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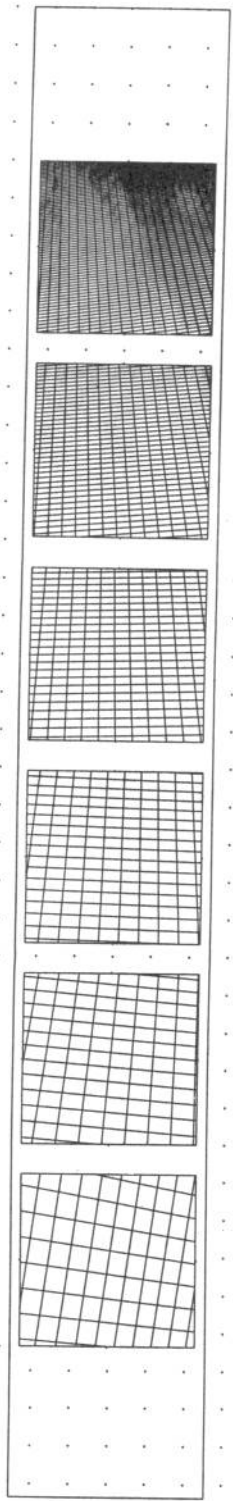
Figure 2: Long range oblique photography in a scanning system, producing individual metric frame photographs. Scanning angles are from 81.6° to 60° off-nadir. Focal length is 66", format is 4.5" x 4.5" for individual sub-frames.

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:
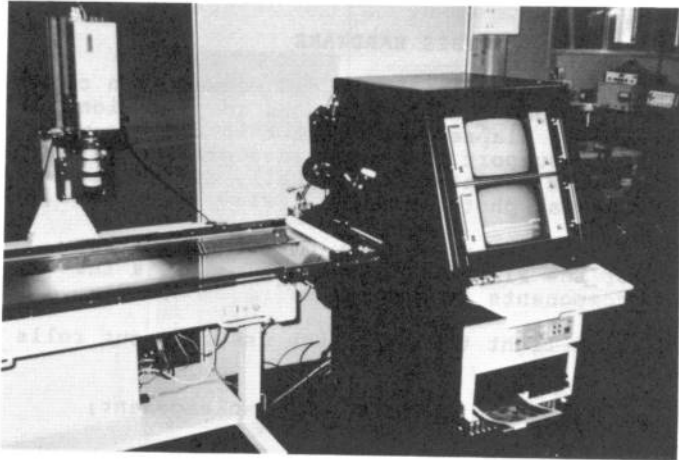
Figure 3:   Video Imaging Display and Recording System
VIDARS.

*   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
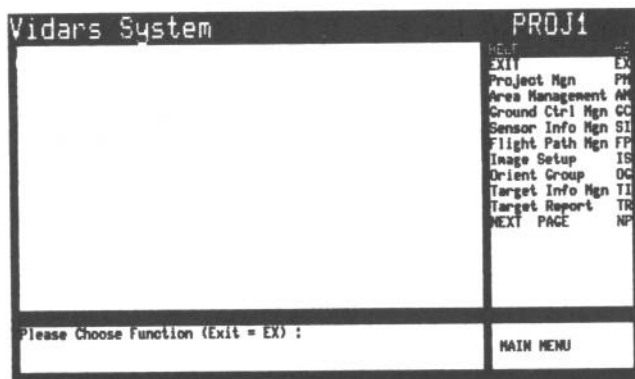coordinate system ("inner orientation");

```
Vidars System                    PROJ1
                            HELP
                            EXIT              EX
                            Project Mgn       PM
                            Area Management   AM
                            Ground Ctrl Mgn   GC
                            Sensor Info Mgn   SI
                            Flight Path Mgn   FP
                            Image Setup       IS
                            Orient Group      OG
                            Target Info Mgn   TI
                            Target Report     TR
                            NEXT  PAGE        NP



Please Choose Function (Exit = EX) :
                            MAIN MENU
```

Figure 4:   Main menu of the VIDARS software.


```
IMAGE SET UP                     PROJ1
                            HELP
                            EXIT              EX
                            QUICKSCAN         QS
                            ALTITUDE          AL
                            ALTITUDE / TILT   AT
                            POSITION          PO
                            NOMINAL VALUES    NV




Please Choose Function (Exit = EX) :
                            IMAGE SET UP
```



```
Image Set Up for ...             PROJ1
                            HELP
                            EXIT              EX
                            Init. FIPS        IF
                            Inner Orient.     IO
                            Ctrl. Distance    CD
                            Contrl. Points    CP
                            Appr. Position    AP
                            Exterior Orient.  EO
                            Height Diff.      HD
                            Measr. Points     MP
                            Revisit Points    RP



Please Choose Function (Exit = EX) :
                            POSITION
```
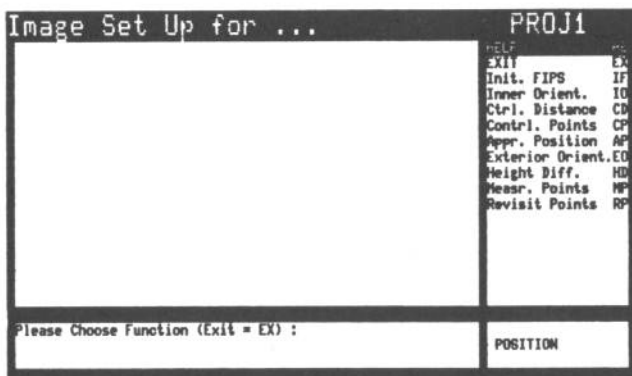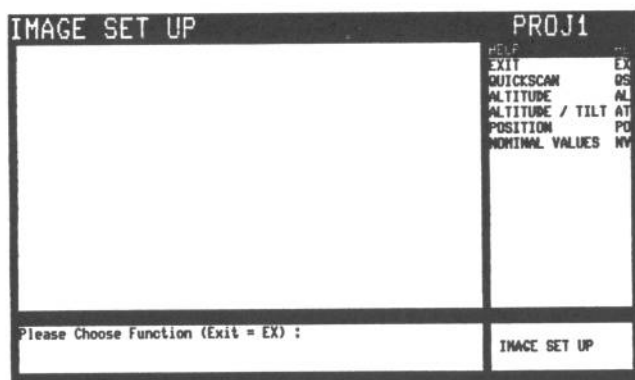
Figure 5:   Menu for Image Set-up and Positioning.

*   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.

REFERENCES

Leberl F. et al. (1984) Photogrammetric tools for panoramic sector scan imagery in the VIDARS analysis station. Proceedings of the SPIE paper #31, Vol. 561.