The Need for International Planetary Cartography Planning and Cooperation

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Outline

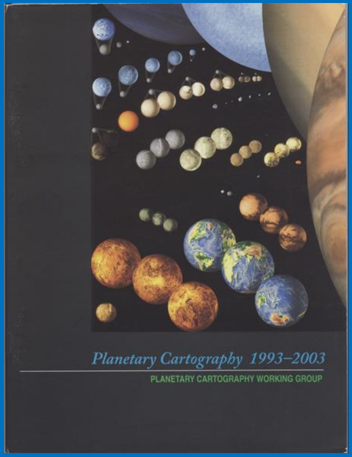
- Background
- Status of international planetary cartography planning
- Outstanding planetary mapping issues
- Recommendations - Goals
- Recommendations - Actions

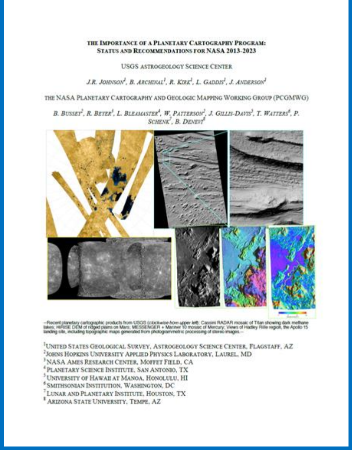
Background

- Cartography is fundamental to planetary science
- Cartography is the technology used to locate and portray data in a spatial context. It is thus useful for studying individual observations and essential for synthesizing multiple sources of spatial data
- A lack of appropriate consideration of this foundation can have and has had serious and expensive consequences
  - Scientific return from planetary missions
  - Safety of future landers (robotic and human)
  - Operation of future landed missions
- We highlight the need for, and recommend cooperative planning of, such cartographic work at international level

Status of International Planetary Cartography Planning

- E.g. NASA had many different groups doing cartography planning, from early 1970's-2012
- Objective: Plan systematic global data acquisition, data processing and development of cartographic products suitable for planetary exploration
  - Mostly via 10 year plans (1993 example at right)
- Planetary Cartography & Geologic Mapping Working Group (begun 1993)
  - Recommendations to Planetary Decadal Survey (2010)
    - Shown at right
  - Ceased making recommendations in 2012
- Other space agencies, e.g., ESA, DLR, are active on mission by mission basis, e.g., Mars Express
- Selected few cross-mission activities in Europe supported by projects funded by EC, e.g., iMars (FP7), very limited in scope and funding





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

USGS ASTROGEOLOGY SCIENCE CENTER

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--Recent planetary cartographic products from USGS (clockwise from upper left): Cassini RADAR mosaic of Titan showing dark methane lakes; HiRISE DEM of ridged plains on Mars; MESSENGER + Mariner 10 mosaic of Mercury; Views of Hadley Rille region, the Apollo 15 landing site, including topographic maps generated from photogrammetric processing of stereo images.--

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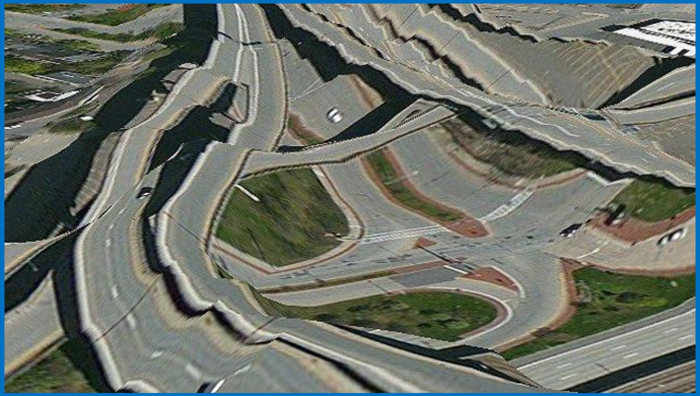
Need for Cartography Planning

Areas of Particular Concern:

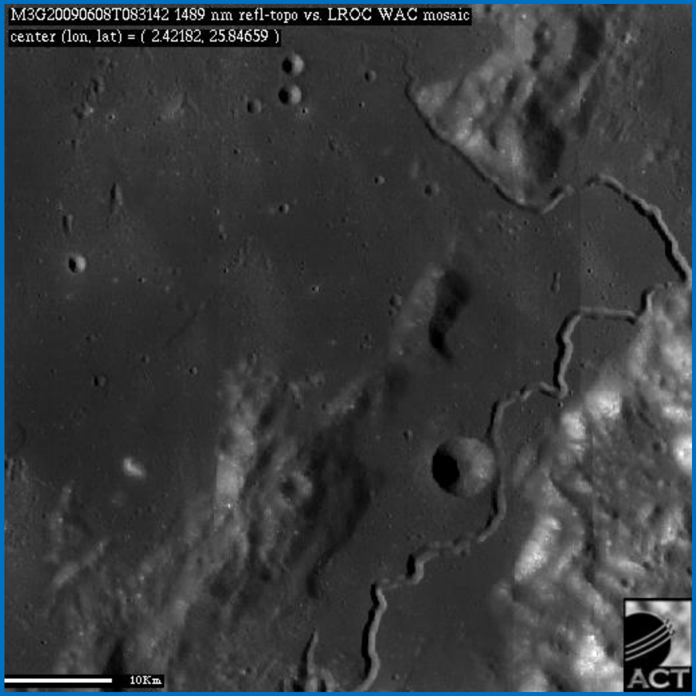
- Geodetic Control
- Standards development and maintenance
- Data processing (mapping) algorithms and software
- Small body mapping
- Massive dataset processing
- International collaboration

Examples: Geodetic Control

- Only way to register data in a common frame
- Yields KNOWN level of accuracy
- ***Applications:*** geology, mineralogy, site selection, 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 be able to determine accurate global shape of Enceladus, but data not yet controlled



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 can be used more effectively for correlation and analysis; Allows joint study of multiple datasets
- Results in standardized product formats
  - Prevents widespread confusion in processing and use of datasets
- Must be adopted by missions and instrument teams early on
  - Everyone saves time and money

Example: Data Processing Algorithms Requiring Improvement

- Better geometric calibration methods and (any) standards
- Faster, more robust tie pointing capability
- Ability to control push-frame 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
- Registering/processing data from multiple platforms
- Small & irregular body mapping
  - Conventional approaches and standards may fail

Mapping: Terrestrial Planets & Satellites

A few examples of major outstanding questions

- 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 are the requirements on missions for mapping standards, instrument calibration, geodetic control (registration and uncertainty) of data & products?
- How can (e.g. NASA or international) R&A funding 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 related to mapping?
- How should standards groups (IAU WGCCRE, IAU WGPSN, ISPRS ETM, NASA MGCWG, others) operate?
- How should space agencies interact with these groups on mapping standards and the creation of mapping products?
- When and how should mapping tools be developed and tested for accuracy?

iMars: Analysis of Mars multi-resolution images using auto coregistration, data mining and crowd source techniques

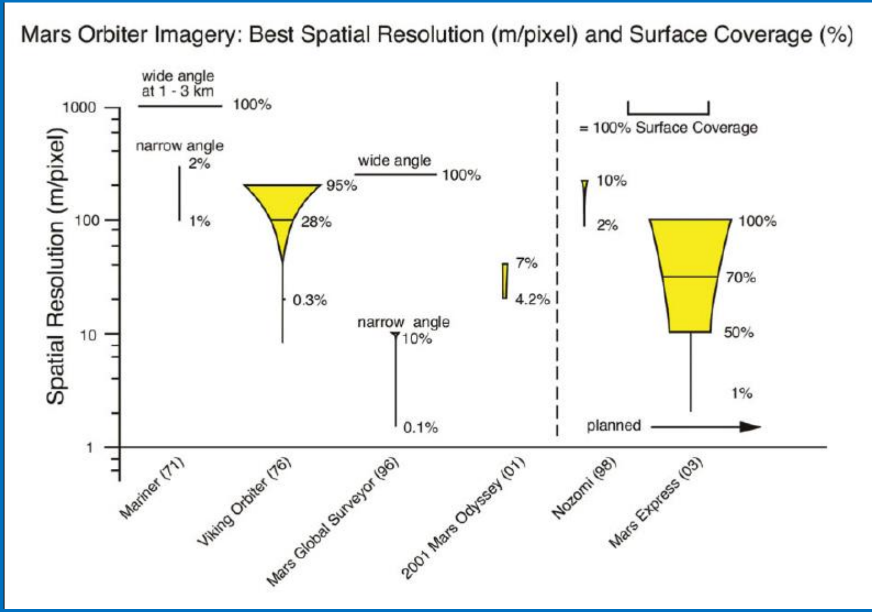
- Example for cross-mission planetary cartography activities in Europe, funded by EC
- Consortium: Europe, South Korea
- Project schedule: 1.1. 2014 - 31.12. 2016
- Budget: approx. 2.5 M€
- iMars Objectives: …..crowd-sourcing from HRSC orthorectified images and Digital Terrain Models as base images and automated co-registration of NASA orbital imagery together with higher resolution DTMs from CTX and HiRISE…..

www.iMars.eu

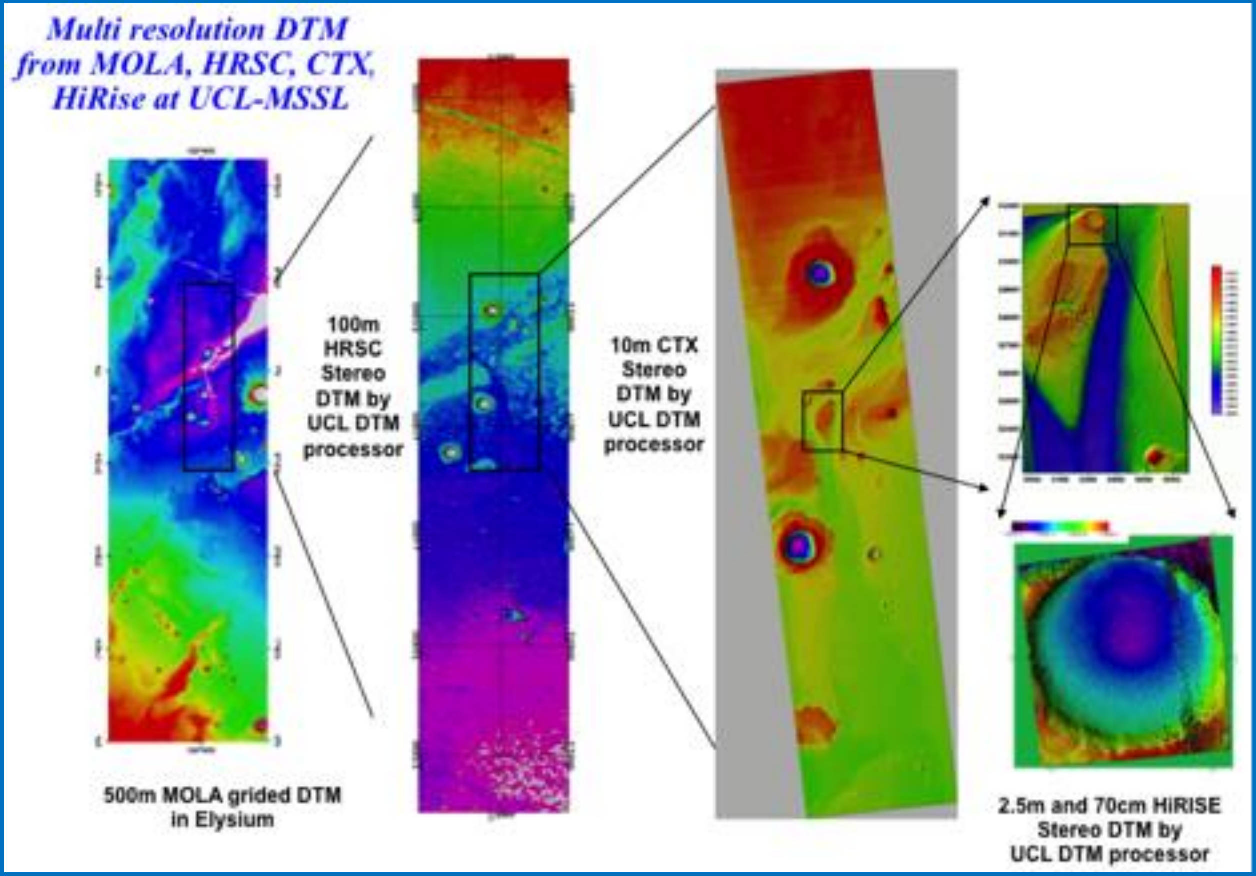
iMars: Background

Images with IFoV ≤ 100m

- Mariner-9 (1971:1%)
- Viking Orbiter (1976-86: 28%)
- MOC(1993-2010:10%)
- THEMIS-VIS (since 2001-100%)
- HRSC (since 2003: 85%)
- CTX (since 2006:85%)
- HiRISE (since 2006:1%)

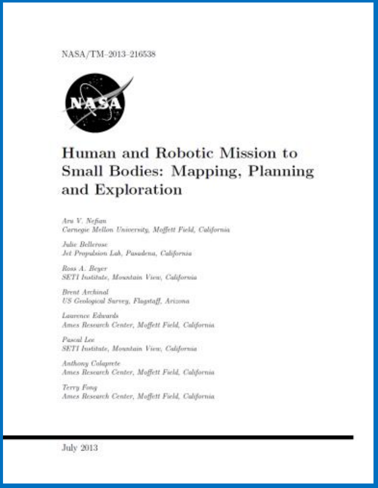


iMars: Example of producing a DTM cascade



Mapping: Small Bodies

- The “state of the art” of mapping small irregular bodies is uncertain and currently poorly developed
- Significant algorithm & software development is required for mapping small bodies
- Accuracy verification---an essential element of development of precise, high-quality products for planetary exploration---is generally not being 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
- International long term standards ignored - Example: Dawn, Vesta
  - Use of non-standard coordinate systems
  - Confusion on geologic mapping standards
  - *Better coordination of and education on cartographic & mapping standards are needed!*
- Refer to the NASA Ames white paper (Nefian et al. 2013, at right)


NASA/TM–2013–216538

Human and Robotic Mission to Small Bodies: Mapping, Planning and Exploration

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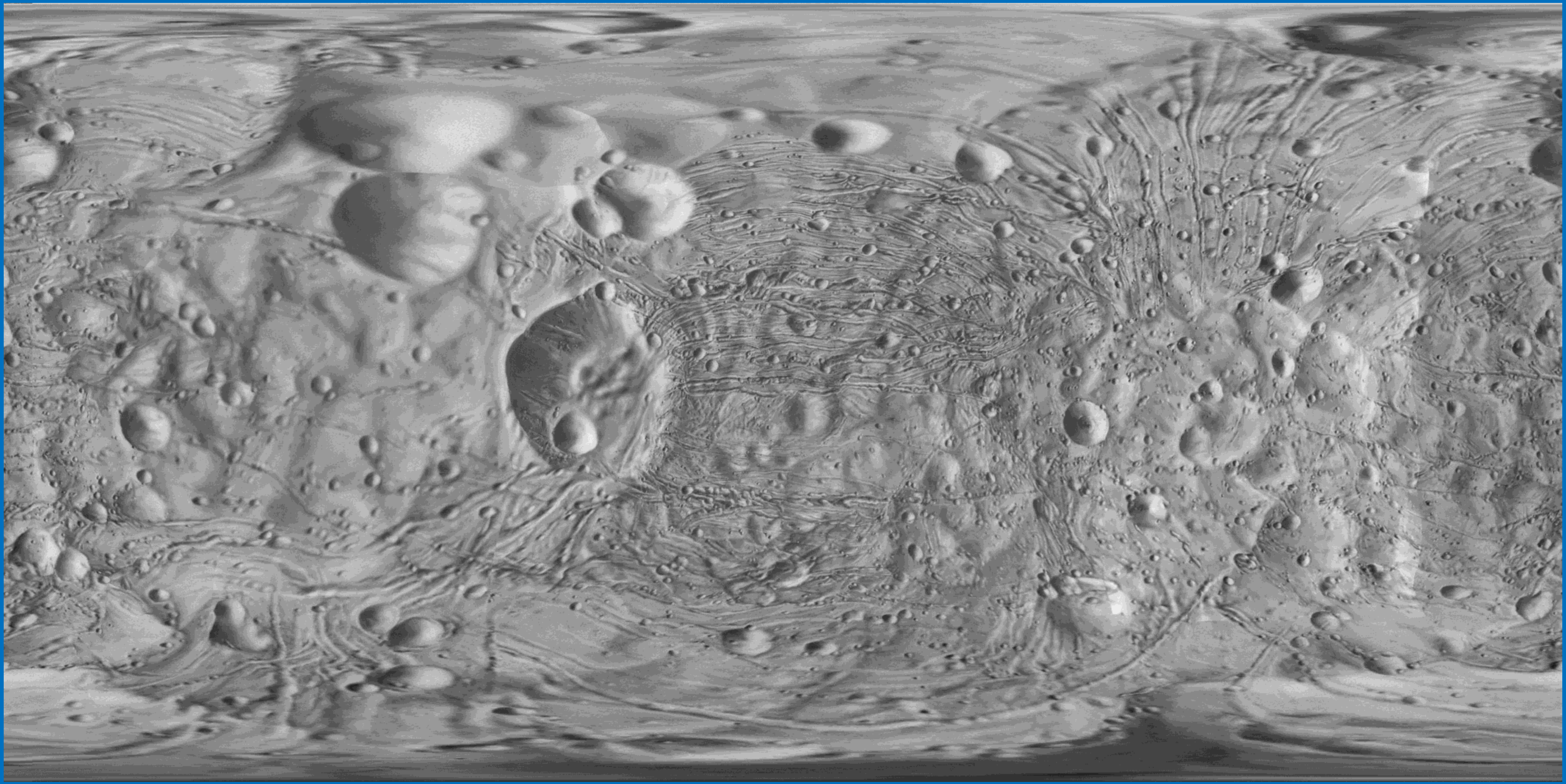
July 2013

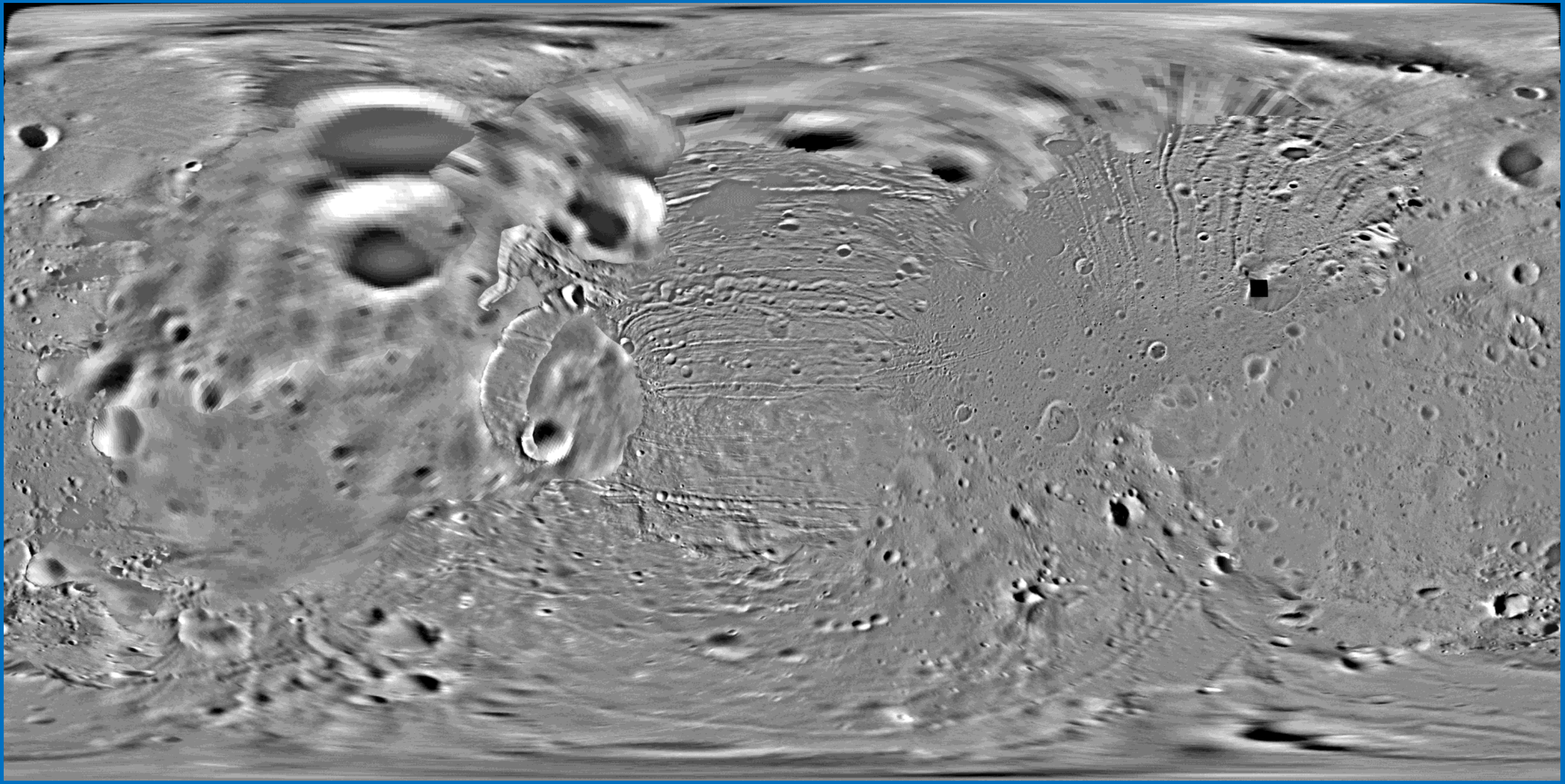
Example: Martian Moon Phobos



Photogrammetric Control: USA, 1974

Credit: USGS

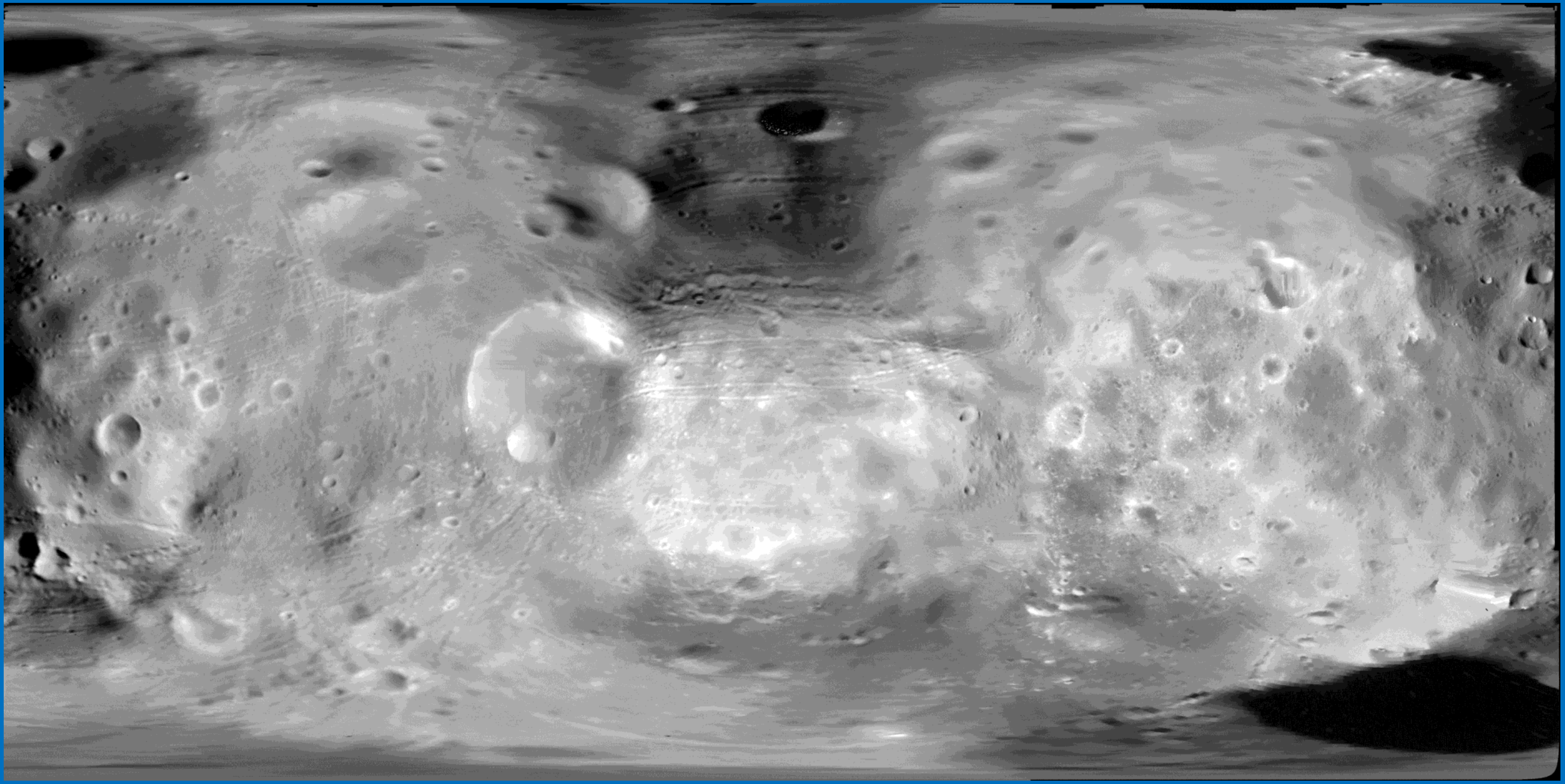
Example: Martian Moon Phobos



Photogrammetric Control: USA, 1993

Credit: Simonelli et al. (1993)

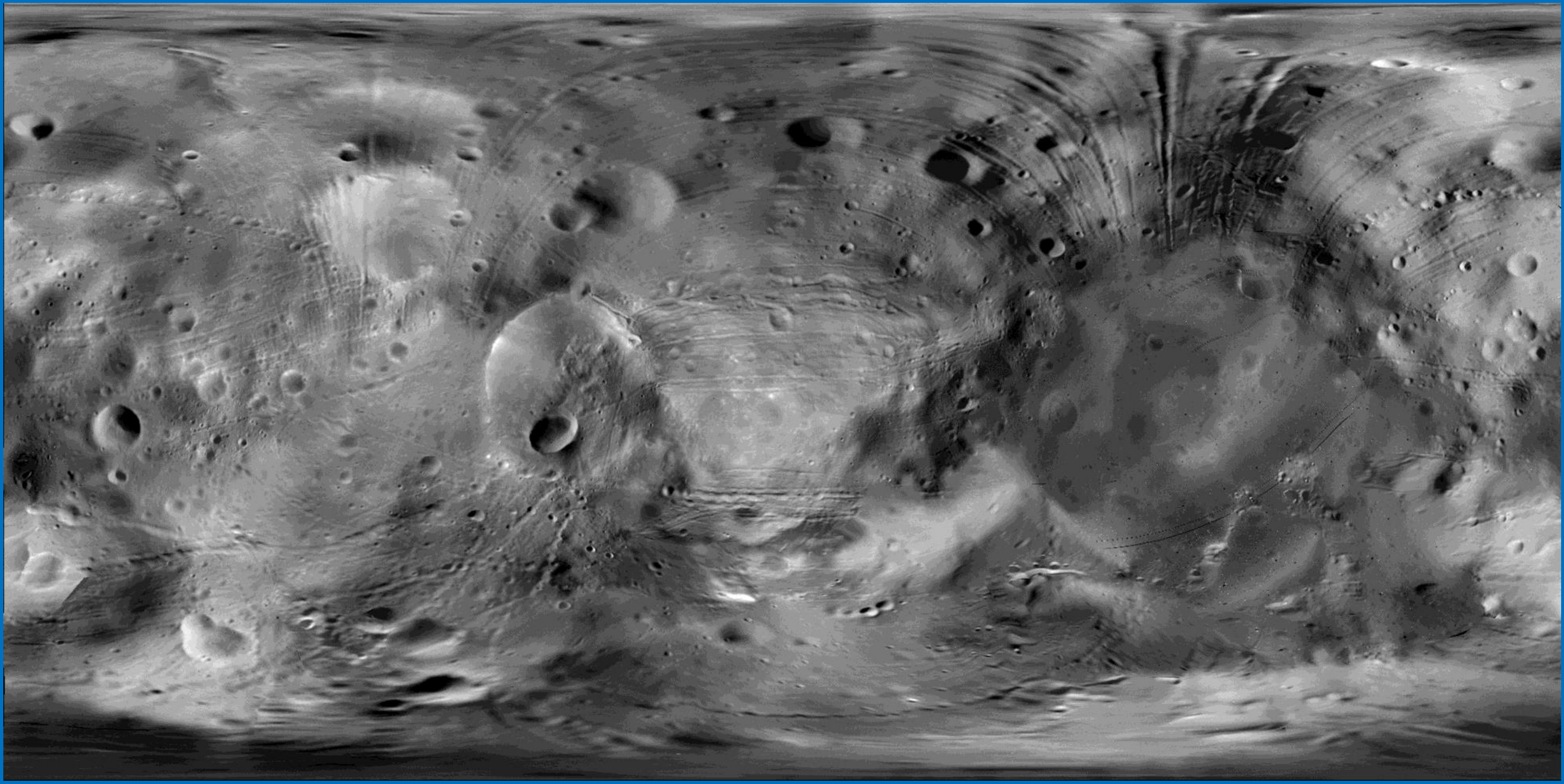
Example: Martian Moon Phobos



Photogrammetric Control: Germany, 2009

Credit: ESA/DLR/FU(G.Neukum)

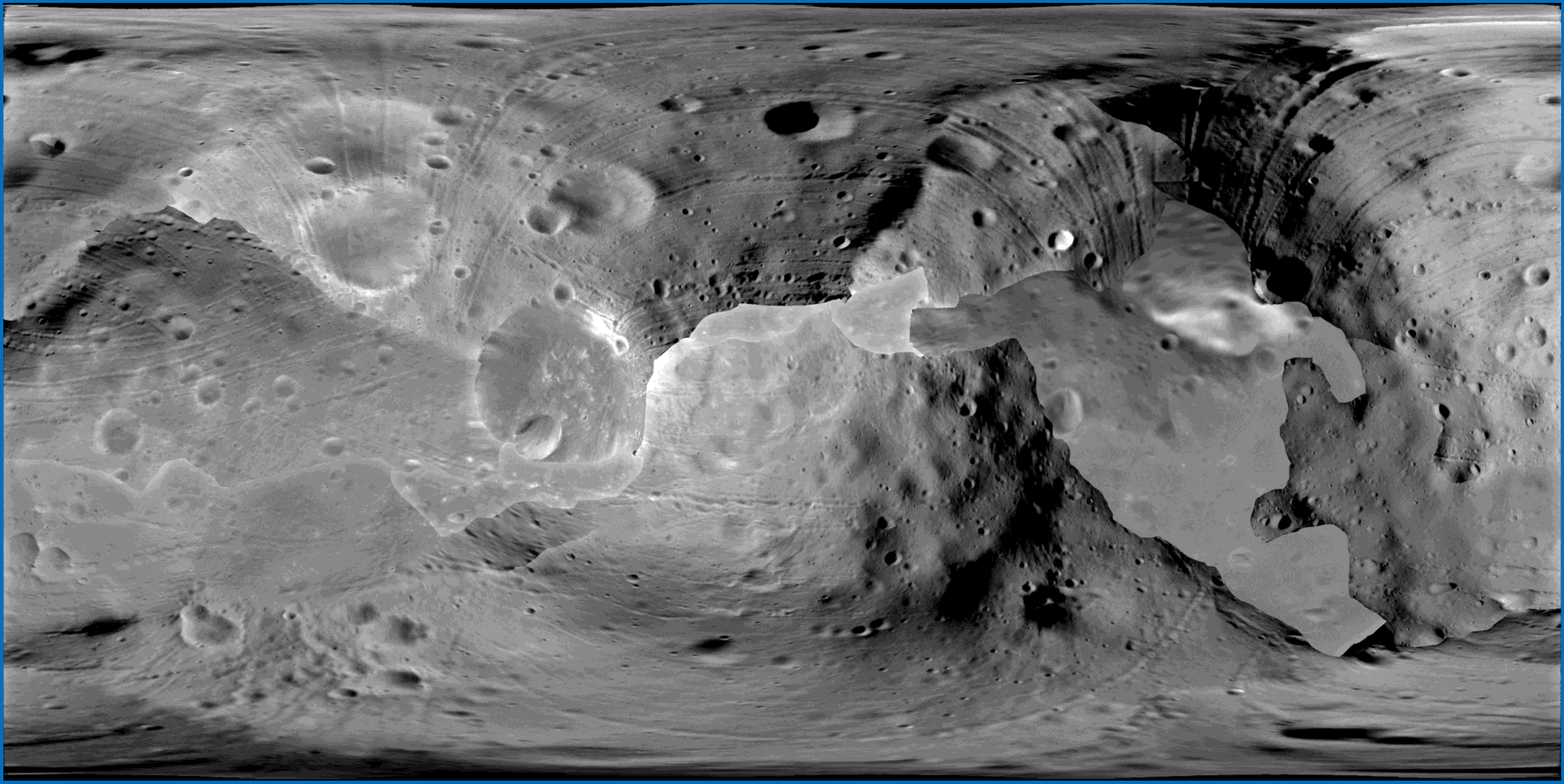
Example: Martian Moon Phobos



Photogrammetric Control: Russia, 2012

Credit: ESA/DLR/FU(G.Neukum)/MIIGAiK)

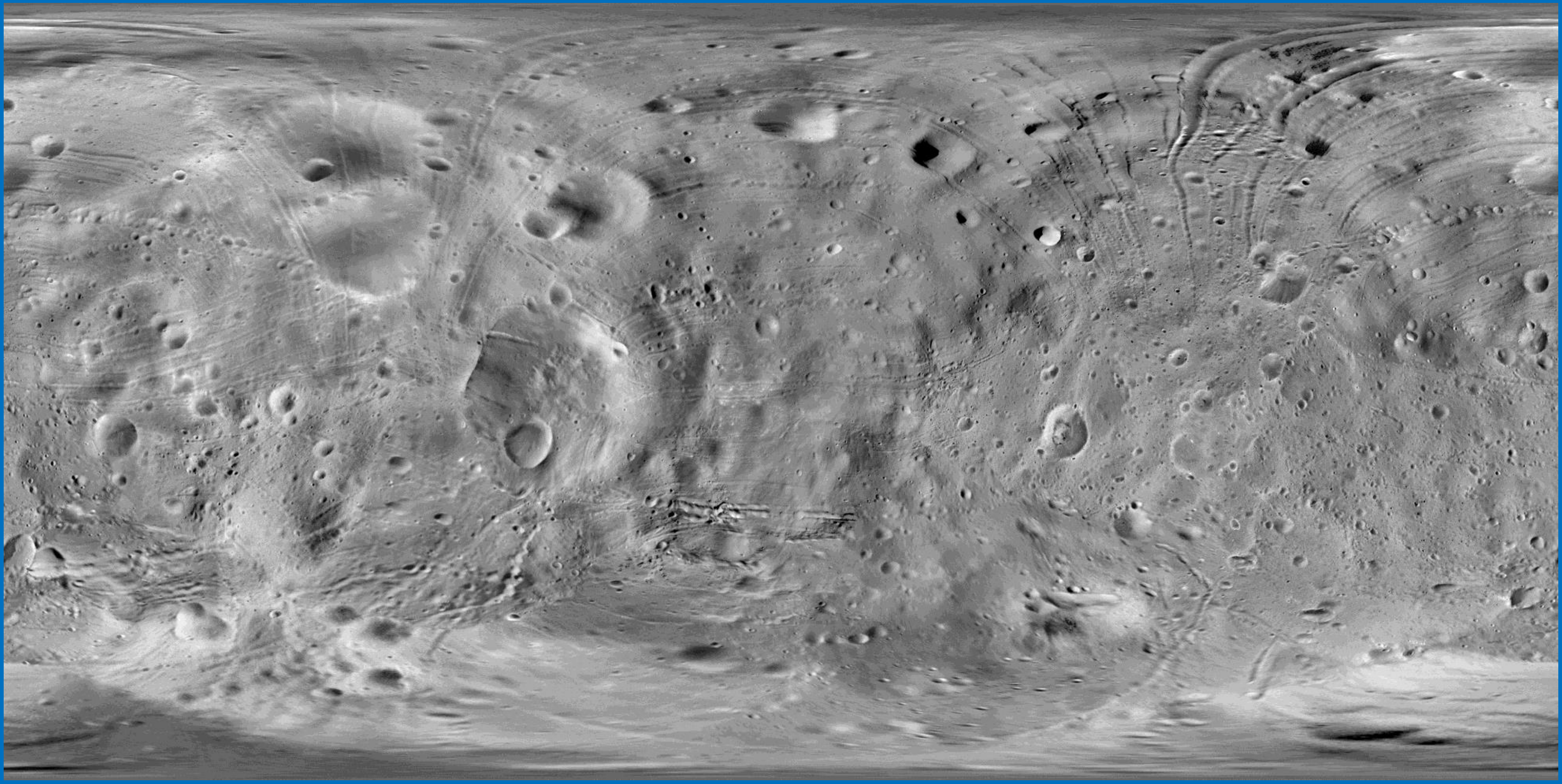
Example: Martian Moon Phobos



Photogrammetric Control: Germany, 2013

Credit: ESA/DLR/FU(G.Neukum)/TUB

Example: Martian Moon Phobos



Photogrammetric Control: Germany, 2009

Credit: Stooke

Example: Martian Moon Deimos

Credit: NASA/JPL/University of Arizona

Example: Martian Moon Deimos


Credit: USGS

- Photogrammetric Control required
- Photoshop cannot do the job

Credit: NASA/JPL/University of Arizona

Recommendations - Goals

Current needs for space agencies to consider:

1. Adequate resources for mapping at all stages from mission design through calibration, operations, development of processing algorithms and software, and processing to archiving;

2. Easy access to data sets and metadata from all nations; consistent (or at least well-documented) data formats; consistent cartographic standards;

3. Cooperation and support leading to the joint analysis of data sets from all nations, in turn leading to integration in a single cartographic coordinate framework at known accuracy levels, and the ability to leverage the powerful synergistic value of multiple data sets.

Recommendations - Actions

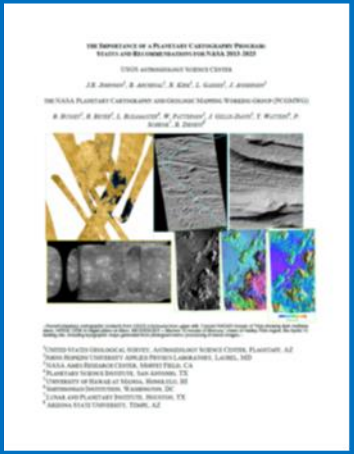
Possible actions to achieve recommended goals

- Require planning and development (and funding) of controlled mapping products as part of missions
- Actively include international participants in missions
  - Promoting international cooperation, exchange of information, experience, software, etc.; joint processing of data; registration of all data
  - E.g. participating scientist programs
- Plan for scheduled releases of all data (including level 0) to an appropriate archive
- Cooperate to develop and adhere to nomenclature, instrument calibration, data format standards

Develop long range planetary cartography plans or roadmaps, to support all of the above

Example - Final Recommendation of PCGMWG to NASA

"Our key recommendation centers on the need to create a long range planetary mapping and cartography plan. … 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 U. S. NRC Planetary Decadal Survey, 2010

We agree completely!

Backup

Example: Martian Moon Phobos

Photogrammetric Control: ?????????????

2014 August 3

Credit: NASA/JPL/University of Arizona

Example recommendation on Geodetic Control - 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

Example recommendation on Geodetic Control - 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.

Example recommendations on planetary mapping - NASA Planetary Decadal Survey

Vision and Voyages for Planetary Science in the Decade 2013-2022 **(2011)**

- …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)

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