A NEW MAP SERIES FOR THE PLANET MARS – CONCEPT AND REALIZATION OF THE »TOPOGRAPHIC IMAGE MAP MARS 1: 200 000«

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1. ABSTRACT

The planet Mars has been subject to mapping activities since decades. Due to the quality of sources and image data this was restricted to small or medium map scales. However, the image data to be acquired by the *High Resolution Stereo Camera* (HRSC) and the *Wide Angle Optoelectronic Stereo Scanner* (WAOSS) will allow the generation of maps in larger scales. These German camera systems aboard the Russian spacecraft Mars96 will provide systematic coverage of the planet's surface. The mapping potential of the data expected will considerably exceed what has been possible so far.

According to the potential of the cameras and in particular the spatial resolution of the image data the scale 1:200 000 was selected as the primary scale for future mapping activities. The new map series »Topographic Image Map MARS 1:200 000« is generated in equal area map projections. For practical reasons the Sinusoidal Projection has been selected for the whole planet except the polar regions which are mapped in Lambert Azimuthal Projection. The paper describes the conception of the new map series for Mars, the map sheet definitions and their layout.

1. INTRODUCTION

The Russian spacecraft Mars 96 will be launched in November 1996 and will reach the planet Mars in fall 1997. The payload includes two German camera systems, namely the *High Resolution Stereo Camera* (HRSC) and the *Wide Angle Optoelectronic Stereo Scanner* (WAOSS). Both cameras have been designed to meet photogrammetric and cartographic requirements, and to provide high resolution multispectral and panchromatic stereo data sets from the Martian surface. The systems follow the three-line approach to obtain stereo image data for photogrammetric evaluation, for the derivation of Digital Terrain Models (DTM) and orthoimages resp. image maps (Albertz et al. 1992a).

Since 1992 the Technical University of Berlin contributes to the software development for photogrammetric and cartographic processing of the data to be acquired during the Mars96 camera experiment. These activities comprise the generation of digital terrain models (DTM), orthoimage generation, mosaicking, and cartographic processing as well.

2. THE NEED AND THE PURPOSE OF THE NEW MAP SERIES

The Martian surface has been subject to mapping activities since decades. However, the image data provided through past space missions were only suited to generate global map series in small or partly medium scales. The camera experiments aboard the Mars96 spacecraft (Albertz et al. 1996) will provide much higher resolution, stereo capability for photogrammetric evaluation and systematic coverage of the planet's surface. This is why the mapping potential will considerably exceed what has been possible so far. This is not only because of the regional and global coverage of stereo imagery and the availability of high precision DTM's but also due to a considerably improved geodetic control network. Thus, a completely new situation for mapping the planet in high-quality topographic maps can be envisaged.

In order to make best use of the image data and also to provide a qualified base for future thematic mapping new map series will be produced as soon as possible. According to the potential of the cameras and in particular the spatial resolution of the image data the scale 1:200 000 was selected as the primary scale for future mapping activities.

It is intended to make these maps available in colour or black & white. The production will make full use of the flexibility of digital image processing and computer-aided mapping. Thus the realization of the new map series provides a modular structure containing all parameters and digital regulations and standards for design, compilation and reproduction of any sheet of this new series, on every hardware standard defined for this project.

3. REFERENCE SYSTEMS

For the generation of a new map series geometric reference systems have to be defined, to which the applied map projections and the provided height information information (e.g. contour lines) refer.

The definitions for the mapping reference system have been subject to many discussions in the *Photogrammetry and Cartography Working Group* (PCWG) of the HRSC/WAOSS Science Team (Albertz et al. 1996). Finally it was accepted that the reference body will be

- for planimetry a bi-axial ellipsoid centered in the Martian center of mass and
- for heights a tri-axial ellipsoid centered also in the Martian center of mass.

The exact values for the axes which define the shape of the reference body will be defined and fixed prior to the processing phase.

4. CARTOGRAPHIC CONCEPT FOR THE NEW MAP SERIES

The guidelines for the new map series of the planet Mars have been subject to many vital discussions in the working group. As a result of these activities it was decided that an equal-area map projection should be applied. Finally the *Sinusoidal Projection* with its useful mathematical and graphical features was selected for this purpose, also because of its properties and the easy transition between the formats of the digital data and the printed maps.

The main attributes of the Sinusoidal Projection are:

- It is an equal-area projection.
- The central meridian is a straight line; all other meridians are shown as equally spaced sinusoidal curves.
- Parallels are equally spaced straight lines, parallel to each other.
- Scale is true along central meridian and along all parallels.

The polar regions however can not be mapped appropriately by the Sinusoidal Projection. Therefore the *Lambert Azimuthal Projection*, which is also an equal area projection, will be applied in the regions between 85° and 90° north and south.

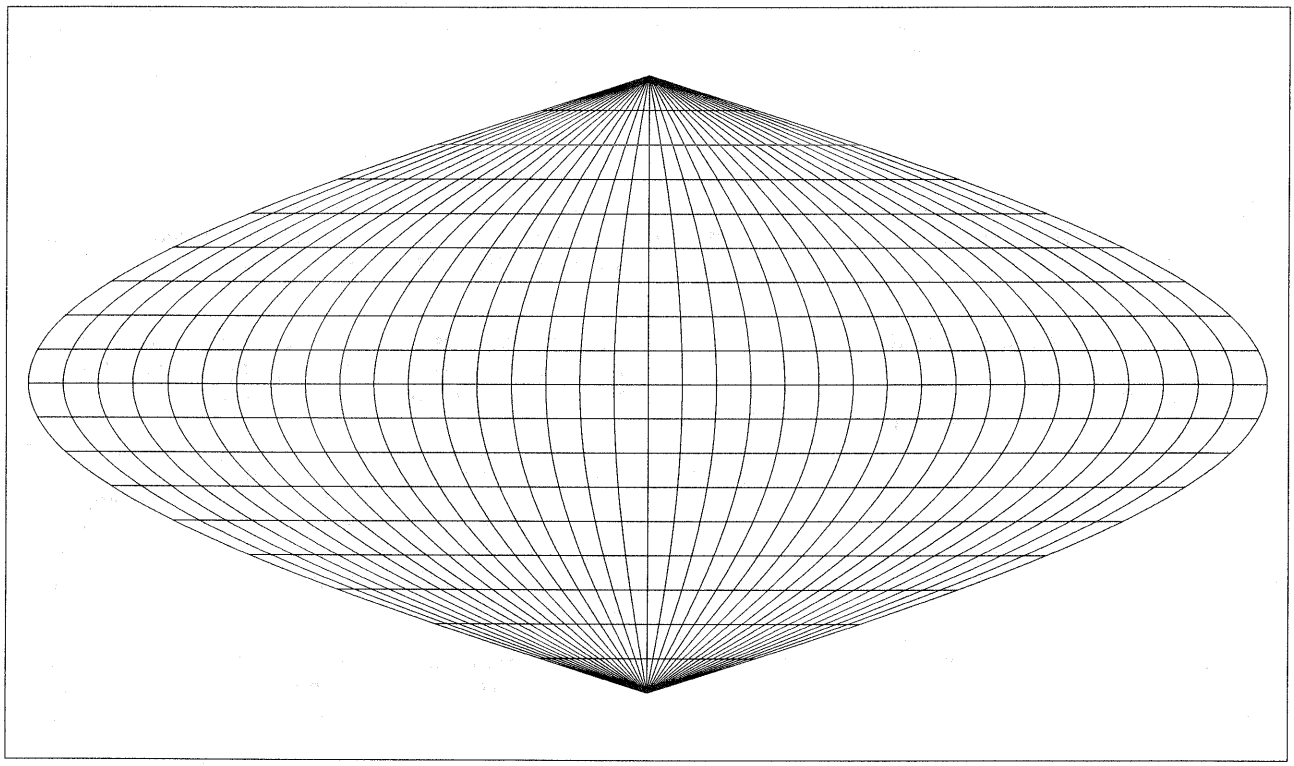


Fig. 1: Sinusoidal Projection for planet Mars, represented as a principle draft in map scale 1:130 000 000

The subdivision of the Martian surface into individual map sheets will follow the *planetographic* coordinate system (Albertz et al. 1996). Latitude and longitude degree values are stated in planetographic coordinates with the longitudes counting positive to the West.

However, for some purposes – especially if it is referred to the digital data – the *planetocentric* coordinate system can be useful. This is why the planetocentric coordinate system will also be integrated in the maps as a secondary system with the longitudes counting positive to the East.

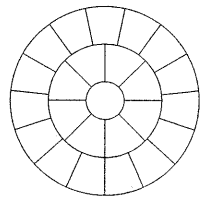
The selection of the map scale requires considerations of many different aspects. The scale of a map series has some serious consequences concerning the planimetric accuracy, selection of objects and generalization. And it causes the graphical efficiency of the cartographic representation and the structure with regard to the content. Finally, in this case, the appropriate map scale is directly interrelated with the resolution of the image data expected.

Following such aspects the primary map scale for the project has been defined to be 1: 200 000. This is a compromise considering the spatial resolution of the image data, i.e. up to 12 m for HRSC (*High Resolution Stereo Camera*,) and a variety of pragmatic aspects as well. One criterium was also that the scheme of the map series in 1:200 000 can easily be used as the basis for the generation of more detailed maps in the scales 1: 100 000 or 1: 50 000. The title of the new series will be:

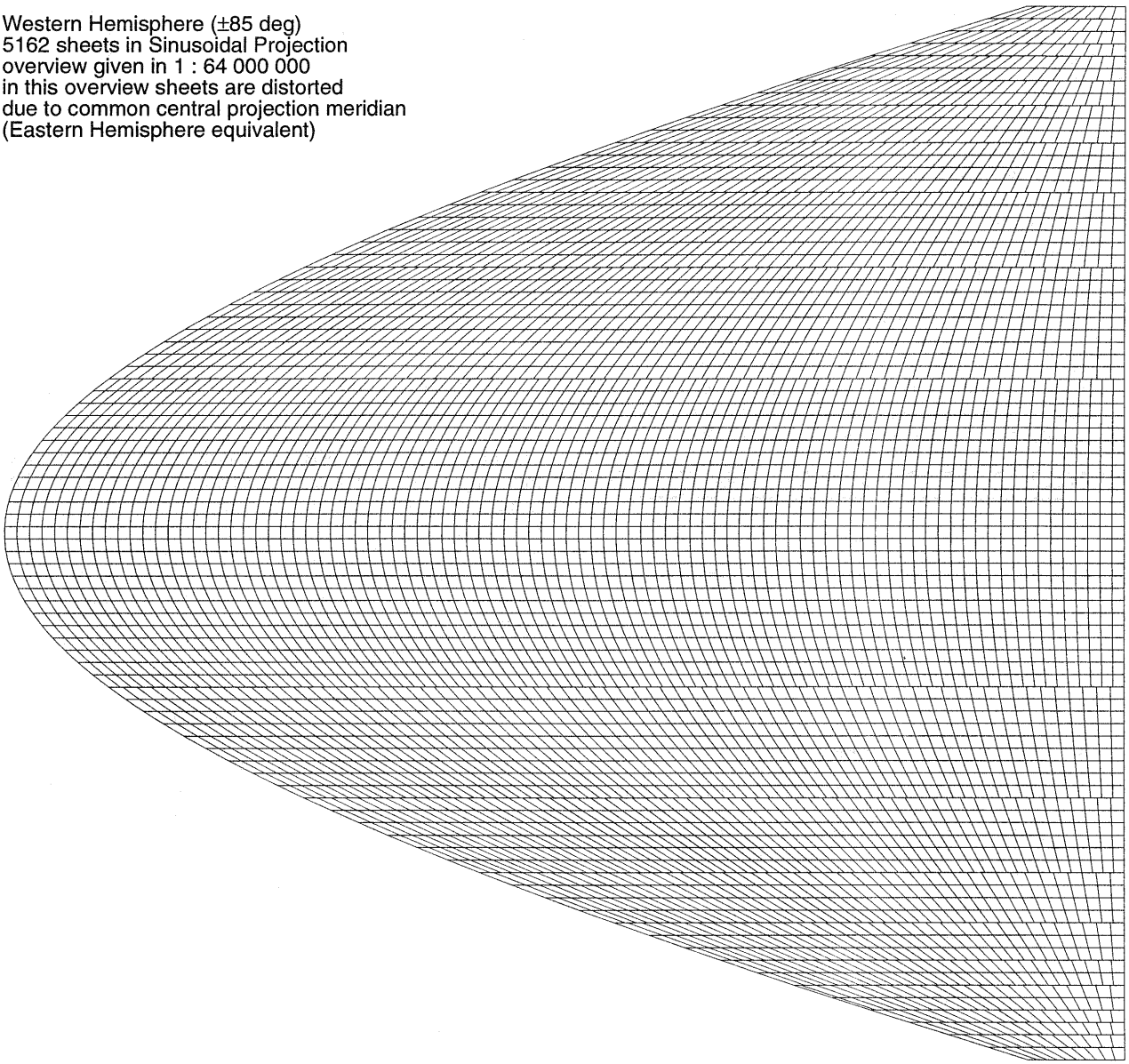
»Topographic Image Map MARS 1 : 200 000«.

Conventional line maps can not be useful under the topographic conditions of the Martian surface. Therefore the map will be produced as a *Topographic Image Map*, i.e. the basic information is the orthoimage, supplemented by topographical names and all necessary specifications with regard to the map frame and the entire marginal annotations. Furthermore, the image map will contain terrain relief informations in the form of contour lines and spot heights. The equidistance of the contour lines must

North Polar Region (85 - 90 deg north)
24 sheets
Lambert Azimuthal Projection
overview given in 1 : 24 000 000



Western Hemisphere (±85 deg)
5162 sheets in Sinusoidal Projection
overview given in 1 : 64 000 000
in this overview sheets are distorted
due to common central projection meridian
(Eastern Hemisphere equivalent)



South Polar Region (85 - 90 deg south)
24 sheets
Lambert Azimuthal Projection
overview given in 1 : 24 000 000

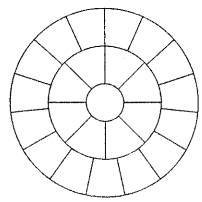


Fig. 2 : Sheet lines system for the proposed map series »Topographic Image Map MARS 1 : 200 000

be adapted to the regional topographic situations, because the relief energy of the planet's surface is varying enormously. It is intended to develop up to 4 suitable equidistance graduations for the contour lines. For best readability and optimal graphical effect a separate printing ink, or the color black should be used for the printing of contours.

5. MAP SHEET DEFINITION AND LAYOUT

In order to define the technical specifications of the map sheets, a variety of aspects has to be considered. The map format was determined due to ease of handling, costs and technical restrictions in the reproduction and printing processes. The latitude dimension was defined for all the map sheets – the sinusoidal and the azimuthal ones – to be 2 degrees. Considering the scale 1: 200 000 for Mars this results in map surfaces of 59.2 cm in height for the sinusoidal projected sheets, and about 62.2 - 62.4 cm (with curved parallels) for the azimuthal sheets. The longitude dimensions, however, depend on the latitudes and are varying for different latitude ranges. For practical reasons these ranges (Table 1) have been defined in such a way that the map sheet formats do not vary to much. The maximum of the mapped area will be 69.6 cm in width. Including the azimuthal projected polar sheets, the total number of map sheets will be 10,372.

Latitude Range	Longitude Range	Width in Map Scale
-1 – 25 deg	2 deg	59.2 – 53.7 cm
25 – 43 deg	2.5 deg	67.2 – 54.3 cm
43 – 55 deg	3 deg	65.1 – 51.1 cm
55 – 63 deg	4 deg	68.2 – 54.0 cm
63 – 69 deg	5 deg	67.5 – 53.2 cm
69 – 73 deg	6 deg	64.0 – 52.2 cm
73 – 77 deg	8 deg	69.6 – 53.6 cm
77 – 79 deg	10 deg	67.0 – 56.8 cm
79 – 81 deg	12 deg	68.2 – 55.9 cm
81 – 83 deg	15 deg	65.3 – 54.4 cm
83 – 85 deg	18 deg	65.3 – 46.7 cm
85 – 87 deg	24 deg	62.3 – 37.4 cm
87 – 89 deg	45 deg	70.1 – 23.4 cm
89 – 90 deg	360 deg	59.2 cm

Tab. 1: Map Sheet Definition for the northern hemisphere. Latitude dimension for every sheet is always 2 degrees. Longitude dimension is varying depending on different latitude ranges.

Definitive identification of each individual map sheet is provided by the assignment of a sheet-number following NASA's PDS (Planetary Data System) and by an additional sheet-name, probably, according to naming conventions set up by the IAU (International Astronomical Union).

The *planetographic* coordinate system is based on the quadrangle map principle. Representation of sheet lines and the graticule including the entire map frame, is printed in black for optimal recognizability. With respect to the latitude-depending width in degrees of the map sheet, the appropriate density of the graticule (longitudes) was also subject of discussion.

According to optimal usage for orientation and picking up of coordinates the integration of the grid lines should be layed out in such a way, that it is easy to recognize but the map content is disturbed as less as possible by the grid's graphical density. As a result the integration of the completely drafted longitude lines varies from every 0.5 degrees at the equator up to every 90 degrees at the polar areas.

Refering to the *planetocentric* coordinate system, its integration is graphically determined as a secondary net, dash-marked with its individual degree value in the map frame, and only by dash at the sheet's central meridian as far as the latitudes are concerned. Longitudes count in the opposite way compared to the planetographic system, however, the graticule lines are identical. Therefore the already given longitudes are labelled by a second well discernible number for the planetocentric degree values in a separate printing ink.

The generation of the »Topographic Image Map« requires the integration of graphical elements into the image. This a relatively new challenge for cartographical design. The traditional approach to separate graphical elements like letters from the topographical background can not be applied if image data are concerned, the image would be affected in an untolerable way. But is has been demonstarated in former studies that the high flexibility of digital image processing is helpful to solve the problem (Albertz et al. 1992b).

It can be derived from psychological knowledge that the integration of black graphical elements is better than white ones. In order to improve the recognizability of black graphics in dark image areas the image data can be modified through filter techniques in such a way, that a brightened seam around the graphical element is generated. It does not interrupt the image information but it enhances the recognizability of the graphics (Albertz 1993).

Thus the layout of map series is based on proven and traditional cartographic experience, new approaches and actual demands (designed as an easy readable representation of the terrain, paying attention to a pleasing and attractive appearence) and is closely connected with the potential and the technical standards for digital image processing also digital reproduction processes.

Another point of view is the requirement for a common paper format for the series with regard to a convenient individual map format. As result of the development the paper format was determined to be 70.0 cm in height and 83.0 cm in width. This format guarantees sufficient space for the map-frame, all the necessary marginal annotations and illustrations, and the title including the sheet number as well.

Figures 3 and 4 give an idea, how areas in different latitude ranges are represented and how marginal elements will be arranged on the map sheets.

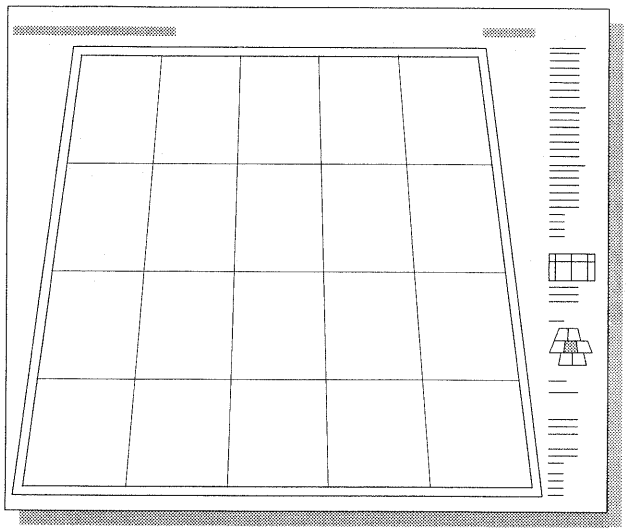


Fig. 3: Arrangement for map surface, map frame and marginal elements for a sheet, based on Sinusoidal Projection. Latitude range: 81 °- 83° north.

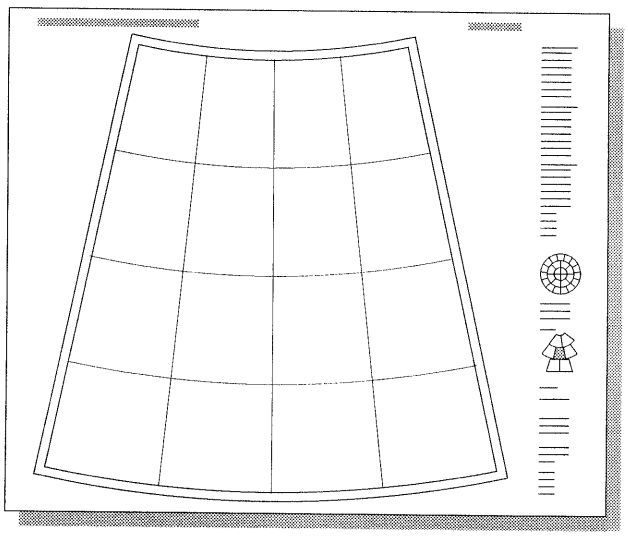


Fig. 4: Arrangement for map surface, map frame and marginal elements for a sheet, based on Lambert Azimuthal Projection. Latitude range: 85 °- 87° north.

A professional folding concept is also part of this map layout. The map sheet will be divided in seven parts in width and three parts in height, resulting in a handy size of 11.86 x 23.33 cm for the folded map. This allows optimal handling and storage characteristics.

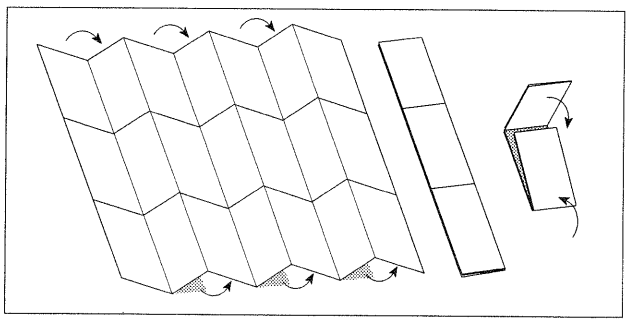


Fig. 5: Folding concept for the new map series

This concept incorporates the advantage of further space for a an efficient design for a separate front page. Furthermore this concept offers additional space on the backside of the folded map for necessary informations with regard to a »quick look« to editors, publishers, copyright, general technical notes and the maps purpose.

As a compromise concerning the costs for reproduction it is accepted to allow additional printing forms and impressions (1 - 4 colors) for the backside of a sheet in favour of the above mentioned advantages.

6. REALIZATION AND PRODUCTION

The complete production line for this map series is layed out as an entirely digital process. It comprises all cartographic processing steps such as compilation and nomenclature of the map content, the determination and placement of graphical elements (all names and symbols) within the mapped area, and the reproduction of the whole map frame and all the marginal elements, with its individual features, for every map sheet. The major part of the cartographic software has already been developed and successfully tested.

The »Topographic Image Map MARS 1: 200 000« was presented for the first time at the 7th meeting of the *Photogrammetry and Cartography Working Group* (PCWG) in Munich, as part of the HRSC/WAOSS Co-Investigator Team Meeting, on October 2 and 3, 1995. Mock-ups of selected sheets from different latitude ranges were displayed. The disign principles of this map series were generally accepted by the Working Group. Thus this layout will be the guideline for future mapping activities on planet Mars.

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