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The Airborne HRSC-A: Performance Results and Application Potential

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ABSTRACT

The High Resolution Stereo Camera – Airborne (HRSC-A), a multispectral multi-line/multi-stereo scanner system, developed at the German Aerospace Center DLR, has been successfully applied in many flight campaigns during the past two years. Together with a comprehensive software package for automated photogrammetric processing it has been used for many investigations in different disciplines. This paper describes the main characteristics of the entire HRSC-A hard- and software system and gives an impression on typical products.

1. INTRODUCTION

The High Resolution Stereo Camera - Airborne (HRSC-A) is a further developed airborne version of the HRSC, which was designed for the exploration of planet Mars by the international space mission Mars96 (Neukum & Tarnopolsky, 1990; Albertz et al., 1992; Neukum et al., 1995) and will now be flown on the European Mars Express mission in 2003 (Neukum et al., 1999). During the past two years the HRSC-A has been applied very successfully in Earth observation in many different flight campaigns (Lehmann et al., 1998). In combination with the photogrammetric software processing system, developed in cooperation between the German Aerospace Center DLR and the Technical University of Berlin, it is the world´s first operational opto-electronic high resolution and multispectral image acquisition and 3D-processing system, providing image and 3D-data products with relative accuracies of about 10-15 cm and absolute accuracies of about 20-25 cm from a flight altitude of 3 000 m (Wewel et al., 1999).

2. DATA ACQUISITION

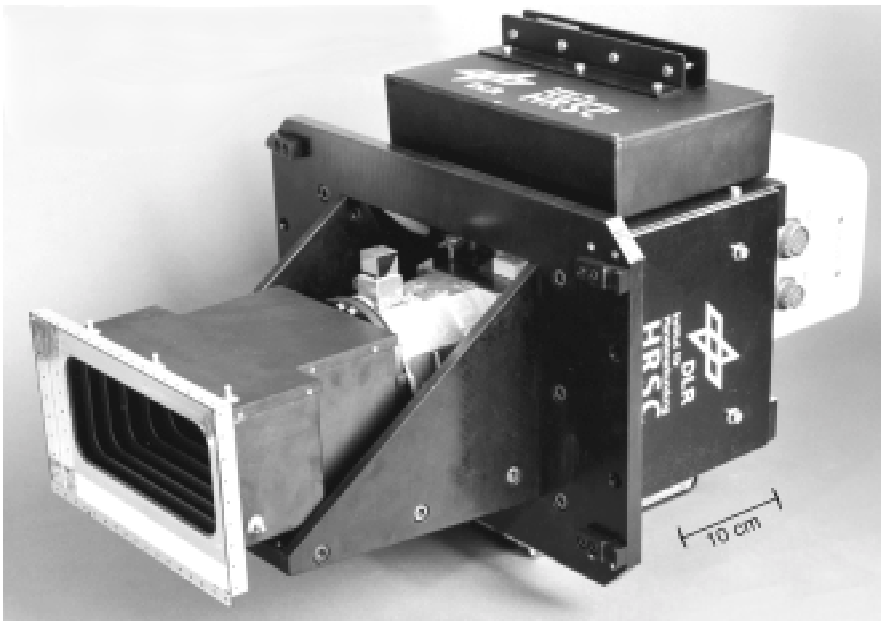

Figure 1: The High Resolution Stereo Camera – Airborne (HRSC-A).

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Digital data acquisition, the consequent step to a new era in photogrammetry, is extremely demanding on imaging systems. Since digital large-format framing cameras for photogrammetric purposes will not be available on an operational basis within the next five or more years, digital line cameras can fill this gap. At the DLR Institute of Space Sensor Technology and Planetary Exploration, the HRSC-A (Figure 1) was developed as a multispectral multi-line/multi-stereo scanner system. According to its development for space missions, the camera has small dimensions, low mass, low power consumption and a robust design. Some additional electronics have been added to meet specific airborne requirements (Table 1).

HRSC-A/QM Technical Parameters	
Focal Length:	175 mm
Total Field of View:	37.8° x 11.8°
Number of CCD Lines:	9
Stereo Angles:	±18.9° and ±12.8°
Pixels per CCD Line:	5184 (active)
Pixel Size:	7 µm
Radiometric Resolution:	10 bit reduced to 8 bit
Scan Rate:	max. 450 lines/s
Mass:	camera 12 kg (32 kg incl. subsystems)

Table 1: HRSC-A Technical Data.

The HRSC-A fulfils the radiometric and geometric requirements of an operational photogrammetric camera system, i.e. precise geometric calibration, high resolution (10 cm/pixel resolution on ground from an altitude of 2 500 m) and multispectral imagery (4 CCD lines for color channels in red, green, blue and infrared), multi-stereo capabilities (5 CCD lines providing stereo angles of ±18.9°, ±12.8° and high resolution at 0°) and a high-end GPS/INS hard- and software system for high-frequent and high-accurate measurement and post-processing of orientation data.
The 9 CCD lines are mounted in parallel behind one single optics, thus yielding 9 simultaneously (along-track) recorded superimposed image swaths. To optimize image radiometry, the recording levels of the individual channels are controlled separately by adjustable gain factors. Data rates of 10 MByte/s provided by four parallel signal chains are stored on a high-speed tape recorder. The camera is mounted on a stabilized platform (Zeiss T-AS) in order to damp mechanical vibrations and to enforce near-nadir viewing. Position and orientation during flight navigation are measured continuously by means of an Applanix integrated navigation system (Hutton & Lithopoulos, 1998) including a GPS receiver and a strap-down inertial navigation system (INS). The INS is mounted directly on top of the sensor unit. With this INS the camera position can be determined after post-processing with an accuracy of ±2-3 cm, while the angular accuracy of the sensor orientation is ±0,004° for roll and pitch and ±0,008° for yaw with a data rate of 200 Hz.

3. DATA PROCESSING

A completely automated procedural software system (Figure 2) has been built up for photogrammetric processing, comprising components for the derivation of Digital Elevation Models (DEM), orthoimages and high-resolution color orthoimage mosaics (Wewel et al., 1998). It makes use of a set of systematically preprocessed image, orientation and calibration data. One of

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the fundamental qualities of the HRSC-A, besides its high resolution and multispectral capabilities, is its multiple stereo capability.

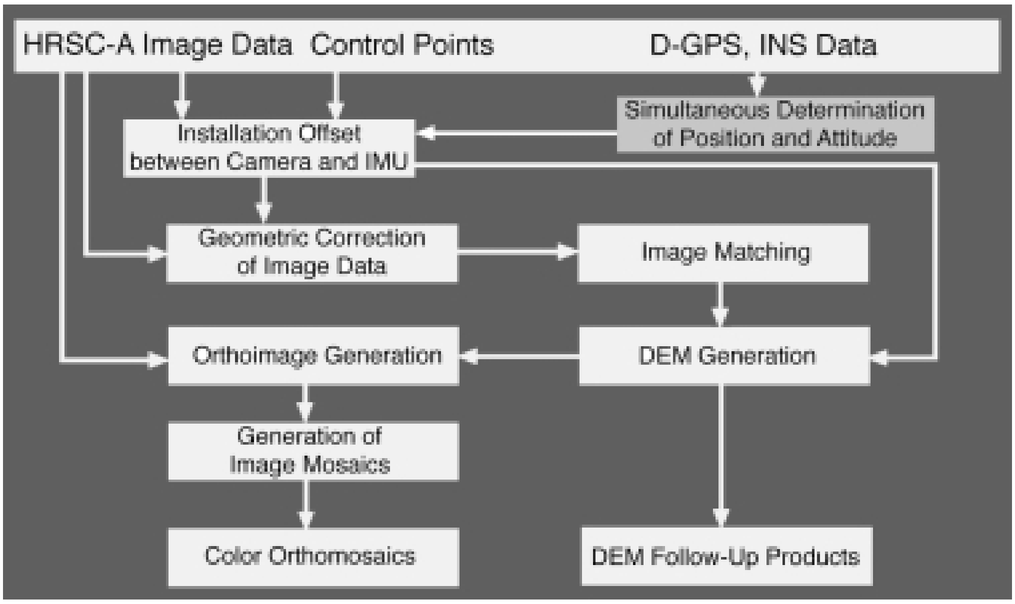

Figure 2: Photogrammetric Processing Line for HRSC-A.

Due to the five different stereo angles, a nearly gapless 3D-data evaluation can be performed even in urban areas, where gaps are more likely to appear with systems providing only two stereo observations. Since there are up to five rays defining an object point, it is also possible to estimate point accuracies and to use these estimates for the automatic detection and elimination of blunders, which is essential for the generation of reliable high-quality 3D-products. A thorough geometric validation of the entire HRSC-A hard- and software system has been performed over different test sites (Wewel & Brand, 1999). According to the mean intersection accuracy, a mean relative point accuracy of ±10-12 cm was achieved, while the mean absolute accuracy, derived from 120 independent ground control points, was determined as ±23 cm corresponding to mean vertical and horizontal accuracies of ±18 cm and ±13 cm. These results, based on the directly measured exterior orientation data, have been derived without any improvement through bundle adjustment.

4. APPLICATIONS AND PRODUCTS

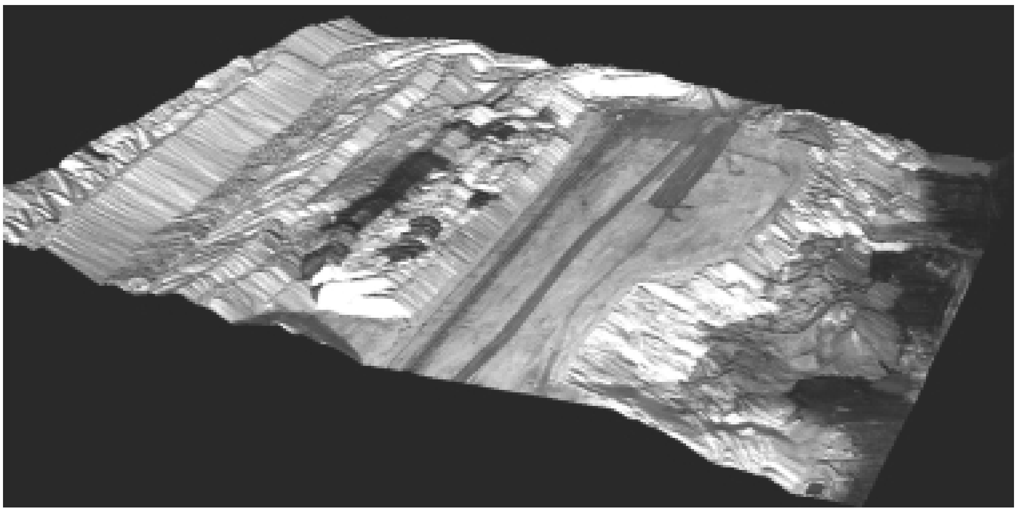

Figure 3: Perspective view of an open coal mining site (Hambach, Germany).

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Since the first airborne experiments (May 1997), the HRSC-A system has been used for a variety of different applications. High resolution multispectral orthoimages and DEM data have been acquired simultaneously for applications as different as volcano monitoring, mapping of urban areas, of flood hazards, of open coal mines (Figure 3) and of coastal zones.
The derivation of morphological characteristics such as slopes, volumes, or drainage patterns through the analysis of Digital Elevation Models is an essential step for many geoscientific and environmental applications. DEM analysis frequently is combined with the analysis of remote sensing imagery, e.g. to classify and measure topographic changes related to volcanic activity, landslides or avalanches. Planning requirements for urban areas increasingly involve GIS technology, e.g. using 3D models for the needs of the mobile phone service of telecommunication industry. Figure 4 shows an application example of a joint ISTAR/DLR project for HRSC-A application in the telecommunication market (Renouard & Lehmann, 1999). The need for both high resolution multispectral images and DEM data can be addressed by airborne digital imaging with the HRSC-A.

Figure 4: Portion of a shaded DEM of Lisbon (Portugal),
processed by ISTAR (France) using HRSC-A Data.

The potential of the the HRSC-A system for photogrammetric surveys in urban areas has been shown in its operational use at several European cities. Specifically, the availability of five stereo observation angles is beneficial for the measurement of man-made objects typically including steep surface discontinuities. Again, DEMs as well as orthoimage mosaics with 15-20 cm resolutions and accuracies have been derived automatically, even for areas greater than 200 km^2.
In May 1997, a flight campaign at the Aeolian Islands (Italy) was carried out to assess the potential of this new data source for applications in volcanology and comparative planetology (Gwinner et al., 1999). Although using a lower level GPS/INS system, impressive products, such as orthoimage mosaics in color, detailed DEMs, shaded relief maps and 3D-perspective views, have been derived for Vulcano Island (21.2 km^2) in resolutions of 0.25-1.0 m from an altitude of 5 000 m (Figure 5).

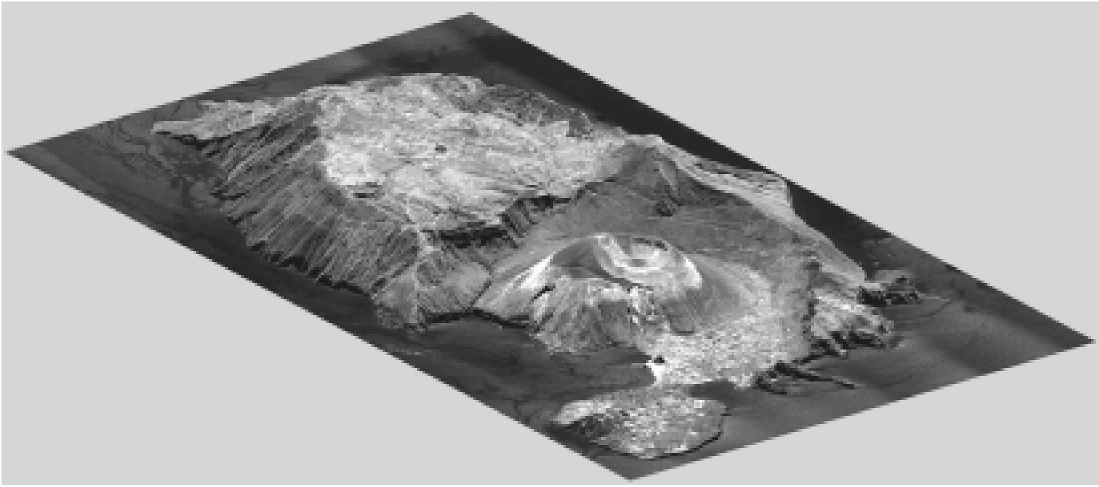

Figure 5: HRSC-A Perspective View of Vulcano Island (Aeolian Islands, Italy).

The cartographic potential of the system was demonstrated by the generation of a map sheet of the Image Map 1:5 000 series of the city of Berlin in cooperation with the "Senatsverwaltung für Bauen, Wohnen und Verkehr, Berlin". Due to the high resolution, the image data can be used also for large scale applications (up to scales of 1:500).

5. CONCLUSIONS

The hardware and electronical qualities of the HRSC-A camera in combination with the comprehensive automated photogrammetric software system define a worldwide unique completely digital photogrammetric camera system, developed and proved in detail and already in operational use. It marks the beginning of a new era of aerial photogrammetry.

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