N.A.S.A.'S PLANETARY CARTOGRAPHY TEN-YEAR PLAN: 1993-2003

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Abstract

Spacecraft exploration during the last 25 years has transformed our view of the planets and natural satellites in the solar system. The National Aeronautics and Space Administration (NASA) charged the Planetary Cartography Working Group (PCWG) to provide advice on cartographic opportunities and methods anticipated to result from on-going and future spacecraft missions. In February of 1994 the PCWG published a ten-year plan that outlined several recommendations and priorities for NASA's planetary cartography activities through 2003. The main recommendations of the ten-year plan are summarized in this paper. The primary motivation behind the recommendations in the report is that the goal of planetary mapping is to provide complete frames of reference for all subsequent studies of planetary objects. As planetary missions become more international in scope, it is important to develop an open dialogue between the international scientific and cartographic communities so that planetary maps will have the widest possible use in the most consistent and easily interpreted formats.

1 Introduction

The advent of spacecraft exploration of the solar system has greatly increased our knowledge about objects orbiting the sun. There now exist significant mapping data for over 20 planets and satellites located throughout the solar system. The National Aeronautics and Space Administration (NASA), the government agency responsible for developing space-related activities for the United States of America, charged the Planetary Cartography Working Group (PCWG) with the task of advising NASA of the best cartographic opportunities and methods associated with data returned from spacecraft exploration. The PCWG is made up of representatives of many different fields and institutions from government, industry, and universities. In early 1994 the PCWG published a ten-year plan outlining several recommendations and priorities projected for NASA's planetary cartography activities through 2003 [1]. This paper summarizes the main recommendations contained within that report, in an effort to disseminate

NASA goals and plans to the international cartographic community. Limited numbers of copies of the full report are available from the author (please address all such inquiries directly to him at the above address).

The PCWG ten-year plan is the result of a large effort by numerous individuals over a period of several years. The author served as the Chairman of the PCWG during the two years which culminated in the final report. However, the ideas contained within the report are the result of input from many individuals; listed below are all of the authors who contributed to the final published report:

James R. Zimbelman, Smithsonian Institution (Chair, 1991-1994)
Raymond Batson, U.S. Geological Survey
William V. Boynton, University of Arizona
William Cannell, Environmental Research Institute of Michigan
Merton E. Davies, RAND Corporation
Frederick J. Doyle, Environmental Research Institute of Michigan
Daniel M. Janes, Cornell University
Baerbel Lucchitta, U.S. Geological Survey
Harold Masursky, U.S. Geological Survey
Peter J. Mouginis-Mark, Hawaii Institute of Geophysics, University of Hawaii
R. Stephen Saunders, Jet Propulsion Laboratory
Paul Schenk, Lunar and Planetary Institute
Peter C. Thomas, Cornell University (Chair, 1988-1990)
Steven H. Williams, University of North Dakota
Sherman Wu, U.S. Geological Survey
Joseph Boyce, NASA Headquarters
Stephen Baloga, NASA Headquarters

2 Background

Since 1962 more than 1600 planet and satellite maps have been published in the United States. Most of the maps are of the Moon (50%) and Mars (43%), representing the focus of most U.S. spacecraft efforts in the 1960s and 1970s. The production of lunar maps largely ceased after production of orthophotomosaics to support the Apollo 15, 16, and 17 missions, but the recent phenomenal success of the unmanned Clementine spacecraft in providing global coverage of the lunar surface [2] will undoubtedly result in new mapping products of the Moon in the coming years.

The necessity for a balanced strategy of planetary mapping is best illustrated by considering the total solid surface area present within the solar system (see Figure 1). Viewed in this context, the land area of Earth is but a fraction of the total 1.6 billion square kilometers of available surface area.

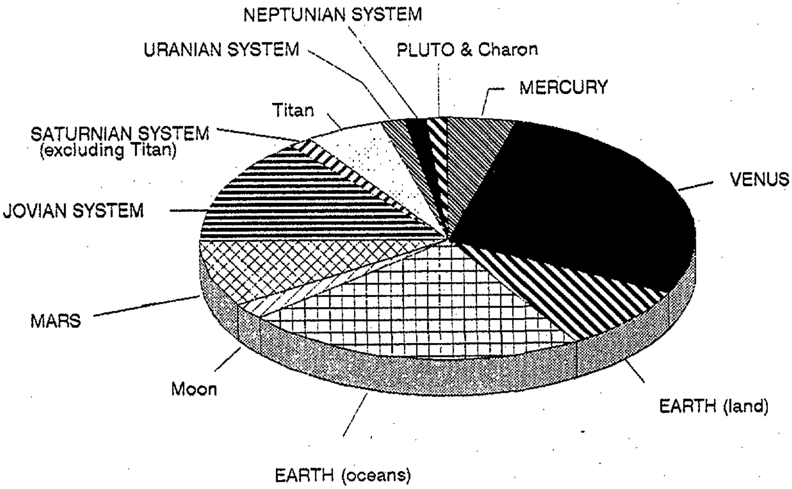

Figure 1: Surface area of solid planets and satellites in the solar system. The total surface area included above is about 1.6 billion square kilometers.

The full report is divided into several sections, briefly summarized below. Following an Executive Summary in Part 1, Part 2 describes the diverse but fundamental uses of planetary cartographic data, both for use in any scientific study of the surface of a solar system object, and as the key to indexing all kinds of data on the surfaces of planets and satellites. Parts 3 and 4 describe the cartographic methods, spacecraft missions, and data that have and will provide information on planetary surfaces. Part 5 reviews the status of cartographic products that have been produced through 1992. The final part is a set of recommendations for planetary cartography from 1993 to 2003; these recommendations are summarized in the next section.

Two fundamental themes pervade the entire report: the need for a variety of digital products and the large volume of planetary data that should be generated during the next several years. Analysis of planetary data in general is increasingly dependent upon digital storage, display, correlation, and calculation. The need to record coordinates of features visible in images requires that many different map products be in digital form so they can be used in conjunction with a variety of geophysical and remote sensing data products. The sheer volume of planetary data anticipated through the end of the millennium requires a reevaluation of how data products are analyzed and archived. For example, data from the Magellan *mission to* Venus [3] alone have a a volume that exceeds all previous planetary digital images combined. Careful organization will be required to keep future planetary data fully useful to the international community.

3 Recommendations

The general recommendations of the report list the following priorities:
1) from 1993 to 1995 the mapping of Venus with Magellan radar data,
2) from 1994 to 1996 the mapping of inner solar system objects,
3) from 1996 to 2000 the mapping of Galilean satellites and Mars, and
4) from 1994 to 2003 the mapping of small bodies from a variety of missions.

3.1 Venus

In the near future the planetary cartography effort should concentrate on the production of image and topographic maps of Venus using Magellan radar data. The immense quantity of data from Magellan represents a more complete global picture of Earth's sister planet than presently exists for our own home planet, which will be of particular value for studies in comparative planetology (Figure 2). This resource is presently available to the global scientific community in archival form through Compact Disks (CDs) of Magellan data produced by NASA's Planetary Data System (PDS), and through the continuing release on CD of mosaiced and rectified full-resolution image maps (FMAPs) by the U.S. Geological Survey. Photographic prints of FMAPs at 1:1.5 million scale are available for viewing in the NASA-sponsored Regional Planetary Image Facilities located throughout the world. Paper versions of selected products hopefully will also be available eventually through the U.S. Geological Survey.

3.2 Inner Solar System

At the time of publication, the report briefly acknowledged the recent loss of the Mars Observer spacecraft and the consequent delay in new data from Mars. The Mars Global Surveyor (MGS) spacecraft should recover much of the science planned for Mars Observer; MGS is scheduled to begin data collection at Mars in early 1998 [4]. MGS instruments will provide global coverage of low-resolution images, altimetry, and thermal infrared spectra, plus selected very-high-resolution images; these data are essential to providing a global context for understanding the Red Planet, and they now should result in a variety of new cartographic products later in this decade. The Mars Pathfinder engineering demonstration spacecraft should provide information from a landing site in the martian northern hemisphere in mid-1997 [5], but these data likely will have extremely limited regional extent and thus very little cartographic potential. While we wait for these new data from

Mars, the report recommends that present base maps of Mars should be refined with improved processing of existing Viking data.

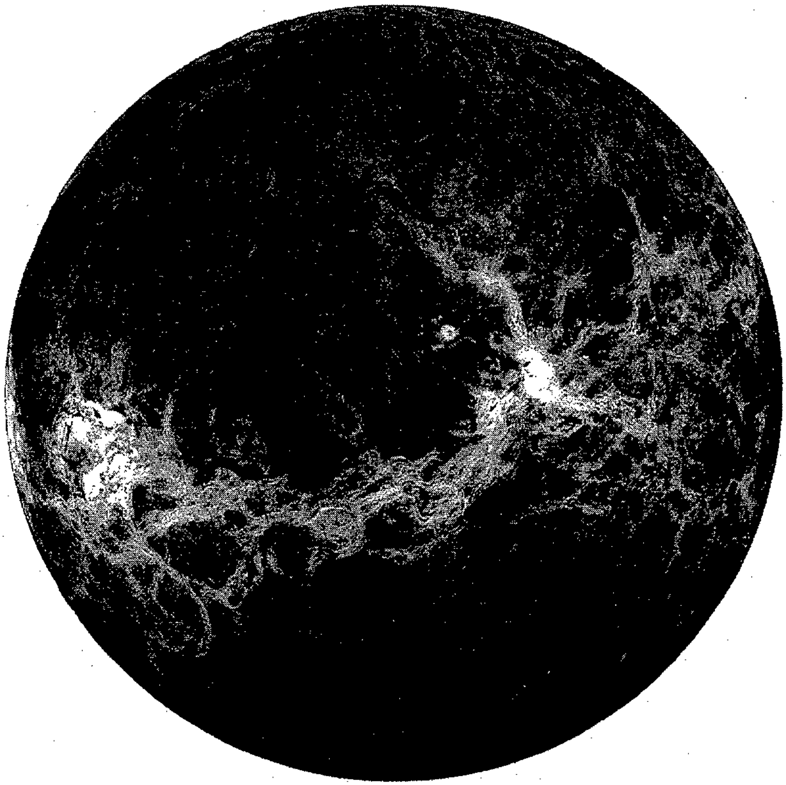

Figure 2: Hemispheric view of Venus compiled from Magellan radar images; centered along longitude 180.

The report compilation date preceded the launch of the Clementine spacecraft to the Moon. The success of the Clementine spacecraft in global mapping of Earth's Moon in early 1994 [2] has produced an 11-wavelength imaging database [6] that is just beginning to be utilized fully. Along with the multi-spectral imaging, Clementine altimetry data provided the first global perspective of the relief and shape of the Moon [7]. A great *wealth of* cartographic products will result from these new data sets, which will form the geographic reference for interpreting geophysical and geochemical data planned for the Discovery-class Lunar Prospector mission approved by NASA in early 1995.

3.3 Galileo and future Mars missions

The Galileo spacecraft will reach Jupiter in December of this year, going into orbit around the largest planet in the solar system. The incomplete deployment of the high-gain antenna on Galileo has greatly reduced the data transmission rate, but new data compression techniques should allow roughly 70% of the original science objectives to be met at the reduced rate. Images and other data of the four large Galilean satellites will allow refinements to be made to maps of these worlds, each comparable to or larger than Earth's Moon. The Galileo mission should be nearing completion at the time systematic mapping of Mars begins with MGS; both missions together should produce a steady stream of new data through the rest of the decade.

Several nations are working on plans for sending additional spacecraft to Mars around the end of the decade. NASA is studying a possible series of small orbiters and landers to further the detailed study of geochemistry and geophysics at locations around the planet. The European Space Agency is considering a mission to Mars to emplace a global network of landers for geophysical studies. The Russian Space Agency is actively working toward launching sophisticated orbiters to Mars during launch opportunities in 1996 or 1998. A Japanese spacecraft might explore the particles and fields environment surrounding Mars. Should even a fraction of these ambitious missions be operational in the specified time frame, the volume of new planetary data could be enormous by the end of the decade.

3.4 Missions to small bodies

The Galileo spacecraft recently has given us the first detailed images of the asteroids Gaspra and Ida (including the discovery of Dactyl, the first confirmed natural satellite of an asteroid). The irregular shape of these bodies presents a challenge to traditional cartographic representations of surface features, but scientists are hopeful that the surface details will provide valuable clues to materials and processes from early in the history of the solar system. Later in the decade the Near-Earth Asteroid Rendezvous (NEAR) mission, presently under construction in the United States, should result in the first artificial satellite of an asteroid as NEAR flies in close proximity to an asteroid for several months.

All future planetary cartographic products are recommended for release in both paper and digital form. The PCWG emphasized the need for *both* kinds of products in order to assure full utilization of the data by a wide range of communities and interests. Many different scales and areas of coverage are desired for the high-priority scientific analysis of planets and satellites. The recommended map products are a subset of the possible products from the anticipated data, selected to meet the greatest range of requirements without unduly taxing the limited available resources.

4 Anticipated Map Series

The ten-year plan is designed to guide the production of cartographic products that support scientific research, planning for future planetary missions, and educational activities. The products are largely in four general categories: controlled image photomosaics, shaded relief and albedo maps, topographic maps, and selected thematic maps (such as geologic maps). Next we summarize the primary mapping products recommended to meet both scientific and cartographic objectives.

4.1 Planned Conventional Map Series

Venus will be mapped at scales of 1:50M (where M indicates 'million'), 1:10 M, 1:5 M, and 1:1.5M, providing coverage of the entire planet on from one to 334 sheets. The 1:1.5M scale is the one being used for the FMAPs currently being produced at the U.S. Geological Survey. The Moon will be mapped at 1:5M and 1:2M, which will provide continuity with maps that resulted from the Apollo missions in 1969-72. Mars will be mapped at scales of 1:15M, 1:5M, and 1:500,000, the later supporting detailed topical studies selected through peer review based on scientific potential. The Galilean satellites will be mapped at scales of 1:15M (providing global coverage of each satellite on one sheet), 1:5M, and from 1:2M to 1:100,000, depending upon the resolution available from either Voyager or Galileo images.

4.2 Planned Digital Map Series

Digital cartographic products are increasingly in demand as computational capacities continue to grow. In an attempt to make the products as comparable as possible between planetary objects, the PCWG has supported the generation of Digital Image Models (DIMs) at scales that are binary fractions of a degree for each picture element (e.g., 1/2, 1/8, 1/64, 1/256 degree per picture element). An exception to this scaling plan is the FMAP series for Venus, where the full-resolution data are *uniformly* portrayed at 75 meters per picture element. DIMs of Venus, the Moon, Mars, and the Galilean satellites are recommended for generation during the next ten years, with particular scales determined by the available resolutions of the original images used in making each DIM. A DIM of Mars, generated from Viking Orbiter images, has become widely used in the last two years, allowing individual researchers to make base maps of selected areas from a common source readily available in the planetary community. We foresee this trend to be followed with each planetary body for which global coverage is obtained. It is likely that the global image data sets of the Moon obtained from the Clementine spacecraft will be the next planetary DIMs to be produced and distributed.

5 Conclusion

As planetary missions become more international in scope, it is important to develop an open dialogue between the international scientific and cartographic communities so that planetary maps will have the widest possible use in the most consistent and easily interpreted formats. It is the hope of the PCWG that the dissemination of plans at NASA for future planetary cartographic products will aid in making the data accessible to a broad audience, one that encompasses the global cartographic community.

References

[1] Planetary Cartography Working Group, 1994. Planetary Cartography: 1993-2003. Report published for NASA through the Lunar and Planetary Institute, Houston, TX, U.S.A. 50 pages, with 18 figures.

[2] Nozette, S., R. Rustan, L.P. Pleasance, D.M. Horan, P. Regeon, E.M. Shoemaker, P.D. Spudis, C.H. Acton, D.N. Baker, J.E. Blamont, B.J. Buratti, M.P. Corson, M.E. Davies, T.C. Duxbury, E.M. Eliason, B.M. Jakosky, J.F. Kordas, I.T. Lewis, C.L. Lichenberg, P.G. Lucey, E. Malaret, M.A. Massie, J.H. Resnick, C.J. Rollins, H.S. Park, A.S. McEwen, R.E. Priest, C.M. Pieters, R.A. Reisse, M.S. Robinson, D.E. Smith, T.C. Sorenson, R.W. Vorder Breugge, and M.T. Zuber, 1994. The Clementine mission to the Moon: Scientific overview. Science, vol. 266, pp. 1835-1839.

[3] Saunders, R.S., A.J. Spear, P.C. Allin, R.S. Austin, A.L. Berman, R.C. Chandlee, J. Clark, A.V. DeCharon, E.M. DeJong, D.G. Griffith, J.M. Gunn, S. Hensley, W.T.K. Johnson, C.E. Kirby, K.S. Leung, D.T. Lyons, G.A. Michaels, J. Miller, R.B. Morris, A.D. Morrison, R.G. Pierson, J.F. Scott, S.J. Shaffer, J.P. Slonski, E.R. Stofan, T.W. Thompson, and S.D. Wall, 1992. Magellan mission summary. J. Geophys. Res., vol. 97, pp. 13067-13090.

[4] Edgett, K.S., 1994. MGS approved, TES fabrication begins. TES News, Vol. 3, No. 4, Nov-Dec 1994, p. 1. Thermal Emission Spectrometer Project, Mars Global Surveryor Space Flight Facility, Department of Geology, Arizona State University, Box 871404, Tempe, Arizona, 85287-1404, U.S.A.

[5] Golombek, M.P., and A.J. Spear, 1994. Mars Pathfinder science investigations and objectives. IAA-94-IAA.11.1.752, pp. 1-10. Paper presented at the 45th Congress of the International Astronautical Federation, 3-5 Rue Mario-Nikis, 75015 Paris, France.

[6] Pieter, C.M., M.I. Staid, E.M. Fischer, S. Tompkins, and G. He, 1994. A sharper view of impact craters from Clementine data. Science, vol. 266, pp. 1844-1848. Shoemaker, E.M., M.S. Robinson, and E.M. Eliason, 1994. The south pole region of the Moon as seen by Clementine. Science, vol. 266, pp. 1851-1854. McEwen, A.S., M.S. Robinson, E.M. Eliason, P.G. Lucey, T.C. Duxbury, and P.D. Spudis, 1994. Clementine observations of the Aristarchus region of the Moon. Science, vol. 266, pp. 1858-1862.

[7] Zuber, M.T., D.E. Smith, F.G. Lemoine, and G.A. Neumann, 1994. The shape and internal sturcture of the Moon from the Clementine mission. Science, vol. 266, 1839-1843.