

# TRUE-3D VISUALIZATION OF THE MARTIAN SURFACE BASED ON LENTICULAR FOIL TECHNOLOGY USING HRSC IMAGERY

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### ABSTRACT:

Following the conceptual idea "from 3D camera to 3D view", the production of true-3D image maps for the glasses-free stereo-viewing of parts of the Martian surface, is described. The image data have been acquired by the DLR High Resolution Stereo Camera (HRSC) as a part of the Mars Express Mission of ESA. This multi-line scanner delivers digital multispectral scanner data of highest quality in a fore, aft and nadir mode, thus offering a perfect data set for true-3D visualization.

A true-colour image-line map in true-3D appears to cover both the requirements of the Mars research community and of the public best. In order to be able to view the map without viewing aids such as polarisation glasses the decision was made to generate it on the basis of lenticular lenses.

The present paper demonstrates the workflow from the georeferenced image data set and the DTM to a true-3D visualization. The technology used is based on the principle of lenticular foils. Micro-lenses on a transparent plastic foil allow the map user to view the integral of two or more interlaced strips of stereo-mates through this foil with the left and right eye respectively. The calculation of both the strip width and the interlacing is done by means of commercially available software.

Due to the interlacing of the sub-millimeter strips of the stereo-mates below each lenticular lens and the resulting decomposition in x-direction the integration of well-designed and easily legible signatures and letterings represent a challenge, both in terms of three-dimensional modelling and cartographic elaboration. Tests and approaches to overcome various constraints in order to generate optimized hardcopies are described.

To date, maximum formats of 60 cm x 90 cm oblong and 65 cm x 50 cm upright can be produced.

## 1. SCOPE

Based on unpublished studies carried out in the 1970ies and the 1980ies by Manfred Buchroithner, Dresden University of Technology, with probationers who were members of alpine climbing courses, it has to be stated, that roughly 60 % of all map users are not in the position to spontaneously derive information about the third dimension from topographic maps. This applies particularly to high-relief terrain. Based on the finding of these studies (which are still intended to be published in the near future) the prime author of this paper has been trying to develop methods which enable the map reader to spontaneously perceive the relief information with the unaided eyes, i.e. without the use of either anaglyph glasses, chromadepth glasses, or polarisation glasses.

In a first attempt a high mountain map based on a white-light transmission hologram (holo-stereogram) has been produced (Buchroithner, M. F., Schenkel, R., 1999; Buchroithner, M. F., 2000; Kirschenbauer, S., Buchroithner, M. F., 1999). However, it turned out that apart from the need of an illumination with coherent light, the production costs of such high quality holographic maps are exorbitant.

This led to the search of other, more appropriate and also cheaper methods for the generation of true 3D cartographic hard copies. Some years ago first attempts using the so-called lenticular foil approach have been carried out with quite some success. The positive echo caused by these first thumbnail specimens made us think of the generation of a larger format maps of high-relief terrain.

In preparation of the Mars Express (MEX) Mission which started in December 2003 several terrestrial test flights have been carried out. Apart from a test data set of Stromboli Island, the area around the internationally renowned Alpine Instruction and Training Centre of the Rudolfshuette of the Austrian Alps has been chosen for testing (Hauber, E., Jaumann, R., Wewel, F., Gwinner, K., Neukum, G., Slupetzky, H., 2000). An area of approx. 90 km<sup>2</sup> (7.7 km W-E und 11.5 km N-S) has been covered by a high quality data take of the High Resolution Stereo Camera (HRSC) developed by the Institute of Space Sensor Technology and Planetary Exploration of the German Aerospace Center DLR. This camera is actually a one-to-one pre-runner of the actual camera mounted on the Mars Space Probe. The imaging led to the production of a first image map.

Since this sensor is a digital three-line scanner with sensing capabilities for nadir, fore and aft looks, already three different views of the target area exist. This forms an excellent basis for the calculation of further views for the lenticular foil vision (cf. Chapter 4. Data Processing).

## 2. INPUT DATA

### 2.1 Topographic Base

As the major source of topographic information served the sheet "Mars" of the multi-lingual series of ICA Maps of the Planets and their Moons (Mars Map, 1999) plus other material out of which this maps has been compiled.

### 2.2 Remote Sensing Imagery

The imagery used has been acquired since January 2004.

The post-processing carried out at DLR Berlin-Adlershof includes in a first step the rectification of the single image strips based on DGPS and INS data. In the second step the image strips have been mosaiced to the whole image. In the case of HRSC it means, that the majority of the pixels displays synthetic radiometric values, calculated for the overlap areas of the strips which amount to nearly 50 percent across track.

Parameter	Value
detector type	THX 7808B
sensor pixel size	7 $\mu\text{m}$ x 7 $\mu\text{m}$
field of view per pixel (IFOV)	8.25 arcsec
active pixels per ccd line	9 sensors a 5184
radiometric resolution	8 bit
spectral filters	5 panchromatic, 4 colour
nadir, 2 stereo, 2 photometric	675 $\pm$ 90 nm
stereo angle of stereo channel	$\pm$ 18.9 $^\circ$
stereo angle of photometric channel	$\pm$ 12.9 $^\circ$
Blue, Green, Red, Near Infrared	440 $\pm$ 45 nm, 530 $\pm$ 45 nm, 750 $\pm$ 20 nm, 970 $\pm$ 45 nm
stereo angle of Red, NIR	$\pm$ 15.9 $^\circ$
stereo angle of Blue, Green	$\pm$ 3.3 $^\circ$
maximum scan rate	450 lines/s

Table 1. Technical data of HRSC Mars Camera, in part based on (Hauber, E., Jaumann, R., Wewel, F., Gwinner, K., Neukum, G., Slupetzky, H., 2000).

The original data, with their excellent ground resolution, have been resampled to an appropriate size which suits to the respective map product. The excellent radiometric properties of the imagery proved ideal for a true-colour depiction of this high-relief terrain.

## 3. MAP DESIGN

In order to reach an optimum balance between the area to be covered, the final geometric resolution of the remotely sensed

image data, and the available sizes of lenticular foils, the final formats of the actual map areas had to be chosen.

Due to the fact that an excellent image data material was at our disposal, already at an early stage the decision was made that the final product should be a so-called CIL (combined image-line) map, thus combining the advantages of a sort of photo-realistic depiction of the terrain in true-3D and the abstracted cartographic information (Buchroithner, M. F., Kostka, R., 1997). For further remarks on the lettering and other cartographic aspects see Chapter 5.

Based on the assessment of tentative map layouts, the final map designs with the title on the top, legend and overview map had to be determined. Some peculiarities in comparison with "normal" two-dimensional maps had to be considered. Since the lenticular foil will cover the whole map format including the margin special attention had to be paid to the legibility of all the collateral map information (imprint, legend, title, overview map). This process is determined by the initial image data resolution, the print resolution and the resolution of the human perception capability and led to a final map scales. The actual layout of the maps is slightly differing.

## 4. DATA PROCESSING

### 4.1 Geometric Modelling

Initially, some basic remarks concerning the geometry of lenticular foil true-3D maps shall be made. With reference to the renowned textbook by Okoshi1975 (Okoshi, T., 1976) and the paper by Buchroithner and Waelder (these proceedings; (Waelder, O., Buchroithner, M. F., 2003)), the ray geometry implied by the tunnel shape of the individual lenses can be derived from the Figures 1 and 2.

In contrast to classical parallax stereoscopy, for a high-quality true-3D representation based on lenticular technology, a number of stereomates significantly higher than two had to be calculated. In a way simulating an east-west airplane overflight a minimum of seven convergent views was generated. This is a prerequisite for a "smooth" viewing of a lenticular scene from different east-west directions. Further research in the optimisation of the lenticular techniques is planned.

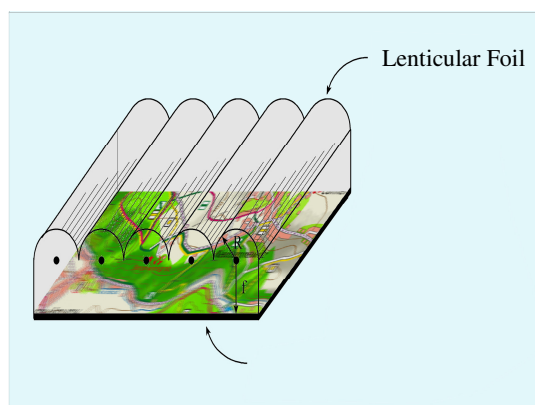


Figure 1. Scheme of lenticular foil principle.

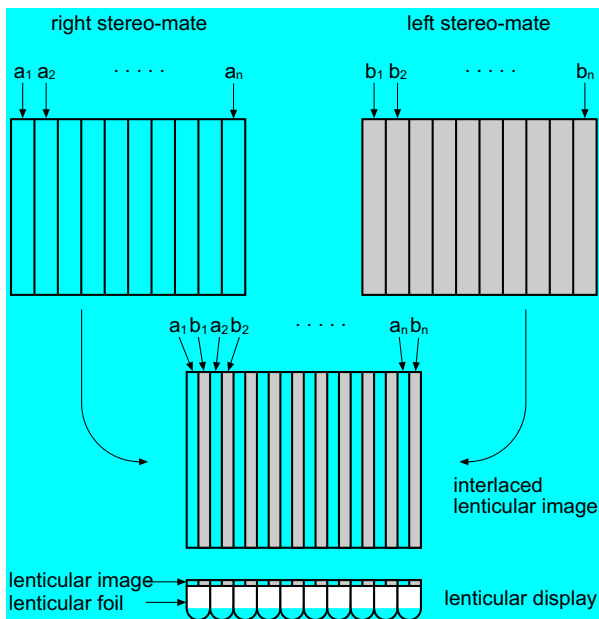


Figure 2. Interlacing of stereo-mates demonstrated with the simplest case of two perspective images only.

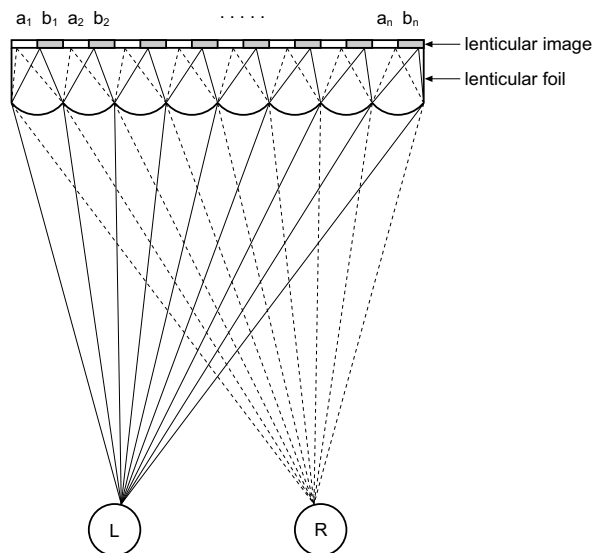


Figure 3. Principle of stereo-viewing using the true-3D lenticular foil technology.

3D outputs in digital and analogue form require an interface to existing modelling and output systems. The problem of the optimal matching the cartographic information with relief surface is discussed presently in MEX-Group. As far as these aspects are concerned, initial experiences with AutoCAD and 3D-StudioMAX have been gained. For high-quality hardcopies algorithms and methods have to be developed and tested which aim at the operational production of high-resolution 3D visualisations based on lenticular sheets.

The calculation of the single 3D-views was carried out by means of the software packages SCOP++ and SCOP classic (TU Vienna) for the image data and 3D Studio MAX for the vector data and cartographic names. The computation of both the strip width and the interlacing was accomplished using the

commercially available software MAGIC INTERLACER Pro 100, a plug-in for Adobe Photoshop.

#### 4.2 Graphic Modelling

An indispensable requirement for the generation of a homogeneous image map is the brightening of the shadows and cast shadows. Due to the fact that most of the shadow areas are represented by synthetically calculated pixels of the merged individual image strips, the generation of a shadow mask was not possible based on a rigid geometric calculation but had to be materialised by shadow classification. Subsequently, correlation parameters derived for certain reference areas were used to compute the “de-shaded” image portions in a way that still the slightly darkened radiometric features of the respective areas can be easily observed. Moreover, this enhances the relief perception, since this “synthetic shadow” serves as a sort of analytical hill-shading.

### 5. CARTOGRAPHIC WORK

One big advantage of a true 3D map based on the lenticular foil technology is, that the whole vector information, i.e. the map symbols and the lettering, in particular the geographic names, can be modelled in a way that they are not hiding the actual surface- (image texture) or relief information (elevation contours, spot heights) and seem to hover over the terrain, cf. (Buchroithner, M. F., 2000; Kirschenbauer, S., Buchroithner, M. F., 1999).

The software used for cartographic work is MACROMEDIA Freehand and 3D-StudioMAX.

### 6. CONCLUDING REMARKS

The major advantage of the map products described in this paper is that they can be viewed in true-3D with unaided eyes. Apart from frequently applied true-3D visualisations on digital displays, this hardcopy map has the big advantage that it can be easily moved and viewed by various persons simultaneously. This implies that it can also be moved, either as a whole or cut into partitions which are cloth-bound. The biggest advantage, however, is that this type of map needs neither a particular illumination like a hologram nor particular viewing means like anaglyph (red/green) glasses or similar. The combination of image data (artificial or natural) shading and - partly hovering - topographic line information yields an optimum for the map user. To this end, by combining all the above mentioned assets the described map type represents a novelty in the cartographic visualisation of the third dimension which yields tremendous benefits for all those who until now had serious troubles in deriving relief information. In this sense, it has an enormous potential for future applications both in topographic and thematic cartography.

Today, photogrammetric processing and cartographic work are supposed to be made completely digitally. As far as the production of lenticular foil maps is concerned, this is, however, a rather optimistic point of view. Still, for the generation of a high-quality graphic output of high-resolution 3D hardcopies interim steps of visual human quality control have to be foreseen. However, the transformation of digital 3D models into appropriate true-3D maps shall be automated as far as possible.

## 7. ACKNOWLEDGEMENTS

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