Int. Archives of Photogr. & Remote Sensing, ISPRS Congress Vienna '96, Austria, July 9-19, Vol. XXXI, Part B2, pp. 186-191.

PROJECT SWISSPHOTO - DIGITAL ORTHOPHOTOS FOR THE ENTIRE AREA OF SWITZERLAND

Thomas Kersten, William O'Sullivan
Swissphoto Vermessung AG
Dorfstr. 53, CH - 8105 Regensdorf-Watt, Switzerland
Phone +41 1 871 22 22, Fax +41 1 871 22 00
e-mail: [thomas.kersten, willie.osullivan]@swissphoto.ch

Intercommission Working Group II/III

KEYWORDS: Acquisition, aerial, digital, DTM, automatic orthophoto generation

ABSTRACT

Digital orthophotos are an essential and up-to-date basis for various applications in geographical information systems, which can fulfill the significantly increasing need for up-to-date, accurate, fast acquired, reasonable and blanket coverage 3-D data and maps in various scales for environmental planning and monitoring, and resource management.
In this paper, we introduce the project SWISSPHOTO, which was established in 1995 to provide digital image data, Digital Terrain Models (DTMs), and Digital Orthophotos (DOPs) covering the entire area of Switzerland (42,000 km²) as standard products for a various number of applications and for many users. The production flow and some technical specifications of the project are presented. Advantages and reasons for the increasing significance of orthophotos are discussed. The versatility and flexibility of digital orthophotos as an integrated basis of a GIS is shown in this paper with many examples for the use of orthophotos in different applications.

1. INTRODUCTION

The development in computer technology and graphical data processing, and the increasing availability of high quality digital data have led to new forms and ways of data processing and management in governmental offices and in the private economic sector. This caused an increasing need for digital topographical information, which is necessary as the basic data level for spatial and thematical digital data processing in geographical information systems (GIS). The need for up-to-date, accurate, fast acquired, reasonable and blanket coverage 3-D data and maps in various scales for environmental planning and monitoring, and for management of resources is significantly increasing. Spatial data and high quality maps are required for various applications in planning offices, in many surveying service companies, departments of governmental offices (state, cantons, communities), in communication, transport and traffic offices, in energy supply companies, and many other fields such as research and tourism. Therefore digital orthophotos derived from satellite or aerial images are an ideal solution to provide topographical data for many users and applications. The georeferencing of the orthophotos guarantees later the common use of several different data sets in the GIS. For the following reasons the significance of digital orthophotos is increasing. (Gruen et al., 1994):

- Using satellite or aerial images blanket coverage digital data is easily available.
- High quality scanners allow the digitisation of analog images and other data.
- Digital terrain models (DTMs) as a basis for digital orthophoto generation is available in different quality levels using various modern data acquisition methods, e.g. digital image correlation, laser-scanning, etc.
- Necessary control point information can be acquired by GPS in an accurate, fast and reasonable way.
- Computers of high performance and increased disk storage capacity are available today at a reasonable cost.
- Commercial software for orthophoto generation is available from a variety of vendors.
- Digital cartography uses increasingly digital orthophotos for map restitution.
- Swiss official approved surveying uses digital orthophotos for the restitution of ground coverage outside urban areas and for the verfication of the large scale maps.
- Digital orthophotos (DOPs) are an important and up-to-date information level in GIS.
- With reasonable visualisation software on PC's, digital orthophotos will gain entry into the public market.

The building of a GIS plays more and more an important role in various applications. Therefore, the individual factors of costs must be correctly estimated in the building phase of a GIS. In the era of the high performance and low cost computers, the hardware costs for a GIS are only 5%, personnel and software costs are 10% each, while the data acquisition is 75% of the costs of a GIS. This demonstrates clearly, how important is the availability of blanket coverage and up-to-date data. To provide digital data including image data, terrain models, and orthophotos covering the entire area of Switzerland as standard products for a various number of applications and users, swissair Photo+Surveys Ltd. started the project SWISSPHOTO in 1995. The project includes the flight and the data processing in several processing modules.

2. DIGITAL ORTHOPHOTOS

As the first operational products of modern techniques in digital photogrammetry, digital orthophotos are generated in a fully automatic process. Digital orthophotos provide the following advantages:

- High accuracy, stability and information density
- Short production, low cost, high efficiency
- Flexibility in the production and in derived products
- Computer supported extraction of information with the capability of a high degree of automation
- Simple radiometric manipulation (image quality, mosaicing, colour editing, dynamic range adjustment, etc.)
- Integration of vector data and additional information (frame, geographical names, numbers, etc.)

For the generation of digital orthophotos the following data must be available: digital image data, orientation parameters of the image, digital terrain model of the area covered by the image. For scanning analog photos high precision photogrammetric scanners, e.g. Helava/Leica DSW 200, Zeiss/Intergraph PS1, which provide a certain geometric and radiometric stability, or also desktop publishing scanners using on-line calibration procedures (Baltsavias, 1994) can be used. Depending on the specified application, in general, resolutions between 10 and 50 mm are used for digitisation of photos. The interior orientation is established by measuring the fiducial marks, which can be performed fully automatically (Schickler, 1995; Lue, 1995, Kersten and Haering, 1995). The exterior orientation parameters can be derived in a single image by resection in space, in a stereo model or in a photo block by aerial triangulation as an automated process. Digital terrain models can be derived by several methods: (a) topographical data acquisition in the field, (b) digitisation of available maps, (c) data acquisition on analytical plotters, (d) digital image correlation, and (e) laser scanning (Lindenberger, 1991). The area of the orthophoto to be generated must be covered by a DTM. For the automatic generation of digital orthophotos the geometrically related location in the image and the radiometrically related density value from the image will be determined for each pixel of the orthophoto (Figure 1). In the geometric rectification process the related height value of the orthophoto pixel, which is known from the collinearity equations, will be interpolated from the DTM. For the radiometric rectification on grey resp. colour values, which are interpolated from neighbouring pixels in the image, will be addressed to each orthophoto pixel. The computation time for generating digital orthophotos depends on the computer performance and the selected resolution, but, in general, it takes approximately one hour per photo.

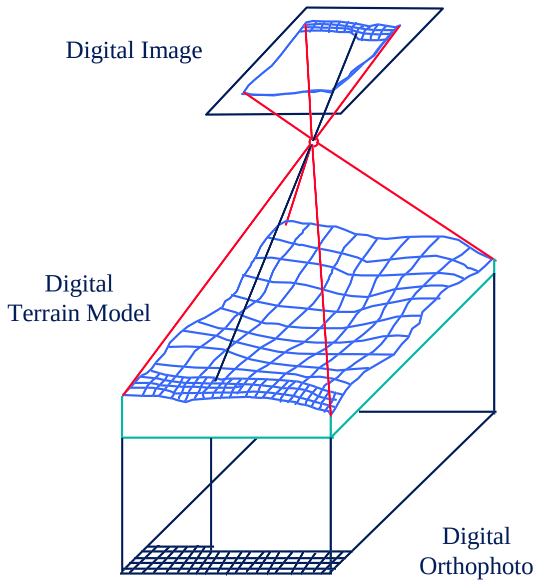

Figure 1: Principle of digital orthophoto generation

3. PROJECT SWISSPHOTO

The project SWISSPHOTO was started in spring 1995, in order to provide up-to-date geo-data covering the entire area of Switzerland with aerial images. As standard products analog and digital image data, digital terrain models, and digital orthophotos can be offered ***to*** many users from different fields.

3.1 Flight

For the project SWISSPHOTO the entire area of Switzerland was flown in two phases using colour and infra-red films simultaneously. In phase 1, the urban areas and the northern part was flown from June to August, while in phase 2 the southern part and the southern valleys were flown from August until October 1995 (Figure 2). The photo scale was approximately between 1: 24 000 (non-mountainous area and valleys) and 1: 38 000 (alps). The entire photo block includes more than 7800 images for each film material. Flight and block data are summarized in Table 1. To reduce costs for control point signalization and determination of the 3-D coordinates, the coordinates of the camera stations were recorded with DGPS using one Leica GPS receiver on the plane and up to three reference stations on the ground during the flights. Additionally, 104 well distributed points of the new Swiss GPS primary network LV'95 were signalized prior to the flight.

Int. Archives of Photogr. & Remote Sensing, ISPRS Congress Vienna '96, Austria, July 9-19, Vol. XXXI, Part B2, pp. 186-191.

Area:	entire area of Switzerland
Area covered:	~42000 km^2
Ground height:	~400 - 4800 m
Flying height a. s. l.:	~4400 - 9800 m
Camera:	Wild RC30/20, 15/4 UAGA-F
Photo scale:	~1: 24000 - 1: 38000
Forward/side overlap:	90-70%/40-30%
Number of strips:	116
Number of images:	~7800
Date of flight:	June - October 1995
Film:	colour diapositive + infra-red
Scanner:	DSW200
Pixel size:	25 µm

Table 1: Flight and block data of the entire block Switzerland

3.2 Data production

To satisfy the increasing need for just in time topographical data and maps in the future, modern and efficient methods must be used for deriving spatial data. Using modern techniques and methods of digital photogrammetry, 3-D data and maps can be derived from up-to-date aerial images in an operational and highly automated way. Therefore, some of the processes (e.g. image frame import, interior orientation, triangulation, DTM and orthophoto generation, etc.) will be performed fully automatically or partly automated in a batch mode. The SWISSPHOTO production was divided into several processing modules for optimized organisation. The basic processing steps are summarized in the following:

- Scanning
- Data Archiving
- Digital Aerial Triangulation
- Automatic Digital Terrain Model Generation
- Automatic Digital Orthophoto Generation
- Mosaicing
- Data Management
- Data output and transfer

For the data production swissair Photo+Surveys Ltd. purchased digital photogrammetric equipment from Helava/Leica: two Digital Photogrammetric Workstations DPW770 and one Digital Scanning Workstation DSW200. As computer platforms for these stations three SPARC Station 20/71 from SUN microsystems are used. For the test phase the software release SOCET 3.1.6b (beta version) was used, while for the production the latest SOCET 3.1.1.2. version was implemented.

The whole production of the data should be finished within the next two years in oder to provide up-to-date data for the users. In 1998 or 1999 Switzerland will be flown again to obtain new photos of the entire country.

3.2.1 Scanning and data archiving

All images are scanned on a Helava/Leica Digital Scanning Workstation DSW200 in RGB mode. With the current hardware configuration the turn around time for scanning for each photo is about 30 min. This will result in a total scanning time of approximately 3900 hours, which corresponds to almost two years. For triangulation and DTM generation the digitized

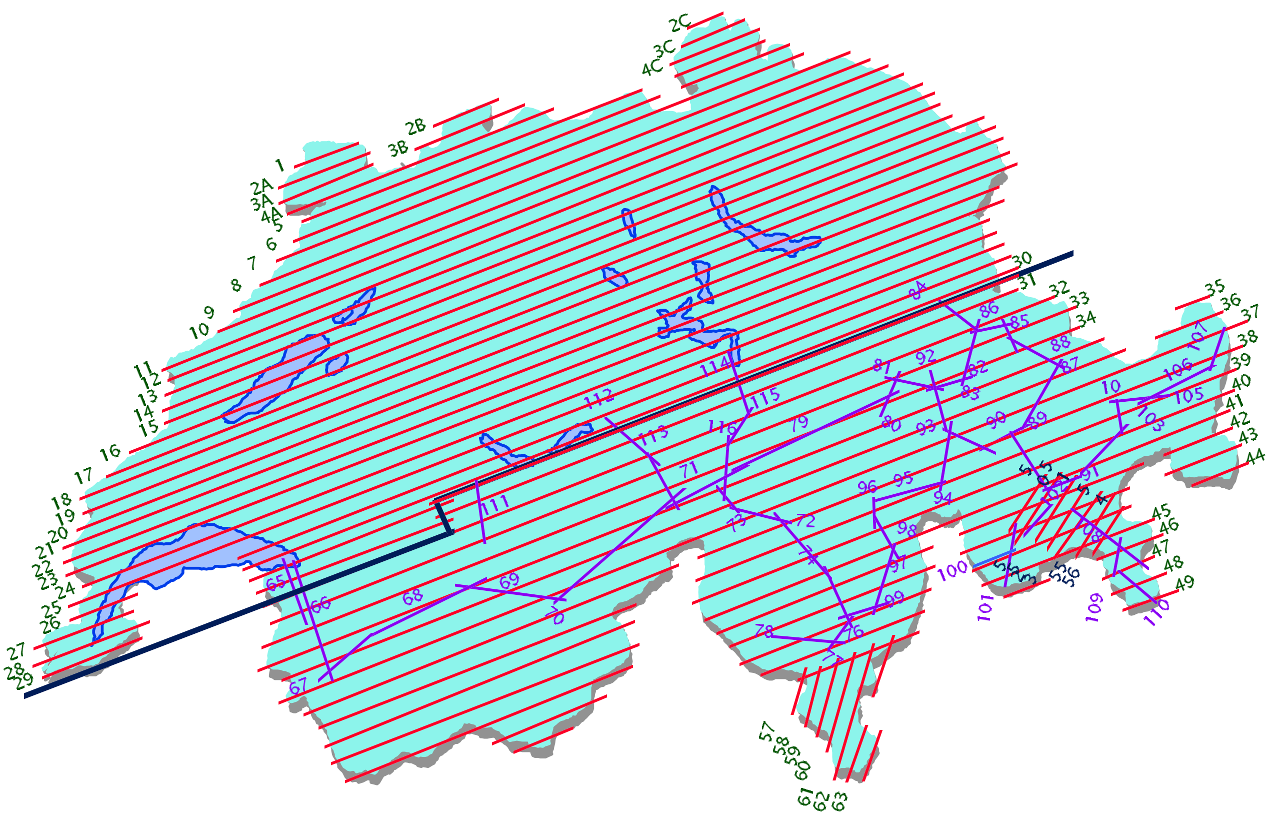

Figure 2: Flight lines of project SWISSPHOTO

colour images are converted into greyscale images in order to reduce disc space usage. The resolution of the images is 25 µm (1016 dpi), which corresponds to a footprint of approximately 0.7 m on the ground, and the size of each colour (resp. greyscale) image is about 240 (resp.80) MByte. Portions of the approximately 75 GByte available disc storage capacity are used for temporarily data storage after scanning and for subsequent data processing. Exabyte tapes (video8) are currently used for the stripwise archiving of the image data. Additionally, CD-ROMs are being currently tested for possible storage of compressed image data.

3.2.2 Aerial triangulation

For the aerial triangulation observations the Helava Automated Triangulation System HATS was used. The triangulation process is divided into several processing steps, which included the preparation, observation and the final bundle adjustment. The preparation includes the import of the images and their minification (image pyramids) and also the import of GPS photo centre coordinates of each image providing approximate values for the overlapping of the images in the blocks. The data import is performed in a batch mode. To obtain sufficient ground control points without establishing an additional GPS campaign, the following types of control points were used: signalized points from the new Swiss GPS primary network LV’95, 3-D control points from previous photogrammetric in-house projects measured on the SD2000, planimetric control points from cadastre maps at 1:500 - 1:2,000 scale and height control from LK25 maps (Swiss 1: 25’000 map series). The AT measurements start with a fully operational automatic interior orientation, which is performed in batch mode without any operator intervention. The functionality and the concept of this used algorithm is described in Kersten and Haering (1995). The processes of AT measurements in HATS are divided into several steps which includes Automatic Point Measurement (APM), Interactive Point Measurement (IPM), and Blunder Detection and Simultaneous Solve (Re-measurements). First tests showed that APM measures in average 75% of all points successfully, while the remaining points require interactive measurements. It is not always necessary to reach 100%. Blunder detection could be used after both measurement modes, APM and IPM, and gross errors can be eliminated. This is a very useful tool for „online“ checking of model and strip connections as all images could be displayed, and all connections rechecked and re-observed if necessary.

Ground control points and additional points were measured with IPM. If the datum is fixed by measurement of three control points as the first 3 points to be measured in the block, the program drives the operator to the approximate position of the subsequent ground control points automatically. The procedure used for triangulation with HATS and the results of two test blocks are summarized in Kersten and O’Sullivan (1996). All observations (image coordinates, control point coordinates and GPS photo centres) were adjusted in a combined bundle adjustment with self-calibration using the bundle adjustment program BLUH from the University of Hannover. For the test data the root mean square values of differences at control points is about 0.6-0.7 m in planimetry and about 1 m in height. The RMS value of the GPS photo centres are about 0.6 m in X_0 and Y_0, and better than 0.2 m in height. These results from the adjustment showed that the quality of the used ground control points was not very good. This demonstrates clearly that it is necessary to perform the GPS supported triangulation using only signalized points, GPS photo centres and additional height control at overlapping strip ends.

After the first experiences with HATS it is currently possible to measure 32 models per day (8h shift). Comparing the time for measuring on analytical plotters this is a speed-up in triangulation, however, there is still potential for improvements in digital triangulation using HATS. In Kersten and O’Sullivan (1996) some triangulation processes are specified, which could be even more automated in the future. Furthermore, suggestions for improving HATS are also given in this paper.

3.2.3 DTM generation and merging

Digital terrain models are generated in a 10 m grid by automatic image correlation in digital stereo image models on the DPW770. The corrolation of one stereo pair takes approx.1 hour. Subsequently, gross errors, which can vary between 20 and several hundred meters, are quickly elimenated by various editing tools, which are provided on DPW770 under the SOCET Set software. The DTM’s are then merged together into standard map sheets which correspond to ¼ Swiss LK25000 sheets of 6km x 8.75km. This will create a total of ca. 1000 sheets. These data are then stored as surface DTM’s which can be used for orthophoto generation. These merged files are then subsequently further edited to achieve the desired result of ± 3-5m. This editing stage takes currently a minimum of ca. 3 hours per equivalent stereo model. In some areas with extreme height differences it is very difficult to generate a DTM automatically. In these areas the DTM will be acquired on an analytical plotter. This is especially true for extreme height differences of more than 1000 meters in one stereo model which is not uncommon. This demonstrates, that it is absolutely necessary for such extreme terrain as in Switzerland, to use initial DTMs if available, in order to achieve a much better result by the correlation algorithm. The precision and the accuracy of the generated DTMs are dependent on the resolution of the digital image data, on the characteristics of the terrain (steep, rolling, flat), on the surface of the terrain (e.g. urban areas, forests, lakes, etc.), and on the accuracy of the camera orientation data. Investigations for testing the accuracy of the

DTMs have been performed, but results are currently not available.

3.2.4 Orthophoto generation and mosaicing

For the automatic orthophoto generation colour image data is mainly used. The input data consists of the image data including their support files with the orientation data, DTM, the ground sampling distance (the standard footprint is 0.75 m per pixel), and as a selectable option, the perimeter of the desired area. Before starting the orthophoto generation, a dynamic range adjustment using a modified wallis filter is performed for each digital image in order to avoid vignetting problems in the images. This process takes more than one hour per image, but it runs in a batch mode over night. The images are then mosaiced together into standard map sheets which correspond to ¼ Swiss LK25000 sheets of 6 km x 8.75 km. This will create a total of ca. 1000 sheets which are stored on CD-ROMs.

3.2.5 Data management and data transfer

Currently all digital image data and ASCII files are saved on exabyte tapes (video8) using two tape drives. Thus, all data on the 75 GByte disk (4 x 18 GByte disks plus 1 GByte per SUN workstation) is temporarly used for the processing of the current projects. For data output resp. transfer the following storage media are available: CD-ROM, exabyte tape, optical disk and DAT tape. Hardcopies of orthophotos can be offered on a plotter Hewlett Packard HP750 or on an IRIS plotter.

4. SOME APPLICATIONS OF ORTHOPHOTOS

The possibilities of digital orthophoto application in a GIS or in other fields are multiple. The most essential applications are the use of orthophotos as background information for the overlay of different vector data and for digitisation of new vector data from orthophotos.

In the following several tasks for the use of digital orthophotos are summarized (Baltsavias, 1993):

- Data quality control by overlaying of vector data
- Data acquisition of vector data by digitisation
- 3-D data acquisition from orthophoto and DTM by monoplotting
- Map and data revision
- Generation of orthophoto maps
- Generation of synthetic 3-D views
- Verification of changes by comparison of multi-temporal orthophotos
- Quality control of DTMs using stereo orthophotos
- Building of an orthophotos data base as land information data base
- Data fusion with other image data

In the following examples for using orthophotos in different applications are summarized (Kersten, 1996):

(1) Surveying
- Digital revision of vector data of 1: 10000 and 1: 5000 maps
- Visual verification of castadre maps and revision of ground objects.

(2) Consolidation and property fusion

(3) Management of water resources
- Water information system for monotoring of a drinking water protectorate with an integrated GIS using orthophotos for the land classification (Grenzdörffer et al., 1995)
- water sources information system
- drainage of settlements
- hydrological maps, etc.

(4) Agriculture
- Determination of agriculture contribution areas and fruit sequence areas, revision of slope inclination (von Däniken und Blatter, 1994), etc.

(5) Planning
- Acquisition of an inventory of the nature for communities
- Synethic 3-D views for regional planning

(6) Supply and disposal
- DOPs serve as a basis for the overlaying of supply network (e.g. electricity, gas, water, waste water, long-distance heating system, TV network, etc.) in net information systems.

(7) Environment
- Mapping of the ground
- Noise protection cadastre
- Pollutant emission cadastre
- Danger cadastre
- Suspicious area cadastre, etc.

(8) Infrastructure
- Temporal orthophotos for illustration of developments in various fields, e.g. agriculture, forestry, urban areas, leisure-time activities, etc.

(9) Geomarketing
- Digital orthophotos combined with statistical data (e.g. population density and structure, spending power, etc.) for the optimization of locations of trade business, industry, (public) services enterprise, tourism, etc.

(10) Navigation
- DOPs as a basis for vector data acquisition of road and traffic data for building a vehicle navigation system (e.g. Travel pilot Bosch)

(11) Simulation
- Simulation systems for helicopters and planes
- Simulation systems for computer animation and video games

(12) Tourism
- Digital orthopotos as a new form of excursion maps, city maps, tourism guides, etc.

(13) Transport
- road surface and condition cadastre, traffic control, accident statistics
- railway cadastre

5. CONCLUSION AND OUTLOOK

Automatic methods and automated processing flows in photogrammetric data acquisition guarantee fast and flexible availability of topographical 3-D data. To be able to produce digital data using new digital techniques, swissair Photo+Surveys Ltd. has flown the entire area of Switzerland in 1995 covering the country with more than 7800 photos. With the introduced SWISSPHOTO data the requirements of many users in Switzerland for up-to-date digital images, DTMs and orthophotos can be satisfied, which can be used as a basis in various applications. After a processing period of three to four years, a re-flight of the country will be performed to provide new resp. up-to-date data. Due to their versatility and flexibility, digital orthophotos will be used by more and more users in the future. Custom-made maps in which the perimeter, scale, form of output, and information to be displayed which will be defined by the user, will become standard. Therefore, orthophotos will increasingly support or even replace conventional maps in the future. With the increasing significance of digital orthophotos also hybrid GIS will become more and more popular compared to the vector oriented information systems.

A future vision is the on-the-flight production of digital orthophotos in an aeroplane, which is equipped with a digital camera, a GPS and Inertial Navigation System (INS) and a laser scanning system (Figure 3). The camera stations of the digital camera, which stores the high resolution image data on a real-time disk, are determined by differential GPS and INS, while the DTMs are derived by laser scanning. The on-line data processing will be performed on board of the plane, so that digital orthophotos are available after landing. The technical conditions of most of the mentioned systems are available, but today no digital high resolution camera with more than 16 K x 16 K pixel is available, which is able to store such an amount of image data in real-time on a disk. First investigations using a digital aerial camera (4 K x 4 K pixel) are introduced by Thom and Jurvellier (1993).

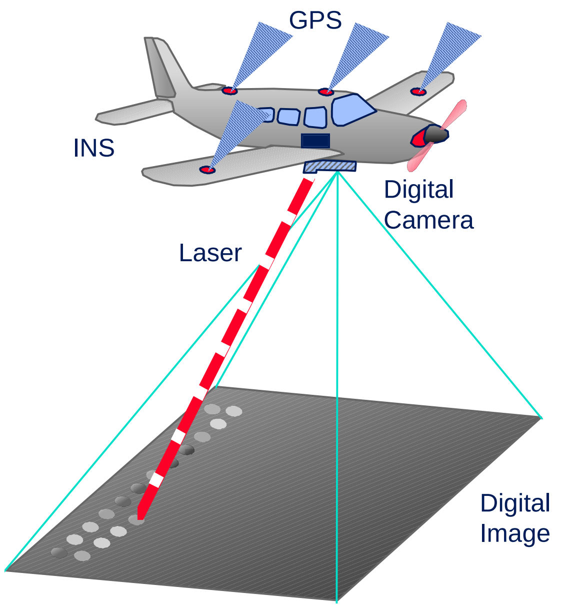

Figure 3: Multisensor aeroplane for on-line production of digital orthophotos

6. REFERENCES

BALTSAVIAS, E., 1993. Integration of ortho-images in GIS. *Photogrammetric Week '93*, Eds. Fritsch/Hobbie, pp. 261-272.

von DÄNIKEN, P., BLATTER, U., 1994. Orthophotos als Ergänzung zur amtlichen Vermessung im Kanton Solothurn. *Vermessung, Photogrammetrie, Kulturtechnik*, No. 12, pp. 547-550.

GRENZDÖRFFER, G., WANNENWETSCH, R., BILL, R., 1995. Digitales Orthophoto im GIS: neue Wege der Luftbildinterpretation. *Vermessung, Photogrammetrie, Kulturtechnik*, No. 3, pp. 129-133.

GRUEN, A., BALTSAVIAS, E., MEISTER, M., 1994. Digitale Orthobilder und Terrain-Visualisierung. *VGI - Österreichische Zeitschrift für Vermessung & Geoinformation*, No. 3, pp. 220-234.

KERSTEN, Th., 1996. Digitale Orthophotos - Die Grundlage für viele GIS-Anwendungen. *SOGI/GISWISS Conference*, April 16-17, Morges, Switzerland.

KERSTEN, Th., HAERING, S., 1995. Automatic Interior Orientation for Digital Aerial Images. *Internal Report, Inst. of Geodesy & Photogr., ETH Zurich.*

KERSTEN, Th., O'SULLIVAN, W., 1996. Experiences with the Helava Automated Triangulation System. *Int. Archives of Photogrammetry and Remote Sensing*, Vienna, Austria, July 9-19, Vol. XXXI, Part B3.

LINDENBERGER. J., 1991. Laser-Profilmessungen zur topograhischen Geländeaufnahme. *PhD. thesis,* University of Stuttgart.

THOM, C., JURVELLIER, I., 1993. Experiences with a Digital Aerial Camera at Institut Géographique National (France). *Photogrammetric Week '93*, Eds. Fritsch/Hobbie, pp. 73-83.