

## **High Resolution Digital Surface Models and Orthoimages for Telecom Network Planning**

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### **ABSTRACT**

DLR of Germany and ISTAR of France have joined forces to apply space technologies to the acquisition and processing of a new kind of airborne data for Telecom network planning applications. Image data are acquired using the HRSC stereo camera, based on an instrument developed for the 1996 Russian Mars mission, and processed using software developed to produce digital terrain models and orthophotos from satellite imagery.

### **1. INTRODUCTION**

German national aerospace centre DLR developed the optoelectronic High-Resolution Stereo Camera for the 1996 Russian Mars mission, then a modified version for airborne remote sensing. The HRSC airborne camera is the first to combine high resolution, photogrammetric accuracy, all-digital acquisition, and multispectral stereo.

One of the challenges associated with the operational use of the HRSC camera is how to process the massive volumes of data. In late 1998, ISTAR first processed HRSC data using its SPOT3D software suite. These tests showed that ISTAR could meet the processing requirements and handle the large volumes of data. The tests further demonstrated the processed data's considerable potential for meeting geographic information needs in general and telecom operators' network planning requirements in particular.

This success and the scale of the potential applications prompted DLR and ISTAR to set up a joint programme to acquire and process HRSC mapping data, formally announcing their decision in May 1999.

The partnership between the DLR's Institute of Space Sensor Technology and Planetary Exploration, headed by Prof. Dr. Gerhard NEUKUM, and ISTAR of France is governed by a three-year agreement covering cooperation and R&D. Both partners see the programme as an essential component of their long-term strategies.

This programme represents a major technological and industrial breakthrough in remote sensing and aerial photogrammetry as it combines a new sensor and proven expertise in 3D digital image processing and software. ISTAR's SPOT3D software suite is currently one of the few capable of processing HRSC imagery to yield 3D digital models and true 25-cm orthoimages on a large scale. These products are expected to attract strong interest from companies requiring large-scale precision urban models for the optimization of point-to-point and point-to-multipoint networks, including micro-cellular networks.

### **2. DATA ACQUISITION SYSTEM**

Extensive testing has demonstrated that the HRSC system is ideal for photogrammetric and general remote sensing applications in that it combines high resolution, satellite quality imaging, with the flexibility of an airborne platform. It has been shown to be thoroughly operational. Advantages over

film-based airborne cameras include: quick access to digital data, high radiometric resolution, 5 stereo/photometric bands and 4 multispectral bands from blue to near IR.

The HRSC features linear arrays, each comprising 5,184 charge-coupled device (CCD) detectors. Nine CCD arrays, mounted in parallel in the instrument focal plane, acquire successive scanlines as the aircraft flies over the terrain. Five arrays acquire panchromatic stereo and photometric imagery while the four remaining arrays are fitted with filters to acquire multispectral imagery. The camera is extremely sensitive to variations in light intensity, allowing aerial mapping to continue under a wide range of weather conditions.

Whereas the geometry of satellite-based imaging instruments is ensured by the regularity of the platform's trajectory over the terrain, the HRSC system uses a precision position and orientation system (POS) to compensate for platform motion. Another key consideration is the camera's mechanical and thermal stability, which ensure that it remains perfectly calibrated under normal operating conditions.

Aside from the camera, the HRSC data acquisition system comprises: Sony 32-Mbyte/s digital tape recorder, Applanix precision position and orientation system (POS) combining an inertial navigation system and differential GPS, and Zeiss gyro-stabilized platform.

At an airspeed of 250 km/h (70 m/s), the camera acquires data at 7 Mbytes/s (5,184 pixels/scanline x 450 scanlines x 3 views). Each tape holds 50 Gbytes, or 2 hours' acquisition time, and it takes just 5 minutes to change tapes in flight.

The camera's three viewing angles ( $-19^\circ$ ,  $0^\circ$  and  $+19^\circ$ ) result in forward, nadir and backward views (see Fig. 1). For a survey altitude of 6,000 m, the pixel size is 24 cm and accuracy 20 cm rms in x and y and 30 cm rms in z. The instrument can be flown higher for increased coverage, at the cost of resolution, or lower for increased resolution.

In addition to the along-track overlap provided by the camera's forward, nadir and backward views, ISTAR has adopted a data acquisition strategy guaranteeing 50% sidelap between adjacent strips. The resulting multiple redundancy of the data gathered during each survey contributes to improved stereo processing and more reliable checking and correcting of anomalies.

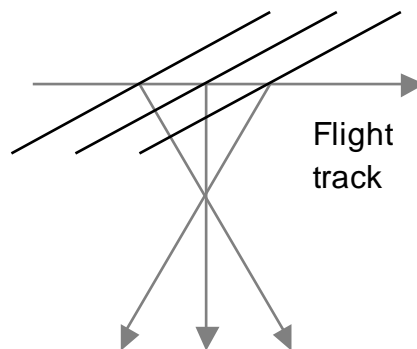


Figure 1: Acquisition of forward, nadir and backward views by HRSC camera.

### 3. DATA PROCESSING

Since 1988, ISTAR has steadily developed and expanded its core skills in digital terrain modelling and geographic data packages. Today, the company offers industrial-scale facilities and the capacity to process huge volumes of 3D image data on a routine basis.

In 1995, ISTAR focused its energies on the special needs of telecoms operators. The company quickly went on to launch a range of map products (satellite image maps, orthoimages,

ClutterMaps, linear network maps, etc.) and custom data packages tailored to this market's specific needs.

To meet the needs of clients requiring higher resolution, ISTAR also began processing digitized aerial photographs acquired using conventional photogrammetric cameras. This work enabled the company to further refine and expand its core skills in digital terrain modelling and geographic data packages.

Following the success of the first tests on HRSC data in late 1998, ISTAR developed the following five-step process for industrial-scale processing:

1. Read and preprocess HSRC output to generate radiometrically corrected "raw" imagery.
2. Resample strips (i.e. forward/nadir/backward views and adjacent views) using POS data to obtain views in epipolar geometry.
3. Correlate stereo images to obtain one DSM per stereopair, then merge the resulting DSMs to obtain a DSM on a 1-metre grid.
4. Resample raw imagery using DSM to obtain true 25-cm orthoimages.
5. Manually edit DSM, depending on client's needs, to obtain a digital terrain model and/or building vector database.

The first step uses software developed by DLR. Steps 2 to 5 are performed by ISTAR using its own facilities, software and methods. Step 5 involves optional labour-intensive tasks tailored to the client's needs. Note that, in contrast with conventional stereo-photogrammetry, and with the one exception of step 5, all data processing is fully automatic, which is to say, without human photointerpretation.

To get an idea of the data volumes involved in the process: a ground area of 200 km<sup>2</sup> generates 32 Gbytes of HRSC data input plus 3.2 Gbytes for the DTM and the true orthoimage. For those familiar with satellite imagery, the correlation of 200 km<sup>2</sup> of HRSC imagery represents about 100 times the processing required to correlate a Spot stereopair covering 60 x 60 km<sup>2</sup>.

Key data processing steps are illustrated in sections 3.1 to 3.4 below.

### 3.1. Read and preprocess HRS C output

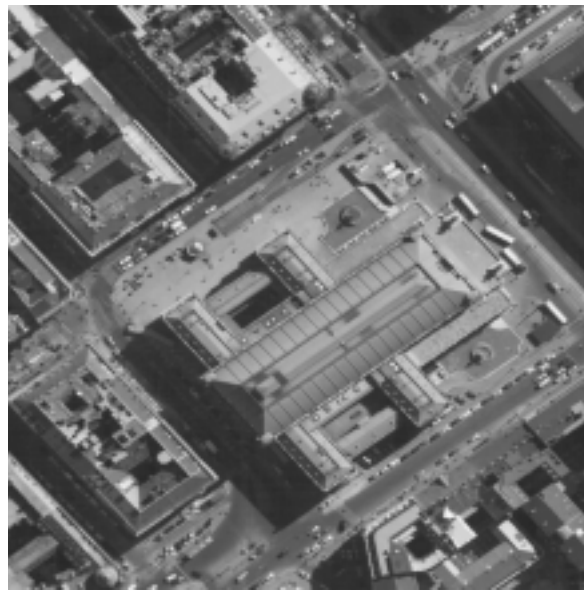
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Figure 2: Radiometrically corrected "raw" imagery: Forward, nadir and backward views.

### 3.2. Resample views

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Forward view

Nadir view

Figure 3: Images are resampled to obtain views in epipolar geometry.

### 3.3. Correlate stereo images and merge resulting DSMs

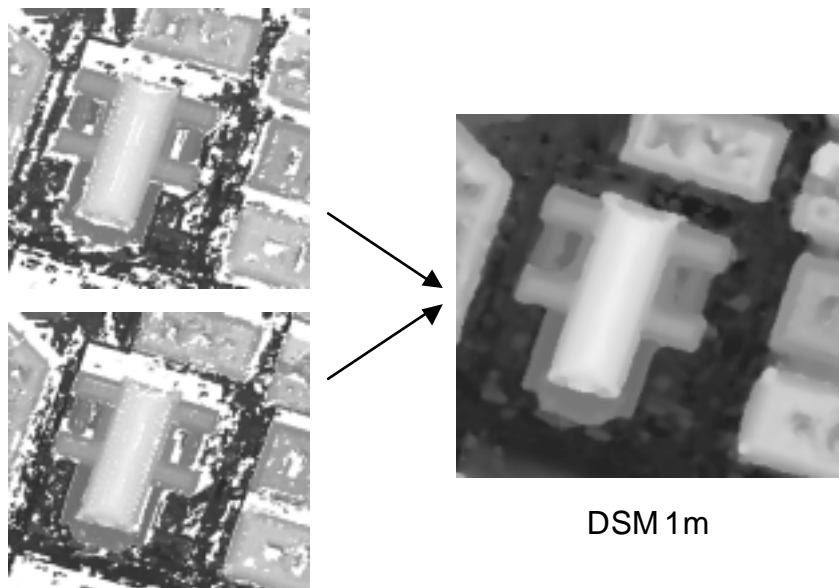
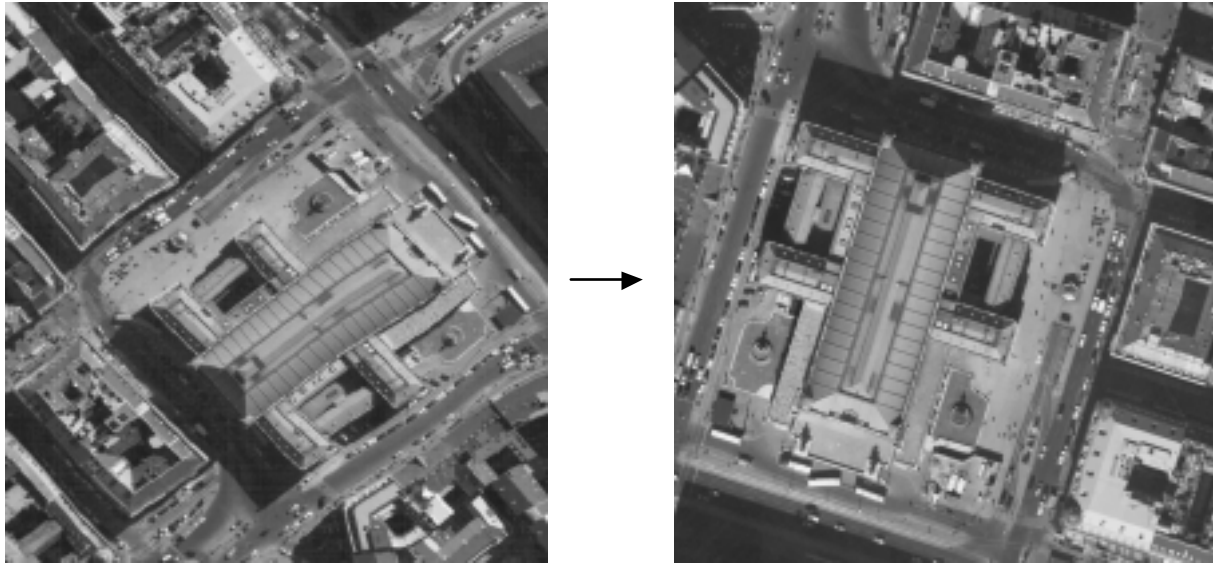


Figure 4: Stereo views in epipolar geometry are correlated, then unit DSMs are merged to obtain a DSM on a 1-meter grid.

### 3.4. Resample raw imagery in true orthoimage geometry

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Raw imagery

True Orthoimage, 25cm

Figure 5: Raw imagery is resampled using the DSM to obtain a true 25-cm orthoimage.

This process is slightly more complex than conventional orthorectification in that ground-level surfaces (roads, fields, etc.) are rectified at ground elevation while roofs are orthorectified at roof elevation, thus ensuring the precision planimetric positioning of all features, irrespective of height.

ISTAR processes HRSC data using its own SPOT3D software suite, a Sony 8-Mbyte/s recorder for data entry and a cluster of 25 Sun workstations for data processing.

To process an HRSC survey of a city covering 200 km<sup>2</sup> takes about 50 hours using 25 Sun workstations, giving ISTAR a production capacity of about one city per week.

## 4. DATA ACQUISITION CAMPAIGNS AND FUTURE PLANS

In early 1999, DLR and ISTAR decided to survey 43 cities in 12 European countries.

Additional campaigns will be organized when DLR makes two additional cameras available in the fourth quarter of 1999 : HRSC-A with a resolution of 25 cm at 6,000 m and stereo imaging in five panchromatic bands plus four multispectral bands (blue, green, red and near IR), and HRSC-B with a resolution of 1 m at 6,000 m and stereo imaging in three panchromatic bands plus two multispectral bands (B1 and B2).

HRSC-A will be used to acquire 25-cm 3D data of city centres while HRSC-B will acquire 1-m-resolution data of suburban areas and city environs.

In 2000, DLR and ISTAR will use the HRSC-A camera to acquire imagery of 100 cities in Europe and the United States producing DSMs on grids from 2 to 5 m with an rms accuracy of 1 m. Products will include building vector databases and true 25-cm orthoimages in colour or B&W.

The wider-angle HRSC-B will be used to survey selected areas totalling 500,000 km<sup>2</sup> in Europe and the United States and produce DSMs on 5-m grids with an rms accuracy of 2 m. Products will include true 1-m orthoimages (panchromatic or multispectral).



## 5. CONCLUSION

ISTAR and DLR have successfully transferred new know-how in imaging instrument design and data processing from satellite-based remote sensing to conventional photogrammetry. Practical experience acquired to date suggests that these technologies have the potential to revolutionize aerial surveying and photogrammetry, with RF network planning expected to prove a major early application.



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Figure 6: Perspective view of Lisbon, Portugal (Resolution: 0.5m) Main alignment, from top: *Avenida da Liberdade, Praça do Marquês de Pombal, Parque Eduardo VII.*