ACT)

Examples: Standards

- Cartographic standards must be required for all missions and data providers
  - Cost-effective: Process the data correctly only once
  - Supports science: Coregistered data of known accuracy with common coordinate systems can be used more effectively for correlation and analysis
- Results in standardized product formats
  - Prevents widespread confusion in processing and use of datasets
- Must be adopted by missions and instrument teams early on
  - Saves time and money for everyone

Needs 1/3: Other cartographic development / technology needs

- Faster, more robust tie pointing capabilities
- Ability to control push-frame & pixel scanning camera images
- Widespread and consistent use of coordinate system, mapping, and format standards
- Robust and detailed comparison of quality and cost-effectiveness of different DEM generation methods
- Controlling and processing massive datasets - 100s of Tbytes

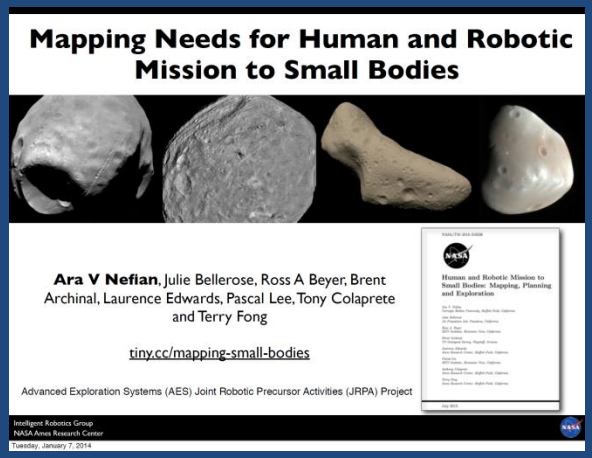
Needs 2/3: Mapping: Terrestrial Planets & Satellites

- How should the current massive planetary datasets be geodetically controlled and integrated to best enable science and operation of science and future missions?
  - Moon, Mars, Mercury, Venus, Saturnian satellites, etc.
  - Control and creation of global topographic models
- What should be the requirements on missions for mapping standards, instrument calibration, geodetic control (registration and uncertainty) of data & products?
- How can R&A funding – including Participating Scientists – better support development of mapping procedures for large scale and complex products?
  - Work is often too large and complex (and "not enough science") for R&A programs
  - PDART may help – but how are priorities for PDART products going to be determined?
- 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 issues?
- When and how should mapping tools be developed and tested for accuracy?

Needs 3/3: Mapping: Small Bodies

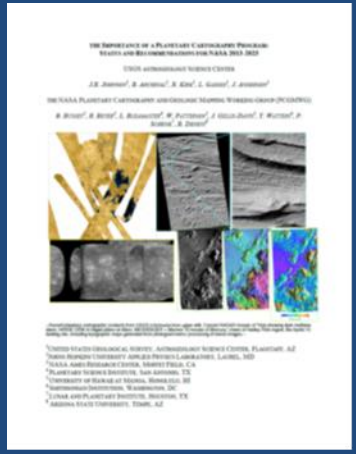
- The "state of the art" of mapping irregular small bodies is uncertain
- Questions about best way to generate shape models, formats, format conversions, image projection onto shape models, handling occluded surfaces, handling all instruments, and all data, and, most importantly…
- Accuracy verification---an essential element of development of precise, high-quality products for planetary exploration---has generally not been done
- Active efforts to use existing data, new data from currently active and planned missions, and data from future robotic and human asteroid missions for development of cartographic products must begin ASAP

- Example: Dawn, Vesta
  - Use of non-standard coordinate systems
  - Confusion on geologic mapping standards
  - Mapping accuracy uncertain
  - Better coordination of and education on cartographic & mapping standards are needed!
- Refer to the NASA Ames white paper, input on SKGs to the SBAG at the January 2013 meeting, and January 2014 SBAG presentation =>



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

Next Steps? / Vision

Follow the final PCGMWG recommendation…

The “CRAG” should:

1. Gather input from and represent the interests and needs of the planetary science community
2. Generate a roadmap and recommendations
3. Present and publicize as “Findings” to NASA
4. Continue to maintain and update the roadmap and recommendations

Resources on Planetary Cartography Planning

- See http://astrogeology.usgs.gov/groups/nasa-planetary-cartography-planning
  - Index and links to 39 documents, 1981 to present
  - Including items cited above
  - Will be updated soon

Backup

NASA Advisory Council

On the need for lunar geodetic control

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

On the need for geodetic control

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)

References to planetary 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)

LEAG Findings 2014 September 4

exploration science resources commerce

Issues: Facilities & Cartography

Questions and possible responses for Cartography:

- PSS Whitepaper?
- Cartography Analysis Group (similar to CAPTEM) to focus on scientific oversight?
- Interim – chair of the PCGMWG to be on PSS?
- Where is the present Cartography program going to be, now that PGG is gone?

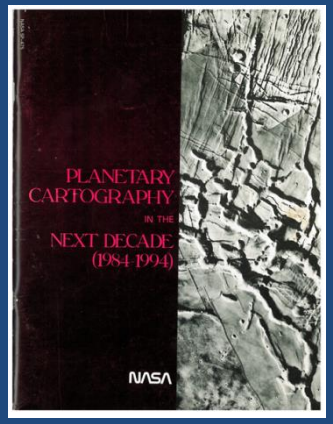
Findings:

PSS should conduct an official review of the science associated with the facilities and cartography.

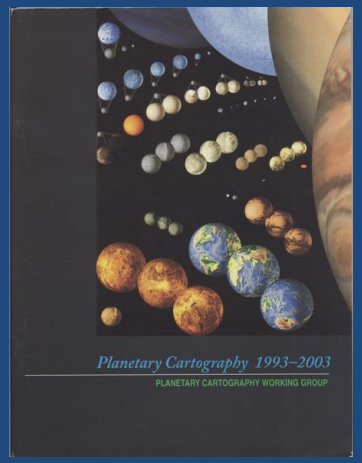
Formal representation of Planetary Cartography on the the PSS should be approved ASAP.

Background

- Global maps and mosaics are integral to planetary missions
  - Both for planning and as products, starting in development and continuing through mission operations and data analysis
  - In recognition, NASA established several committees, working groups, and panels
- ***Objective: Plan systematic global data acquisition, data processing and development of cartographic products suitable for planetary exploration***

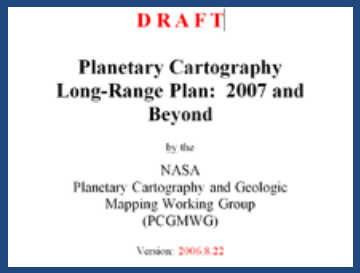


- From 1974 to 2012:
  - 1974: Lunar Photography and Cartography Committee (LPACC)
  - 1977: Lunar and Planetary Photography and Cartography Committee (LPPACC)
  - 1979: Planetary Cartography Working Group (PCWG)
    - Produced two 10-year plans and a supplement (at right)
  - 1994: Planetary Cartography & Geologic Mapping Working Group (PCGMWG)
    - Included the chair of the NASA Geologic Mapping Subcommittee (GeMS)



End of the PCGMWG

- From 1994 to 2012, the PCGMWG made cartography recommendations to NASA
  - Drafted 10 year cartography plan in 2006
  - Recommendations briefed to NASA PSD in 2008 >> “wait for Decadal Survey”
- Submitted white paper on cartography to NRC Decadal Survey
- The PCGMWG stopped making formal cartography recommendations in 2012 *(FACA issues?)*
  - Still reviews USGS PG&G Cartography proposal
- This left a major gap in long-term planning for cartography in the planetary science community
  - Groups on mapping standards for Moon & Mars don’t make general recommendations on cartography planning (*LGCWG, 2007~2009; MGCWG, mid 1990’s to present*)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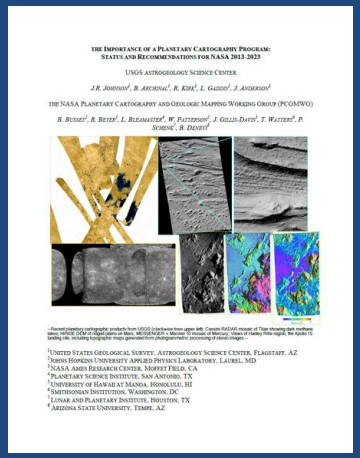
Planetary Cartography Long-Range Plan: 2007 and Beyond

by the

NASA
Planetary Cartography and Geologic Mapping Working Group
(PCGMWG)

Version: 2006.8.22


THE IMPORTANCE OF A PLANETARY CARTOGRAPHY PROGRAM: STATUS AND RECOMMENDATIONS FOR NASA 2013-2023

USGS ASTROGEOLOGY SCIENCE CENTER

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Why (pay for) Cartography??!!

X Attractive maps + antique frames = office decorations

X Jobs program for carto-geeks

√ Maps = data fusion = MORE UNDERSTANDING / $

- Multiple images –> mosaics of larger regions
- Multiple sequences –> changes, photometry, stereo topography
- Multiple instruments –> synthesis of data to test theories

  …morphology + topography + photometry + change + spectra + elemental abundance + thermal properties + radar properties +…

- *DOESN'T HAPPEN* unless we develop, maintain the tools to make maps from images & remote sensing
- *CAN'T BE TRUSTED* unless we assemble data in a rigorously physical way w/uncertainty estimates

THAT'S WHAT CARTOGRAPHY IS