SPACE SHUTTLE RADARGRAMMETRY RESULTS

F. Leberl, G. Domik
Vexcel Corporation
Boulder, CO 80301

J. Raggam
Graz Research Center Joanneum
A-8010 Graz, Austria

J. Cimino, M. Kobrick
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA 91109

EXTENDED ABSTRACT

The Space Shuttle has contributed an array of radar images in the two missions that were thus far flown with the Shuttle Imaging Radar (SIR). The November 1981 mission produced the SIR-A experiment with fixed look angles and purely optical processing; the October 1981 mission included the SIR-B experiment with data with various look angles off-nadir. The scope of SIR-B called for a large data set, larger than what was actually achieved. However, a number of radargrammetric experiments were feasible with data from areas in Argentina and Northern California.

SIR-A

Radargrammetric processing of SIR-A data addressed three data sets:

(a) Trinity National Forest in Northern California;

(b) the Greek islands Cephalonia and Ithaka;

(c) the island Sardegna.

ad (a): New procedures were developed to match a single satellite radar image with an existing digital elevation model (DEM). The combined data set, a so-called "geo-coded imagery product" (Guertin and Shaw, 1981) permitted one to relate the image brightness values (density numbers DN) to slope on the ground. This in turn led to geometric ortho-images, stereo-ortho images and to radiometrically rectified image products.

ad (b): The SIR-A image pair of the island Cephalonia is unique since it produced a valid stereoscopic impression from flight lines that intersected at 34°.

The data have been used to create digital elevation models from stereo radar, and to rectify the images (see Raggam and Leberl, 1984; Domik et al., 1984 a, b; and Leberl et al., 1985.)

ad (c): The Sardegna data set was processed in a manner similar to the Trinity National Forest, resulting in rectified images. An extensive report is by Domik et al. (1985).

SIR-B

Radargrammetric processing has so far addressed two ares:

(a) Mt. Shasta and

(b) Cordòn La Grasa, Argentina.

ad (a): A first result of SIR-B radargrammetry was the contour map and DEM of Mt. Shasta (Leberl, et al., in print (a); this result led to a 2-minute movie with 1,000 simulated frames showing both the DEM and superimposed radar images in a sequence of perspective views. In addition, the three available SIR-B images of Mt. Shasta were used in three stereo models to evaluate the accuracy that can be achieved. It was found that height errors were about ±60 m with stereo intersection angles of 23°.

ad (b): Cordòn la Grasa was imaged four times, leading to six stereo models. The results are reported by Leberl et al. (in print, b). Figure 1 shows a map-derived DEM, a radar-derived DEM and a difference-DEM. Accuracies were computed for each of the stereo models, where stereo intersection angles varied from 5° to 23°. The theoretical accuracy prediction would lead to height accuracies of ±92 m (5° intersection) to ±18 m (23° intersection) assuming a range resolution of 15m.

Actual accuracies were about ±100 m (5°) and ±60 m (23°). This discrepancy between theory and reality is explained by a reduction in quality of the stereoscopic effect as one has to work with larger differences in illumination angles.

ad (c): The SIR-A image pair of the island Cephalonia is unique since it produced a valid stereoscopic impression from flight lines that intersected at 34°. The data have been used to create digital elevation models from stereo radar, and to rectify the images (see Raggam and Leberl, 1984; Domik, et al., 1984 a, b; and Leberl et al., 1985).

OUTLOOK

Additional data sets of interest to radargrammetric work exist in Argentina where ascending and descending orbits intersect at nearly 90°. The "cross-over" point is covered by seven images, leading to a significantly redundant data set. Processing techniques will need to come into existence that permit one to manipulate the image gray values as a function of terrain slope to better utilize the redundancy for thematic studies.

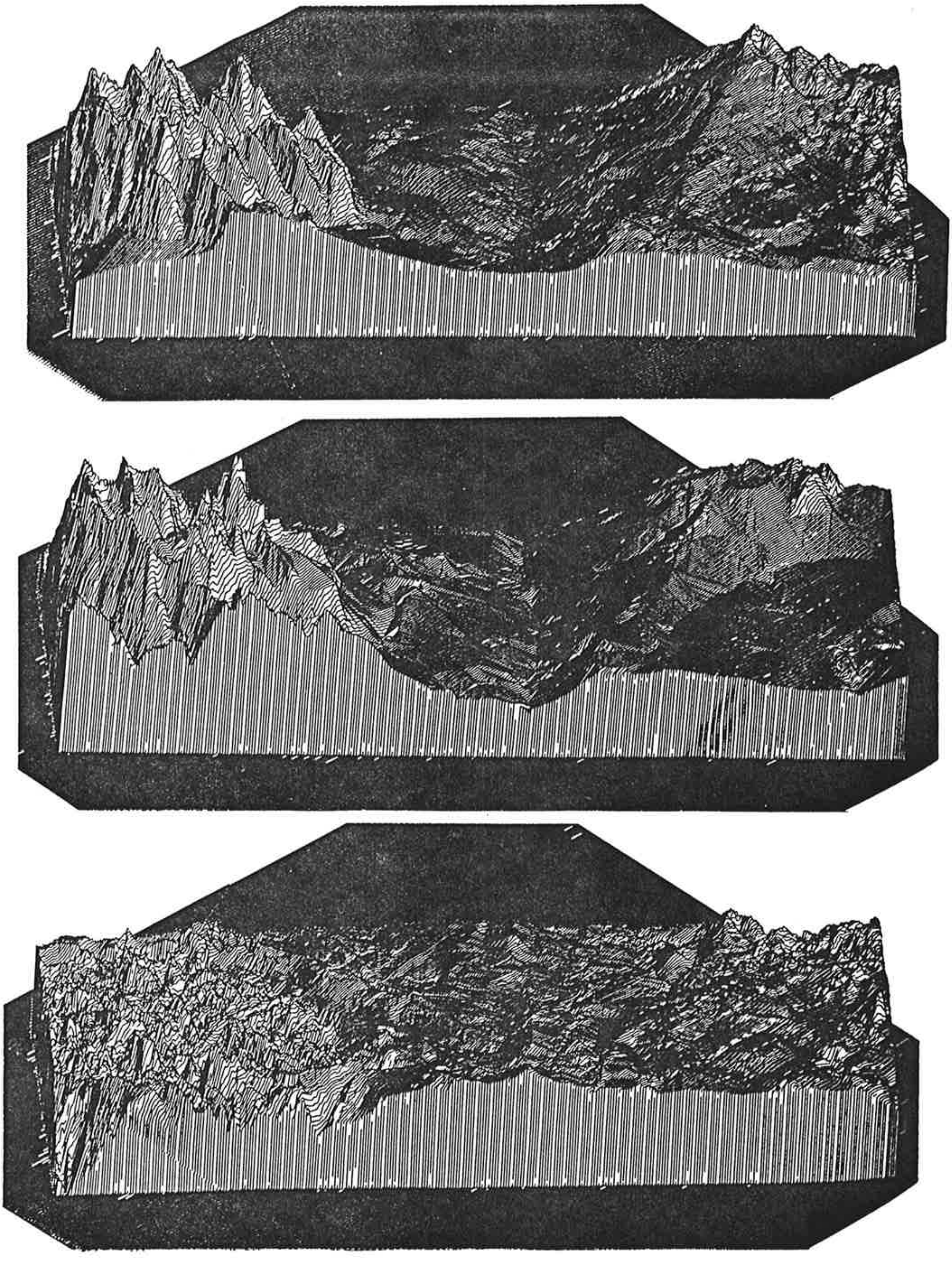

FIGURE 1: Digital elevation model at grid interval 100 m; (a) is from a map at scale 1:100,000 and 50 m contour interval; (b) is from SIR-B stereo radar at 18° intersection angle; (c) is the difference model.

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COMPUTER-CONTROLLED INTERPRETATION OF LONG RANGE OBLIQUE PHOTOGRAPHY

F. Leberl, E. Kienegger, C. Council
Vexcel Corporation
Boulder, CO 80301

V. Kaufmann
Technical University Graz
A-8010 Graz, Austria

Glen G. Gustafson
James Madison University
Harrisonburg, VA

ABSTRACT

Long range oblique photography (LOROP) has hardly a tradition of use in precision measurements. However, such measurements are feasible. Typically LOROP imagery is the result of some form of scanning motion from the horizon down; this results in either a classical "sector scan" panoramic image, or in a sequence of individual central perspective frame photographs.

We have created a software system that permits to make measurements from such imagery, either in the classical mode of photo-interpreters or with the more rigourous approach of analytical photogrammetry. It employs a hardware system created for reconnaissance-type photointerpretation. This paper describes the scope of the system.

LONG RANGE OBLIQUE PHOTOGRAPHY

Figures 1 and 2 illustrate two types of panoramic LOROP geometries that are representatives of the range of possible arrangements. Measurements are supported by fiducial marks in the system of Fig. 2. In common panoramic scan images of the type in Figure 1 (type 1) one generally does not find a rigorous "inner orientation" since the film is moved during the scan to:

- compensate for the overall scan-motion of the camera;
- compensate for changes of the roll angle (roll rate compensation);
- compensate for the forward motion of the airplane.

In LOROP images of the type in Figure 2 (type II) on

Figure 1a: Panoramic sector-scan geometry demonstrated with a scan from the horizon down to 60° off-nadir. Focal length is 72", format is 5" x 36".

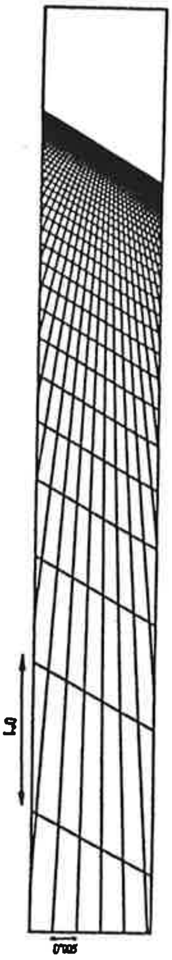

Figure 1b: 30° forward looking panoramic sector scan, scanning from the horizon down to 60° off nadir. Focal length and format as in Fig 1a.

has a more conventional geometry per image segment, but the entire panoramic scan cannot easily be reconstructed from the one to six or more "sub-frames".

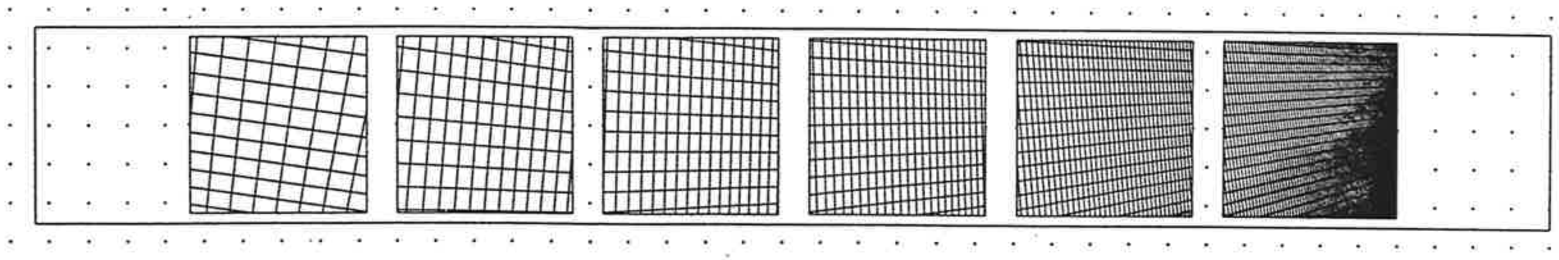

Figure 2: Long range oblique photography in a scanning system, producing individual metric frame photographs. Scanning angles are from 81.6° to 60° off-nadir. Focal length is 66", format is 4.5" x 4.5" for individual sub-frames.

ANALYSIS HARDWARE

The hardware for rapid analysis and mensuration cannot be of the type that is commonly used in precision photogrammetry: elapsed time to obtain results would be too long to support the photo-interpreter (PI) in this work. Film format is drastically different from that of classical photogrammetry. (PI)

Figure 3 represents an overview of the available hardware for the PI analysis station. It has the following components and features:

* mensuration light table for the use of uncut rolls of film;
* a vidicon camera with up to 13 x enlargement;
* a TV-video monitor built into a PI-console;
* a computer (currently PDP-11) for overall control and applications software;
* an a/n video display with keyboard;
* a video-printer to produce hard copies of the contents of the TV video-monitor and of the a/n video display.

Various auxiliary components connect the mensuration light table with the computer so that

* the computer can drive the mensuration light table to a desired location and/or
* the position of a feature on the film roll can be measured.

This requires that both the film transport and the motions of the mensuration surface be measured and controlled.

The system of Figure 3 is denoted as Video Imaging, Display and Recording System -- VIDARS. It is manufactured and integrated by the Richards Corporation in McLean, Virginia.

ANALYSIS SOFTWARE

The software system is available at this time in PASCAL on the PDP-computer of VIDARS. It consists of about 50,000 lines of code in about 500 routines. Figure 4 is the main menu and can serve to outline the major function groups of the system, namely:

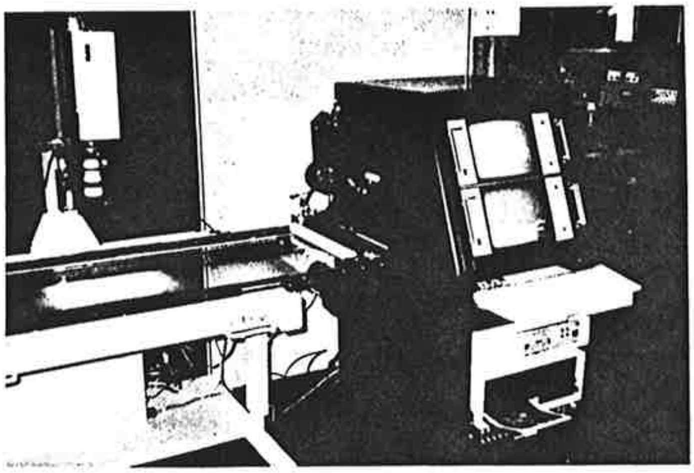

Figure 3: Video Imaging Display and Recording System VIDARS.

- a project definition module;
- a system to enter and administrate ground control information consisting of points or distances, and organized by projects or by areas;
- a sensor management capability to deal with several sensors, either within one single project, or in separate projects;
- a means to enter, add, delete and manage aircraft flight data in various configurations;
- an elaborate system to measure and compute ground dimensions and positions from individual images;
- a means of dealing with an entire strip of images in one step;
- an administration of objects (targets) that have been measured and need to be edited, classified and output;
- a report generation capability.

Figure 5 further details the major and most relevant set of software functions, namely those for measurement. One has available

- a means of quickly scanning through the roll of film and to collect information about targets;
- a measurment strategy to define an image coordinate system ("inner orientation");

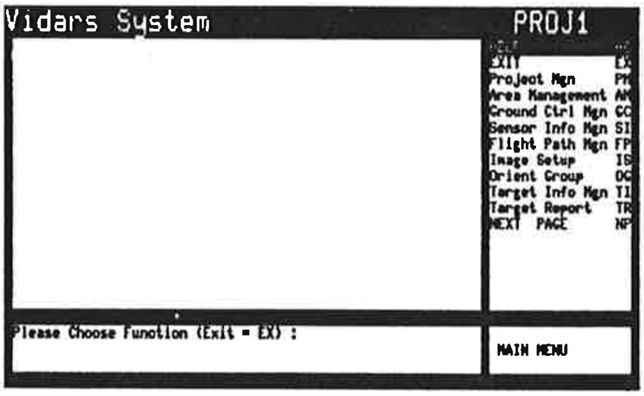

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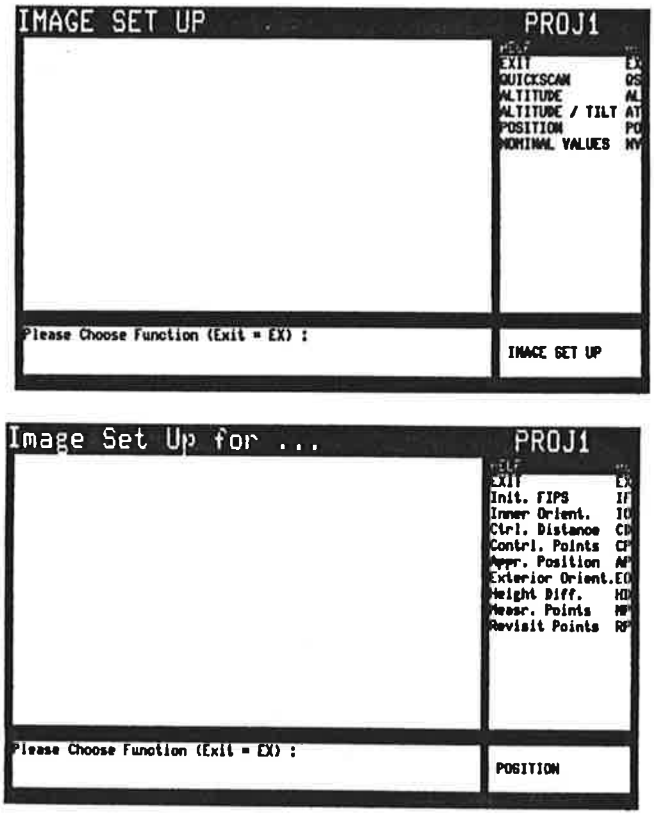
Figure 4: Main menu of the VIDARS software.



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Please Choose Function (Exit = EX) :

Figure 5: Menu for Image Set-up and Positioning.

- support to compute approximate values for the camera positions and attitude, for example using only distances (produces flying height), parallel lines or the horizon (produces the camera tilt angle), or the full ground information in the form of ground control points (produces the camera position and attitude);
- a capability to compute a rigorous "resection-in-space" for LOROP cameras;
- the tools to finally determine horizontal dimensions or height differences of objects, or even their absolute positions.

One has thus available both the classical PI-methods of photo-interpreters and more rigourous analytical photogrammetry. Some specific capabilities of interest include the possibility to quickly "revisit" an image point that was previously observed, to deal with targets even if they extend over several images, to support the reporting of results by graphics tools.

POSITIONING ACCURACY

Individual images are observed without use of stereoscopy. As a result only 2-dimensional positioning is feasible. "Positioning" seeks to determine absolute horizontal ground coordinates in a user-selected coordinate system.

We have presented in the past the results of a simulation study (Leberl et al., 1984); this employed grid simulations such as those shown in Figures 1a and 1b. From a flying height of 15,000 m, with a 72" focal length and scans from 90° to 60° off-nadir (from the horizon 30° down) we found that object positions could be reconstructed to within ±180 m in flight direction, and to ±400 m in scan direction, if image points have errors of ±1mm. It should be noted that such an image

error translate to ±17m at the near range (30° below horizon) and to ±100 m at 30° below the horizon.

Apart from the object positions one can also compute the camera position and attitude. This may normally not be of great interest, except where two sensors combine: an example might be a vertically mounted metric frame camera for aircraft positioning, and a LOROP camera for target positioning. Such requirements can be met with the current VIDARS software.

CONCLUSION

Vidars implements the concept of working with uncut rolls of film and thereby provides computer supported measurement capabilities. It could be beyond the photo interpreter's task to take measurements and to perform complex computation, were it not for the support by the computer.

This paper presents a hardware/software system for rapid analysis of non-conventional film imagery in an ergonomically supportive manner. The system permits to scan through a roll of images rapidly, to collect essential information, and to take precision measurements if needed.

Future enhancements will most certainly concern digital imagery, either by on-line analog-to-digital conversion via an array camera, or by creating an input channel for already available digital images.

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