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CCNS / AEROCONTROL
AN INTEGRATED GPS/IMU SYSTEM WITH STANDARD INTERFACES FOR DATA EXCHANGE

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ABSTRACT:

The *CCNS4* (Computer Controlled Navigation System, 4th Generation) together with the *WinMP* mission planning and documentation software is a GPS based guidance, positioning and management system for aerial survey flight missions. For direct measurement of the exterior orientation elements of a sensor, the *CCNS4* can be used together with the *AEROcontrol* option. *AEROcontrol* is an integrated GPS/IMU system. In addition to the primary task of guidance and sensor management, the *CCNS* provides information like exposure times, flightline numbers and exposure numbers. This information can be included to the sensor data directly (e.g. information can be exposed on film or included to the datastream of an aerial laserscanner), or it can be accessed after the flight mission.

If the *AEROcontrol* option is used, the task of an error free and efficient exchange of the additional information (like position, velocity and attitude) becomes more difficult and more important. In the first part, this paper describes the components of the system and shows their function during a survey flight mission. In the second part, the strategy for the export and exchange of data is shown.

1. INTRODUCTION

Since 1982 IGI is specialized in the development of guidance and management systems for aerial survey flight missions. The first systems were based on portable Precision-DMEs, Loran-C and DME-Tacan networks, since 1990 GPS is used. In 1996 IGI introduced the GPS/INS system *AEROcontrol* as an option for the *CCNS4* to directly compute the position of a sensor at the instant of exposure. This system was based on an IMU with dry-tuned gyros and a 12-channel L1/L2 GPS receiver. Since 2000 the *AEROcontrol-IId* with a fibre-optic gyro based IMU is available for the precise measurement of the position and attitude of a sensor.

While the information from the guidance and management system (information like exposure times, flightline- and exposure numbers, project and area names) is used mainly to organize the final results of the airborne sensor (e.g. the date and exposure time of an aerial orthophoto). A GPS/INS system like the *AEROcontrol* provides additional information that can be used in the workflow of dataprocessing of the sensor data directly (e.g. the use of the exact position and attitude of the camera at the instant of exposure for the orthorectification of an aerial photograph). On the one hand, these tasks are mainly done with automatic systems where very little interaction and control of a human operator is necessary, so unambiguous and error free data exchange is crucial. On the other hand there are many different ways to describe attitude and position in space. Unfortunately, many systems that use the *AEROcontrol* data, e.g. for the production of orthophotos or the introduction of *AEROcontrol* results in a blockadjustment, are using different definitions for historical reasons.

To overcome this situation, two different concepts for the dataexchange are implemented in the datamanager of *AEROoffice*. After a description of the complete system, this datamanager is described and an example for the exchange with an other program is shown.

2. SYSTEM COMPONENTS

2.1 Mission Planning and Documentation: *WinMP*

WinMP is the latest software developed by IGI to plan and document aerial survey flight missions. *WinMP* runs under Windows 95/98/ME/NT/2000/XP on a standard office PC.

The planning consists of waypoints, segments, flightlines, polygons, icons, text objects and digital maps. Digital raster or vector maps of many different formats like DXF, SHAPE, BMP, JPG, TIFF or GeoTIFF can be used as background maps for planning and mission documentation. The georeferencing of the maps can be calculated within the program.

The missions can be planned and documented using a countries local Lat/Lon or X/Y coordinate system. IGI provides more than 70 *Country Modules* with hundreds of tested coordinate systems. The software automatically creates optimal flightline patterns for closed (i.e. blocks) and open polygons (for flying over power lines, rail tracks etc.). These proposed plannings can easily be modified by the user via a graphical interface.

Customized reports of the mission planning and of the flown missions are created automatically. ASCII and DXF export is possible for all planning objects like waypoints and polygons.
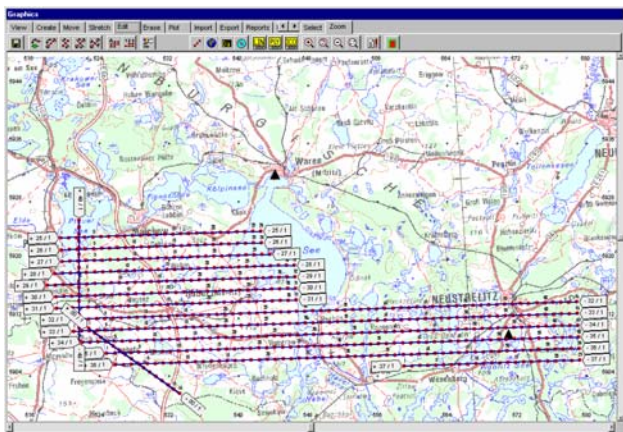
Figure 1. Flight planning on top of a digital map created with *WinMP*

Several databases are provided to store and manage data like:

- all information about flown missions (exposure positions, exposure times, film numbers…)
- used background maps and their georeferencing parameters
- different sensors
- customized reports for different customers
- index fields for planning overviews and photo indices for different purposes

WinMP provides interfaces to the *CCNS4* and other flight management systems.

2.2 Guidance and Management System: *CCNS4*

The *CCNS4* is a guidance, positioning and management system for aerial survey flight missions. The basic system consists of the Central Computer Unit (CCU) and the Command and Display Unit (CDU).

Figure 2. The *CCNS4* CCU with 3" and 5" CDU

The system can be operated together with a large variety of different aerial cameras and other sensors (e.g. all Wild / Leica, Zeiss-Jena, Zeiss-Oberkochen aerial cameras, all current Z/I-Imaging and LH Systems camera systems, different laser scanners and SAR systems).

The *CCNS4* gets its positioning and velocity information from a GPS receiver, which is mounted inside the CCU, and optional heading information from the aircraft's directional gyro. If the *AEROcontrol* option is operated, the directional information from the *AEROcontrol* IMU can be used. The GPS receivers are prepared for differential GPS operations according to RTCM-104 format. The directional information is used for a stable graphical display, allowing fast display reaction on aircraft maneuvers and for computing drift/grab for setting the camera mount. Corrections for local variations and aircraft's deviations can be applied.

To provide simple and error free operation by the pilot in the aircraft, the CDU is designed like an aircraft instrument. A computer keyboard is not used, all operations are controlled via two knobs and five buttons. The EFIS type display of the CDU is divided into a guidance and a system/sensor management part. To cover the planned flightlines, the pilot only has to align the needle that indicates the planned track and the line that indicates the correct real track (see figure 3). The screen can be zoomed to meet different requirements. Outputs with selectable sensitivity for aircraft instruments like HIS (Horizontal Situation Indicator) or VDI/CDI (Vertical/Crosstrack Deviation Indicator) instruments are provided.
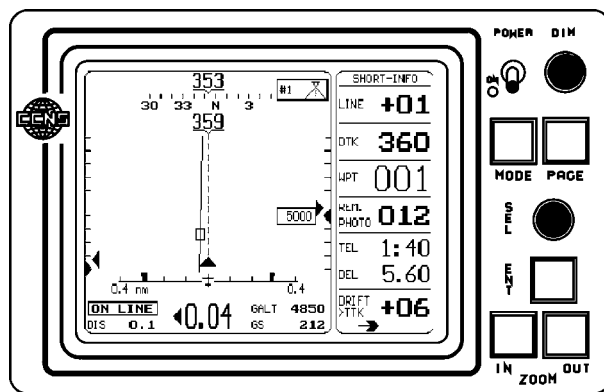

Figure 3. Guidance information on the display of a *CCNS4 5"*
CDU during a photo flight (solid line → planned line; dashed line → real track)

The *CCNS4* is able to control two sensors at a time (e.g. a RC30 and a RMK-TOP camera). The actual flight data, including the aircraft position, are computed and can be provided for data annotation on film. Positions can be in WGS84 or a local coordinate system like UTM or Gauß Krüger. Waypoint data, flight information and GPS positions are stored on a PC-Card for mission documentation with *WinMP*.

2.3 GPS/INS System: *AEROcontrol*

To enable the *CCNS4* to precisely measure the position and orientation of the airborne sensor (EO-Parameters), the *AEROcontrol* option was developed. *AEROcontrol* consists of three components:

- The Inertial Measurement Unit *IMU-IId*:
  The IMU includes three accelerometers, three fibre optic gyroscopes (500m fibre length) and signal pre-processing electronics (figure 5). The six sensors are attached rigidly to an aluminum frame. Through holes in the IMU housing,

this sensor block is mounted directly to the used airborne sensor. The *IMU-IId* provides a high accuracy measurement of the angular rate and of the acceleration with an update rate of 64/128 Hz.

- The GPS antenna and receiver:
  The system can be operated with a number of different GPS receivers. The default configuration was the *Z-fly* (like in figure 4) and is now the Z-Xtreme/IGI receiver (Ashtech/Thales, USA), both 12 channel dual frequency receivers.

- The airborne computer unit:
  The airborne computer unit collects the raw data of the IMU and of the GPS receiver and stores them on a PC-Card for post-processing. It also provides the time synchronization between the GPS, the IMU and the used sensor. A real-time platform calculation allows to introduce the information as navigational input for the *CCNS4*. The system approximately records 12 MB of data per hour. For the example of a 192 MB PC-Card this results in a possible mission time of about 15 hours.

Figure 4. *AEROcontrol* computer with *Z-fly* GPS receiver and IMU

The system can read the attitude information of a stabilized camera mount (like Z/I Imaging's T-AS or LH Systems' PAV30) and store these values for a variable lever-arm correction in post-processing. If it is not possible to read the information from a stabilized mount, an additional attitude sensor to monitor the mount angles is available from IGI.

The *AEROcontrol* is controlled and operated via the *CCNS4*. With a new menu entry in the *CCNS4*, the recording of data can be switched on and off. On an additional *AEROcontrol* info page the operator can monitor the data recording, supervise the GPS conditions and view the results of the real-time platform calculation. The *CCNS4* computer unit and the *AEROcontrol* computer unit may be operated as separate devices or as one 19" rack solution. Mechanical adapters to mount the *IMU-IId* to Wild/Leica, Zeiss and Z/I aerial camera systems are provided by IGI.
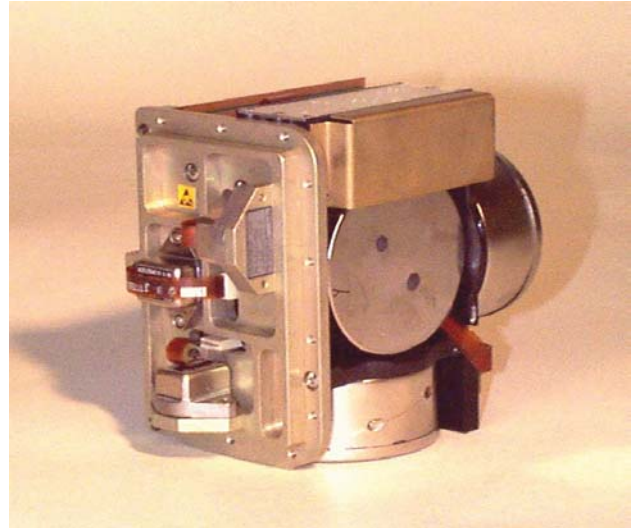

Figure 5. Sensorblock of the IMU-IId with three accelerometers and three gyroscopes

2.4 Post-Processing and Data-Handling: *AEROoffice*

The *AEROoffice* software package is running under Windows 95/98/ME/NT/2000/XP on a standard office PC. It provides all functions necessary for the handling and evaluation of the collected GPS and IMU data, like:

- tools for handling the PC-Cards
- differential GPS post-processing software
- inertial navigation software
- coordinate transformation to the local mapping system
- attitude transformation to the local mapping system
- misalignment transformation (boresight transformation)
- lever-arm corrections for static and variable lever-arms
- a graphical user interface

The processing time for the inertial navigation is less than thirty seconds per hour mission time on a 1GHz Pentium III with 128 MB RAM.

3. DATA EXCHANGE WITH OTHER SYSTEMS

3.1 Available Information

The data provided by the *CCNS/AEROcontrol* can be subdivided into two groups. The first group is related to the guidance and navigation system. This is information like project, area name, flightline number, exposure number and the exposure time. The second group consists of information from the GPS/INS system. This is information like position, velocity and attitude. The information from the first group is easy to handle because the number of useful ways to describe this data is very limited. For the information in the second group the situation is different. E.g. the position and velocity can be given in different coordinate systems and in different units. For the attitude the situation is even worse. The rotation from one co-ordinate system to an other one can be described as a matrix, or in the form of three angles. If the matrix form is used, the underlaying co-ordinate systems can be chosen differently, if the three angles are used, the order of the rotations is an

additional free parameter. If, e.g. the rotation order of the roll and the pitch angle is mixed up, the resulting error is small, as long as the angles are small. If these angles become larger due to rough weather or a problem with the sensor mount, the errors will become larger as well. These kind of mistakes are hard to detect because the effect on the final result is very variable. Unfortunately, many of the processing systems that import the *AEROcontrol* data use different angle definitions. This means for the user of the GPS/INS system, that he has to take care to provide his results in the appropriate form for a number of systems.

To simplify this task for the user, and to keep the possibility to interface with any new system, the *AEROoffice* datamanager follows two different strategies for the dataexchange.

3.2 Predefined Output Formats

Together with the producers of processing systems that use *AEROcontrol* data, IGI established a number of predefined exchange formats. If these systems are used, the operator can select the corresponding output format to export the data from *AEROoffice* and to import the data into the other system without knowing which definitions and formats are used. This method should be preferred to guarantee an error free exchange. If a customer is using a system that is not in the list of the given list of standard output formats, the needed format can be included by IGI.

3.3 *The AEROoffice* Custom Format Editor

If the operator, for any reason, needs an output that is not in the list, he can define his own output formats. In the Custom Format Editor more than 40 different topics can be selected for export. The units and formats can be chosen freely.
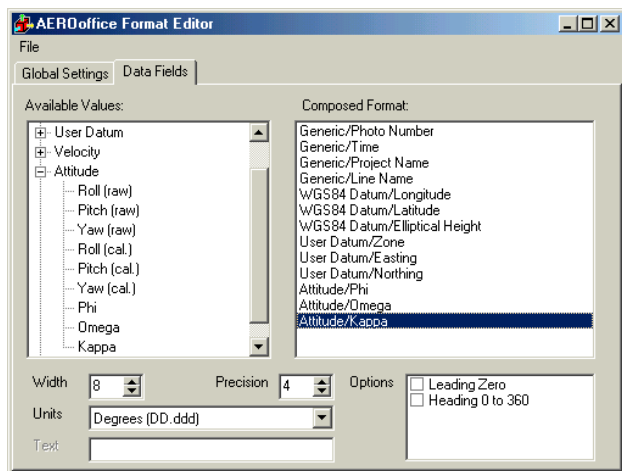

Figure 6. The Custom Format Editor in *AEROoffice*

4. EXAMPLES OF DATA EXCHANGE WITH OHER SYSTEMS

4.1 Data Exchange with the AT Program *BINGO*

The Exterior Orientation Parameters (EO) from *AEROcontrol* can be used in blockadjustment programs to strongly reduce the number of necessary ground control points and to improve the results in case of a weak block geometry.
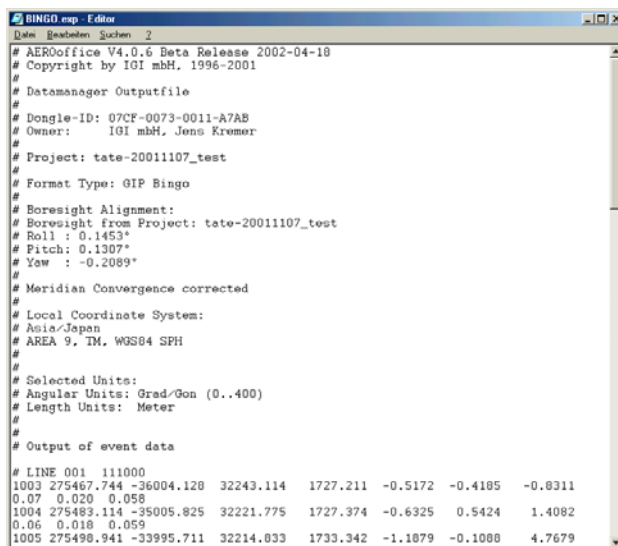

Figure 7. Example for an *AEROoffice* output file for the import of EO parameters into *BINGO*.

In figure 7 an example for an exchange file for the EO parameters with the bundle triangulation program BINGO (GIP mbH, Aalen, Germany) is shown.

After a file header with general information the exposure number, exposure time, EO-parameters and an estimation of the accuracy of the EO-parameters is given for each photo. In the LINE information additional commands for the BINGO processing can be given. The rotation order of the three angles is phi, omega, kappa.

4.2 Data Exchange with the Automatic Aerial Triangulation Software *MATCH-AT*

The input of an *AEROcontrol* result file into the automatic aerial triangulation software *MATCH-AT* (INPHO GmbH, Stuttgart, Germany) can be seen in figure 8.
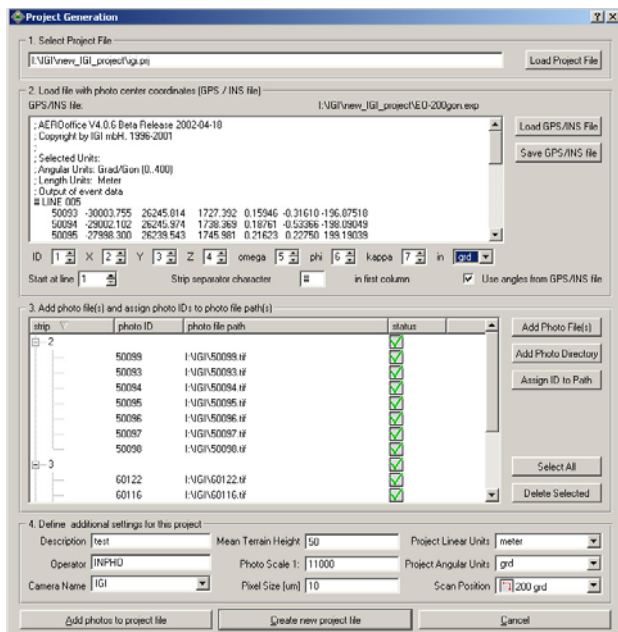

Figure 8. Input of EO-Parameters into *MATCH-AT*

In the top part of the figure the structure of the exchange file with the information photo number, position and attitude can be seen. In this case, the rotation order is omega, phi, kappa.

In figures 8 to 10 a project is shown that was flown in Tatebayashi, Japan in November 2001. Figure 9 was created with *AEROoffice*. It shows the footprints of six photos of the project. In the overlapping area, the position of a control point is marked.

After the import into *MATCH-AT* the overlapping area of the six pictures have been printed into the plots of figure 10. The position of the pictures relative to the control point (marked with a triangle) was calculated with the EO parameters of AEROcontrol alone.
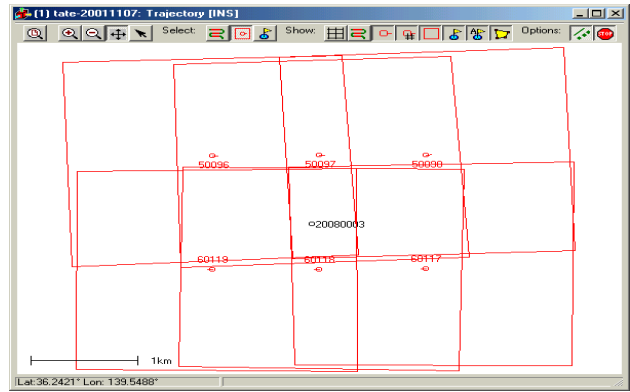

Figure 9. Overview of the six overlapping photos and GCP created with *AEROoffice*

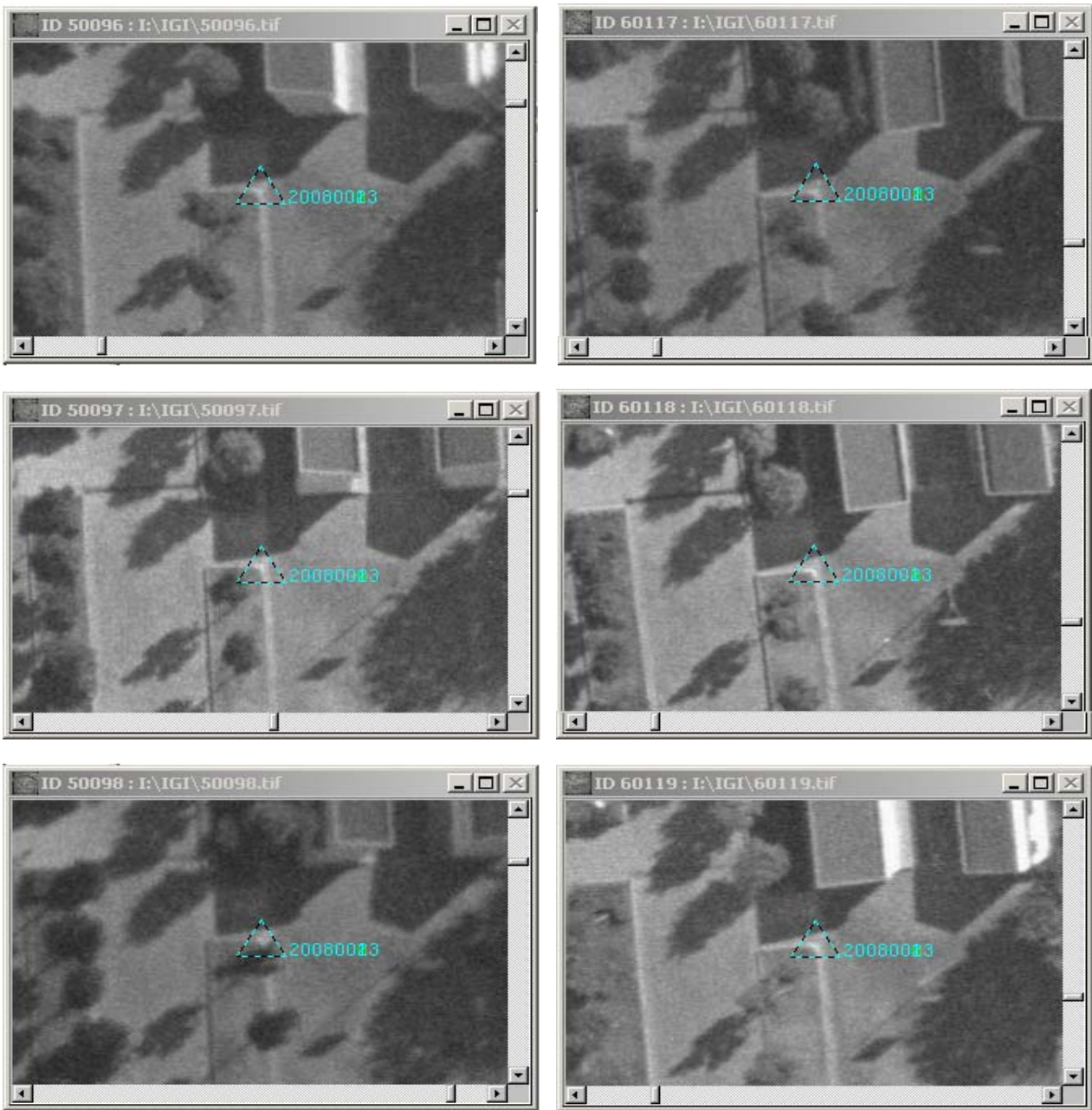Figure 10. Position of a ground control point in six different pictures. The orientation of the was done with the EO parameters from AEROcontrol alone.

5. CONCLUSION

With the *CCNS/AEROcontrol* IGI provides a fully integrated guidance, senor management and position/attitude determination system. The exchange of the collected data with other systems is done via the *AEROoffice* datamanager. This tool provides the functionality to export the results in numerous standard data formats for easy exchange with other systems, or to create a customized output format with the largest possible flexibility.