JAS: The Next Generation Digital Aerial Scanner

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ABSTRACT

With the experience from the spaceborne multi-spectral camera MKF-6 and the airborne MSK-4, Jena-Optronik now returns with the advanced and reliable JAS-150 to the market. Based on Jena-Optronik developments in the area of multi-line CCD sensors and know-how from other camera and spectrometer projects, the company has developed the most capable pushbroom scanner for remote sensing and photogrammetry. With nine CCD lines, each with 12000 pixels, four-band multispectral data is acquired. Five lines acquire panchromatic data from nadir and four different angles to avoid blind spots for a dense digital elevation model. With a ground sample distance of 4.3 cm from 1000 m flight altitude, the 150-mm focal-length device obtains data at high resolution and at the same time with reasonable swath widths. The near-orthogonal view allows the generation of digital coloured true orthophotos in an inexpensive fully automatic work-flow. The Jena Airborne Scanner (JAS) together with its photogrammetric processing software Jena-Stereo provides high spatial resolution, very high positional accuracy and very high radiometric resolution data. The JAS system is based on the pushbroom principle, which has proven its superiority over the framing camera technology in many space-based Earth observation systems. Developed for reconnaissance, remote sensing and photogrammetry the JAS represents a superior and affordable solution. Emphasis during development of the software suite Jena-Stereo is put on provision of an automatic work flow from JAS raw data up to digital elevation models, orthophotos and mosaics. File interfaces to a leading imaging and graphical editing software system have been implemented in Jena-Stereo for visual inspection and editing of processing results. The Jena-Optronik GmbH belongs to the Photonics Business Division of the JENOPTIK AG. The company has an excellent international reputation in the fields of opto-electronic instruments and systems, data management and processing for aerospace, security and defense, based on 30 years of experience. Within the Jenoptik Group, Jena-Optronik takes the lead function for complex opto-electronic system solutions in different kinds of fields, making use of the competence centers and the expertise of the whole group.

1. INTRODUCTION

The slow but continuing shift from film cameras to digital systems caused a higher demand for affordable and flexible systems. Based on former multi-line sensor, camera and spectrometer projects, Jena-Optronik now introduces the Jena Airborne Scanner (JAS). The standard configuration with 150-mm focal-length and four multi-spectral bands and five-stereo bands for a very dense digital elevation model offer the best results for most customers. But customized configuration e.g. with six multi-spectral and three stereo lines are possible on demand. The JAS 150 can moreover be equipped with narrow band filters.

The JAS offers near true orthophoto geometry and together with all color bands in full resolution high-quality colored orthophotos are possible. Through the use of state-of-the-art 12,000 pixel CCD line and a high-quality Jenoptik lens system high-resolution data up to 5cm from 1000m flight altitude and at achievable flight speeds are possible.

During development focus was set on a reliable and flexible system with a long lifetime and low cost of ownership which can be customized and adopted onto new customer demands. Another important goal during development was to offer an affordable solution with respect to industry standards and workflows. Therefore in the first step Jena-Optronik develops a JAS sensor model for SOCET SET®[1] until the photogrammetric software suite JenaStereo is available in fall 2006.

[1] SOCET SET is a registered trade mark of BAE SYSTEMS

2. THE JENA AIRBORNE SCANNER

The Jena Airborne Scanner (JAS 150) is an airborne digital camera that is based on the successful pushbroom scanner technology. The focal plane is designed with 9 CCD-lines, which are integrated in 3 focal plane modules and covered with different filters. The JAS product line will start with 150mm optics, other focal lengths are foreseen in the near future.

The JAS 150 is usable with common types of stabilization platforms (T-AS, GSM-3000, SM-2000 and PAV-30). Further it is possible to use different INS-systems (IGI-AEROcontrol and APPLANIX-POS AV510).

For store of the raw image data the system is equipped with a 1.6 TB RAID-system with a RAID-level3 redundancy standard . The interface from the RAID-system to peripheral workstation or data processing unit is a standard optical fibre-channel interface, so it is possible to read out raw image data with a standard PC-solution.

The JAS 150 will be commanded with special control and command software which is installed in the CCU (command and control unit). This unit is responsible for the adjustment of all camera parameters (e.g. gain adjustment, exposure time, drift input, commanding of the INS-system) and control of camera status parameters (e.g. INS-status, online quicklook, memory status). Further the CCU is equipped with an interface for the offline-quality-control of the raw image data, so it's possible to check each sensor line onboard the aircraft during the flight.

The visualisation of all camera, sub-system and status parameters will be realized on a 17inch TFT-screen which is mounted on the top of the system-rack. The monitor can be adjusted in all directions to prevent reflection effects during the flight.

The transmission of all data and power goes over one cable from camera to the sub-system rack and return, so it is possible to reduce time of systems-changing considerable.

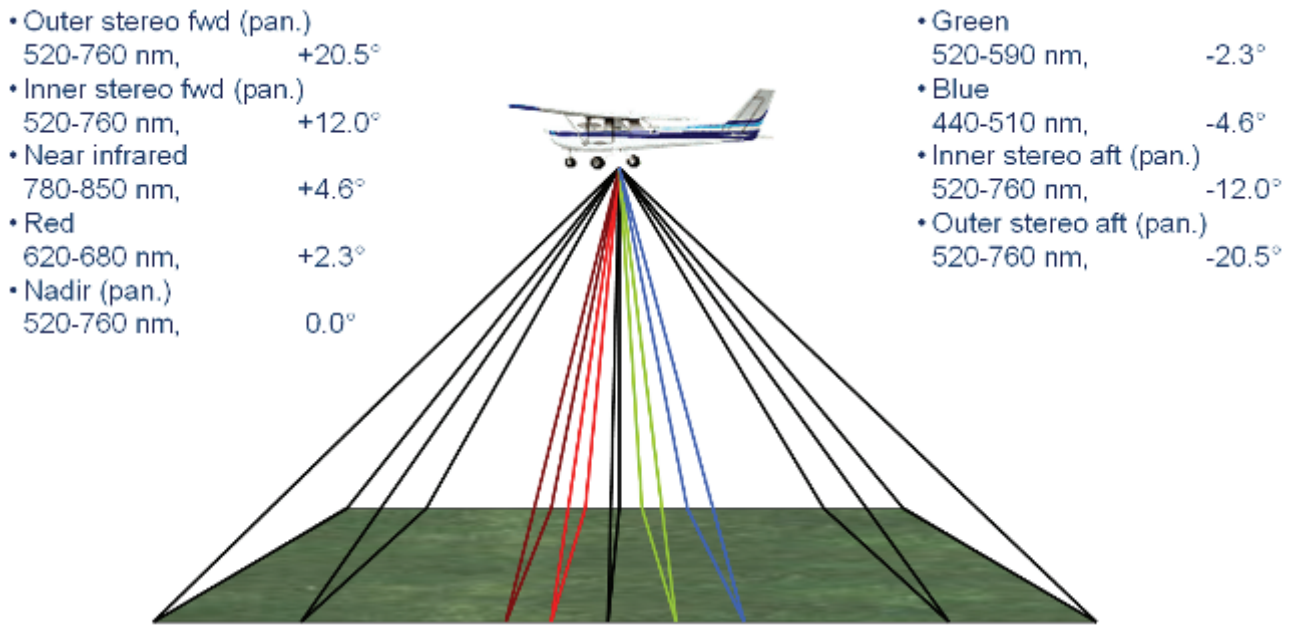

Figure 1: Standard four band multi-spectral configuration of the JAS 150.

System specification			
Image size	12000 pixel wide tiles		
Forward Motion Compensation	Not necessary		
Focal length	150	mm	
Number of CCD lines	9		
Number of pixels per CCD line	12000		
Pixel size	6.5	µm	
Radiometric resolution	12	bit	
Minimum exposure time	1.25	msec	
Stereo angle	±20.5	deg	
Swath angle	29.1	deg	
Maximum incidence angle	75.5	deg	
Lens Aperture F#	5.6		
Max. flight altitude	<8000m	(valid also for all peripherals)	
Spectral bands			
Stereo forward (pan)	520 – 760	nm	@+20.5°
Photogrammetry forward (pan)	520 – 760	nm	@+12.0°
Near infrared	780 – 850	nm	@+4.6°
Red	620 – 680	nm	@+2.3°
Nadir (pan)	520 – 760	nm	@±0.0°
Green	520 – 590	nm	@–2.3°
Blue	440 – 510	nm	@–4.6°
Photogrammetry backward (pan)	520 – 760	nm	@–12.0°
Stereo backward (pan)	520 – 760	nm	@–20.5°
Spatial resolution			
Max. mapping scale	Equal to 1:1000		
Inflight direction @ 70 m/s	> 8.8	cm	
Inflight direction @ 100 m/s	> 12.4	cm	
Across flight direction @ 3000 m	13.0	cm	
Across flight direction @ 5000 m	21.7	cm	
Swath width @ 3000 m	1.6	km	
Swath width @ 5000 m	2.6	km	
Geometric accuracy	< 1	pixel	
Data storage (RAID system)			
Storage capacity	1.6	TB	
Data rate	< 180	MB/s	
Redundancy	Yes	RAID 3	
Peripheral devices			
INS-system	IGI AEROcontrol or Applanix POS AV510		
Flight planning	Every common system		

Weights & dimensions	Mass	width	height	depth
JAS150	44 kg	440 mm	495 mm	405 mm
Rack full equipped (without INS)	52 kg	550 mm	950 mm	650 mm

Power Consumption			
Overall typical power consumption during image capturing	1200	Watt	(28V)

Table 1: Specifications of the JAS 150.

The mechanical structure of the camera and all sub-components is based on the rules of FAR/JAR 23.561 (EMERGENCY LANDING CONDITIONS). Electrical-, electro-magnetical-, thermal-, and pressure testing campaign for the camera system is performed according to DO-160E.

As a digital linescanner with a very precise inertial navigation system the potential for direct georeferencing exit. With current INS solutions based on GPS Jena-Optronik does recommend the use of some ground control points to avoid the risk of errors in the time alignment. When the European satellite navigation system becomes available Jena-Optronik will execute extensive tests to verify if direct georeferencing becomes an viable solution for commercial photo flights.

3. TECHNICAL SPECIFICATIONS

Table 1 shows the technical specifications of the JAS 150. The stereo angle with 41° is optimized for generating DEMs. The near-orthogonal view allows inexpensive highly automated work-flow for digital colored true orthophotos.

4. INFLIGHT QUALITY CONTROL SOLUTION

Different quality control options exist to enable the operator during the flight to control the imaging process online and offline. A disconnectable automatic Anti-Blooming solution exists to enable imaging in difficult regions.

The JAS 150 system provides a possibility to check the raw image data offline, during the flight. The camera operator can read out multiplexed-data-files from the RAID-system, these data files can be de-multiplexed with special software which is installed on the CCU. After this procedure image data from each sensor can be posed on the screen and can be stored on the CCU-HD.
Also during the flight the operator can control all sensors and their amplification by using a histogram

Currently under development is the possibility to operate the JAS through the CCNS4 flight management system from IGI. Other developments will be based on customer demand and the market development.

5. SUBSYSTEMS AND PERIPHERIALS

Several peripheral components are needed to operate the JAS camera:

The RAID system is a commercial of the shelf solution ready to be used in harsh environments like we have during photo flights. The RAID level3 system provides the capability for save data recording at high data rates via a standard optical fiber interface. It is ready for using in non-pressurized aircraft cabins up to FL250 (7.5km) and also designed with an internal shock absorbing systems. It will be operated via the Data Control Unit (DCU), which is a standard industrial PC hosting the data interface to the JAS camera. After flying a backup of the data can be made through the fiber channel interface with a standard PC or laptop on the airfield.

The Command & Control Unit (CCU) is also a standard industrial PC that is providing all the command interfaces to the JAS camera, the DCU, and the INS.

The Inertial Navigation System (INS) is providing the data needed to determine the flight trajectory, which is used for the image data processing. The JAS camera is compatible with both most popular systems Applanix' POS AV510 and IGI's AEROcontrol. If the customer already owns one of theses systems it can be integrated into the JAS to avoid buying a new one.

The stabilization platform is keeping a low profile for the camera in the somewhat vibrational environment of the aircraft. The JAS camera can be mounted on T-AS, PAV30, and the common SM-2000 and its successor GSM-3000.

6. DATA PROCESSING

To enable production of orthophotos, DEMs and other photogrammetric products from the images acquired using the JAS camera, Jena-Optronik is developing the photogrammetric software package JenaStereo, which will provide an automatic processing workflow. JenaStereo will consist of the following modules:

- ASM : JAS sensor model for JenaStereo and SOCET SET®, as well as preprocessing software
- APT : triangulation and bundle adjustment
- ATE : automatic terrain extraction
- ORM : ortho rectification and mosaic creation

Since JenaStereo is still under development and also to provide interactive editing and other advanced features, it is supported processing JAS images with SOCET SET®.
SOCET SET® is an extensive package for digital photogrammetric workstations. It can be used together with the ASM-module to produce orthophotos, DEMs, mosaics and other products from JAS raw data. To this end, the ASM-module contains a JAS-sensor model for SOCET SET® to enable a highly accurate workflow and a preprocessing-software to generate rectified images to be used inside SOCET SET®. The aim of the sensor model is to establish a relationship between image and ground reference systems according to the sensor geometry, sensor position and orientation and other available data.
Since JenaStereo won't be available until the end of 2006, more emphasis is paid here to the description of the processing using SOCET SET®.

6.1 GPS/IMU Post-Processing

GPS and IMU data are collected during the flight and have to be post-processed along with optional GPS base station data to produce precise position and orientation data for every sampled line. JAS supports hard- and software solutions of the companies Applanix and IGI to collect the necessary data and post-process it.

6.2 Image Rectification

The post-processed position and orientation data is used to rectify the image to correct for the aircraft motion and produce a viewable image. This is done by projecting the images to a ground plane at a user specified height (usually zero). This approximately geopositioned image can then be used for human stereo viewing and automated point measurement.

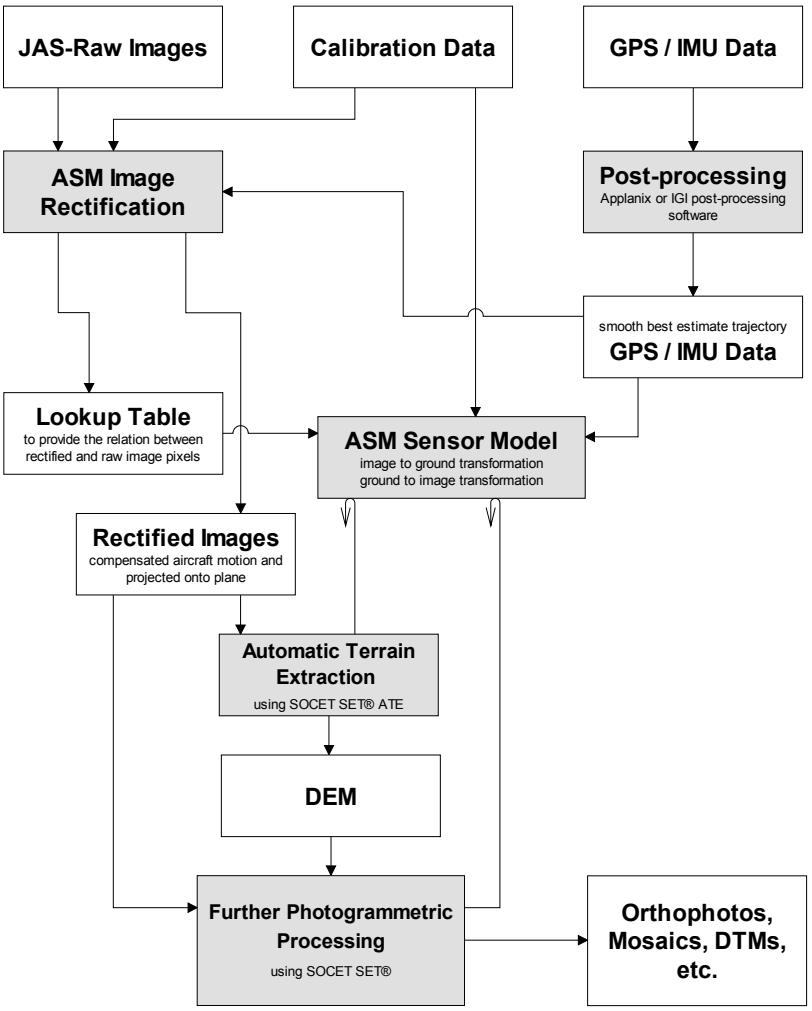

Figure 2: Data Processing Workflow

A look up table is also created to provide the transformation from rectified image to original image. This is necessary to provide the mathematical model for ground to image and image to ground to work exactly by providing the exact position associated with every pixel in the rectified image.

6.3 Aerotriangulation

To further advance the accuracy of the sensor model a triangulation process involving a small number of interactively measured control points and automatically measured tie points can be applied. The extra information provided to the system via control and tie points leads to a very reliable computation of position and orientation of the camera focal plane and other camera parameters and therefore to a more accurate projection of the image to the ground and vice versa.

The needed tie points can be obtained using the APM software module from SOCET SET®. Triangulation and a combined bundle adjustment will be available in 2 ways:

- The APT (Adjusted Point Triangulation) module of the upcoming JenaStereo software suite will provide triangulation and bundle adjustment.

- Usage of the BINGO[2] software together with the ASM module and SOCET SET® is being pursued at the moment.

6.4 ATE

Grid or TIN DEMs can be created from the rectified images using the SOCET SET® Automatic Terrain Extraction (ATE) module and the JAS-sensor model. ATE will take advantage of the multiple stereo views of the camera, owing to the fact, that it is a multiple image algorithm (Zhang and Miller, 1997). This improves the quality of the generated DEM and reduce the amount of occluded surface.

6.5 Ortho Mosaics and other products

Using various SOCET SET® modules together with the JAS sensor model ortho-rectified images, mosaics and other image products can be generated using the rectified images and the DEM.

7. CONCLUSIONS

Jena does have a strong tradition in photogrammetry and the development of airborne cameras. With we Jena Airborne Scanner we return to the market with a advanced and reliable pushbroom scanner. In the current configuration the affordable JAS 150 fits the needs of the most remote sensing companies. All multi-spectral bands in full resolution and the possibility of extent the abilities up to five or six bands with three stereo lines remaining, making it superior to all other devices. With five stereo lines in the standard configuration it gives most photogrammetric applications a very dense DEM and avoids blind spots. The modular and flexible design allows future enhancements to fit the needs in a changing market. The next generation pushbroom scanner JAS therefore offers the widest range of applications of all available devices.
The device was developed with the scope on low cost of ownership. Therefore the first recalibration is necessary after five years. The accommodation on the flight management system CCNS4 from IGI is currently under development. This would allow the pilot to operate the JAS.
As the results of tests and extensive examinations an optic lens system from Jenoptik used. Its performance is superior to all other available solutions. Other mass memory solutions which have been investigated like a tape drive or a solid state memory proved yet to be too expensive to have a too low data rate. Hence the flight certified RAID 3 solution is offered to our customers. New developments in these technologies are under observation.

In order to provide an extensive, reliable and highly accurate solution for processing images from the JAS camera Jena- Optronik GmbH is developing JenaStereo and also supporting third-party software such as SOCET SET®, BINGO and the post-processing solutions of Applanix and IGI.

Next tests will be concentrated on other band configurations and new JenaStereo features. Other camera enhancements are under investigation. A hardware upgrade path for existing models will be provided as service to all customers.

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[2] Bundle adjustment software for standard aerial triangulation; Geoinformatics & Photogrammetric Engineering; Dr. Erwin J. Kruck; Aaalen; Germany

8. REFERENCES

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