LOCAL AND GLOBAL NETWORKS FROM MARS96 HRSC AND WAOSS IMAGERY;
H. Ebner, T. Ohlhof, Chair for Photogrammetry and Remote Sensing, Technical University Munich,
Email: timm@photo.verm.tu-muenchen.de

SUMMARY. For the forthcoming Mars96 mission a procedure for high quality point determination
based on an extended, physically consistent bundle block adjustment has been developed and verified using
simulated and practical data. The procedure serves to reconstruct the exterior orientation of the two stereo
cameras HRSC (High Resolution Stereo Camera) and WAOSS (Wide-Angle Optoelectronic Stereo Scanner),
to improve the existing Mars control network in accuracy and density, and to determine non-photogrammetric
model parameters, e.g. the Mars rotation parameters, more accurately.

MARS96 HRSC/WAOSS EXPERIMENT. The Russian Mars96 spacecraft is scheduled for
launch in November 1996. The German stereo cameras HRSC and WAOSS are some of the most important
instruments of the spacecraft. They will be operated in a highly elliptic Mars orbit to image the planetary
surface at local, regional and global scale. From the recorded imagery the terrain surface will be reconstructed
3-dimensionally by photogrammetric means.

The photogrammetric evaluation of the HRSC/WAOSS data starts with the precise reconstruction of
the exterior orientation of the images and the determination of ground points on Mars within the scope of
a bundle block adjustment. Besides image information represented by a large amount of conjugate points
which are measured automatically, control information is required for point determination. Due to the lack
of accurate ground control points and navigation systems like GPS or INS, orbit and attitude determination
of the Mars96 spacecraft are of high importance. The orbit determination is based on range and Doppler
tracking between the Mars96 spacecraft and ground stations on Earth, and attitude information is derived
from gyro readings and images taken by a star camera. A detailed description of the HRSC/WAOSS
experiment and the photogrammetric processing chain is given in [1] and [2].

In order to properly utilize the image information contained in conjugate point coordinates and the
orbit information contained in tracking data, both data types have to be evaluated in a combined adjustment
process. To this end, the conventional bundle block adjustment algorithm is supplemented by a rigorous
dynamical modeling of the satellite motion to take orbital constraints into account [3]. For the first time orbit
determination results are rigorously incorporated into the bundle block adjustment, which is equivalent to a
combined adjustment of tracking and image data. The proposed concept guarantees the proper utilization
of orbit information in the bundle adjustment and, vice-versa, enables the use of image information to
improve the orbit determination and to support the estimation of scientific parameters (e.g. Mars rotation
parameters).

LOCAL, REGIONAL AND GLOBAL POINT DETERMINATION. The point de-
termination (PD) on Mars will be carried out at local, regional and global levels (Table 1). The interior
accuracy of PD results from a local datum definition using the method of free adjustment. The exterior
accuracy of PD is related to the global Mars-fixed reference system. Comprehensive computer simulations on
local, regional and global PD have been performed to obtain a survey of the attainable interior and exterior
accuracies and to give recommendations in the planning phase of the Mars96 mission [4]. The results of
these simulations are summarized in Table 2.

The local PD is based on HRSC images, which will be acquired around the periapsis with 12-20 m
ground pixel size. The accuracy mainly depends on the number, distribution and precision of conjugate
points and benefits from the high relative accuracy of the orbit and attitude data. If the full imaging
capability of HRSC is utilized, an interior accuracy of 5 m in planimetry and 10 m in height can be obtained.

A large number of simulation runs on regional PD have shown that most accurate results can be achieved
by combining HRSC and WAOSS data and by the simultaneous block adjustment of multiple overlapping
strips with ≥60% side lap and additional crossing strips at the borders of the block.

Since WAOSS will image the entire planet, a global block with complete overlap in all directions may
be processed under ideal circumstances. Because of the extraordinary strength of the closed block and based
on the complete image, orbit, attitude and ground control information, an exterior accuracy of 70 m in
planimetry and height can be achieved.
LOCAL AND GLOBAL NETWORKS FROM MARS96 IMAGERY: Ebner H., Ohlhof T.

<table>
<thead>
<tr>
<th>Images</th>
<th>Local PD</th>
<th>Regional PD</th>
<th>Global PD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Datum definition</td>
<td>HRSC local</td>
<td>HRSC, WAOSS local or global</td>
<td>WAOSS global</td>
</tr>
<tr>
<td>Block configuration</td>
<td>single strips; small blocks of overlapping strips moderate</td>
<td>large blocks of many overlapping strips high</td>
<td>closed block covering the entire surface very high</td>
</tr>
<tr>
<td>Computation effort</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Local, regional and global point determination (PD) on Mars and their characteristics

<table>
<thead>
<tr>
<th></th>
<th>Local PD</th>
<th>Regional PD</th>
<th>Global PD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interior Accuracy</td>
<td>$\mu_X[m]$</td>
<td>$\mu_Y[m]$</td>
<td>$\mu_Z[m]$</td>
</tr>
<tr>
<td>Local PD</td>
<td>5</td>
<td>10</td>
<td>—</td>
</tr>
<tr>
<td>Regional PD</td>
<td>15</td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>Global PD</td>
<td>—</td>
<td>70</td>
<td>70</td>
</tr>
</tbody>
</table>

Table 2: Attainable planimetric and height accuracies ($1\sigma$) of adjusted object point coordinates for the local, regional and global PD on Mars

In case of the global PD, special emphasis is given to the Mars rotation parameters, which define the link between the Mars-fixed object coordinate system as the reference frame for photogrammetry, and the inertial Earth equator and equinox of J2000 coordinate system as the reference frame for orbit determination. The Mars rotation parameters contain the right ascension $\alpha_0$ and declination $\delta_0$ of the Mars north pole, the longitude $W_0$ of the prime meridian with respect to the IAU vector at the reference epoch J2000, the rotation rate $\omega$, and the Mars precession rate $\psi$. Here, the IAU vector is defined as the intersection line of the planes described by the Earth equator of J2000 and the Mars equator.

By combining image and tracking data, as described above, the Mars rotation parameters may be treated as estimation parameters within the bundle adjustment. It can be seen from Fig. 1 that the accuracies of the Mars rotation parameters in the global block adjustment can be improved up to factor 4.

In summary, it can be stated that the synergy effect of image and orbit information is most effective, if many orbital arcs are processed simultaneously in a block of high geometric strength. It can be expected that the accuracy of the current ground control network of Mars will be improved by a factor of 10 or more.