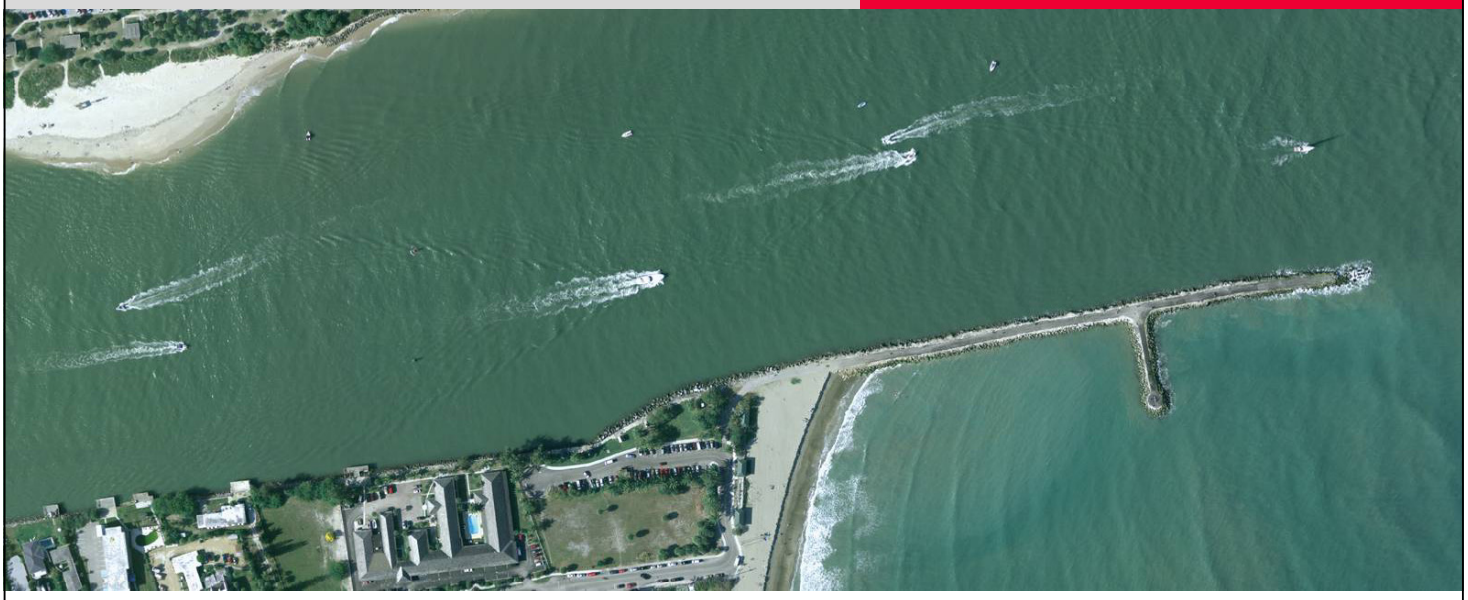


51st Photogrammetric Week, Stuttgart

Raising the Bar for Multi-Band, High-Resolution Airborne Imagery

Peter Fricker, Switzerland

- when it has to be right

Leica Geosystems

Raising the Bar for Multi-Band High-Resolution Airborne Imagery

Contents

- Achievments after 10 years of development
- Design of the ADS40 2nd Generation
- Geometric and radiometric image quality
- Calibration / Certification
- Summary and Outlook

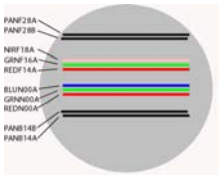
- when it has to be right

Leica Geosystems

Achievments of 10 years development

ADS40 1st Generation (2000-2006)

1 Sensor Head: SH40



1 standard Focal Plate + 1 IMU

ADS40 2nd Generation (2007)

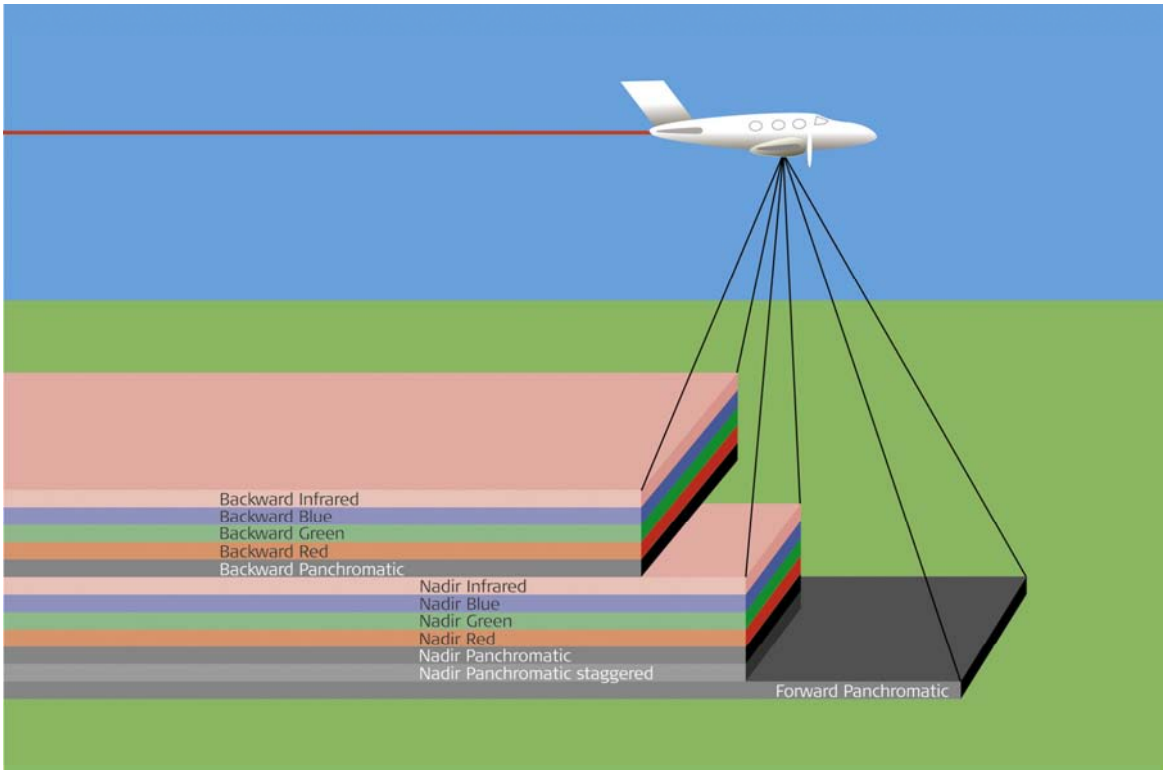
2 Sensor Heads: SH51 & SH52

2 standard Focal Plates + 4 IMU's

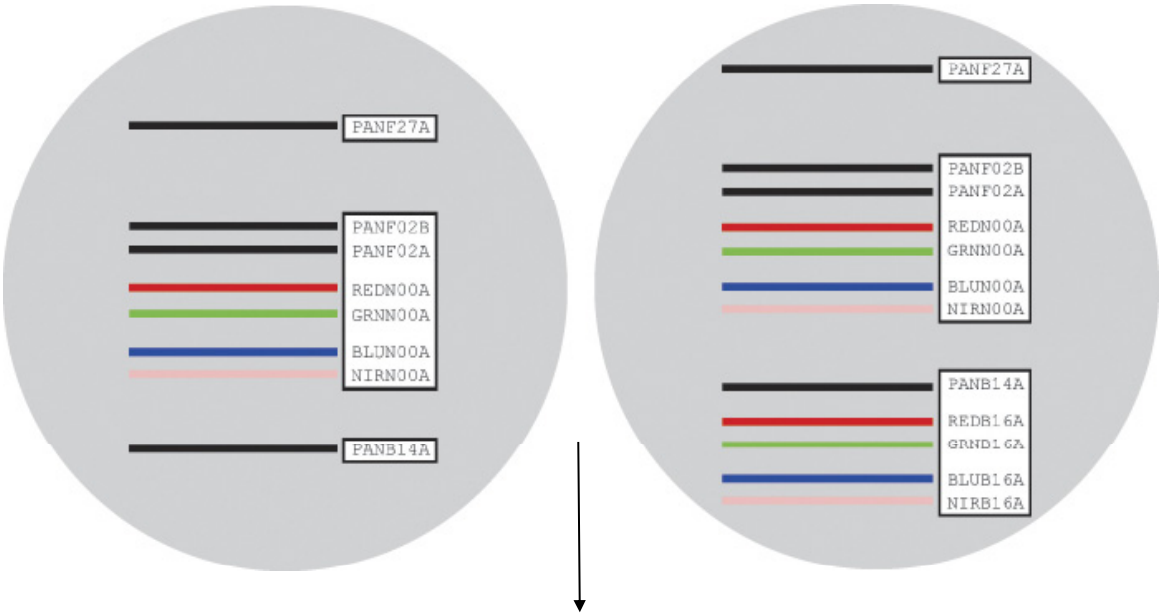
		NUS4	DUS5	NUS5	CUS6
Absolute accuracy after post-processing (RMS)	Position	0.05 - 0.3 m	0.05 - 0.3 m	0.05 - 0.3 m	0.05 - 0.3 m
	Velocity	0.005 m/s	0.005 m/s	0.005 m/s	0.005 m/s
	Roll & Pitch	0.008 deg	0.005 deg	0.005 deg	0.0025 deg[1]
	Heading	0.015 deg	0.008 deg	0.008 deg	0.005 deg[1]
Relative accuracy	Angular random noise	<0.05 deg/sqrt(hour)	<0.01 deg/sqrt(hour)	<0.01 deg/sqrt(hour)	<0.01 deg/sqrt(hour)
	Drift	<0.5 deg/hour	<0.1 deg/hour	<0.1 deg/hour	<0.01 deg/hour

ADS40 2nd Generation

Panchromatic, RGB and NIR data collection



ADS40 2nd Generation
CCD layout in SH51 and SH52 focal plate



SH51 **SH52**

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The ADS40 2nd Generation, a result of technical progress

- **Optics:**
  Microstructured filters allowed a new beam splitter design, the „Tetrachroid“

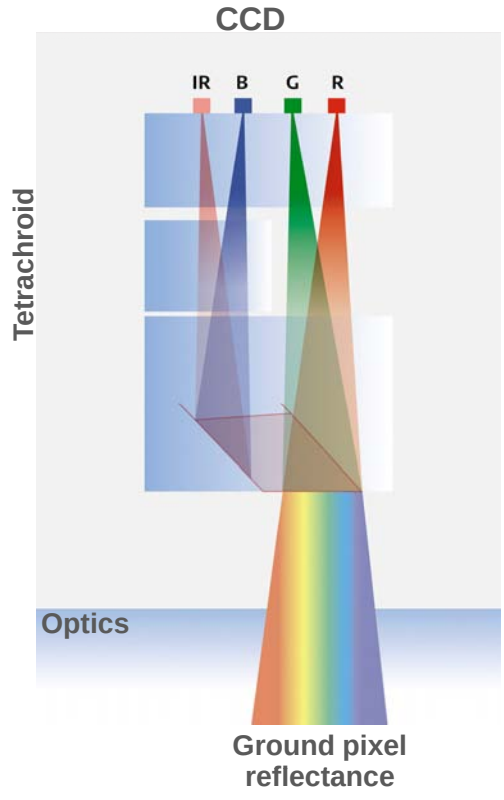
- **Mechanics:**
  A new alloy allowed a quasi-monolithic structuring of all stability-relevant components

- **Electronics:**
  Higher integration density of electronics led to shorter signal paths, resulting in a 4 times higher sensitivity

- **Subsystems:**
  High performance IMUs provided a better initial orientation

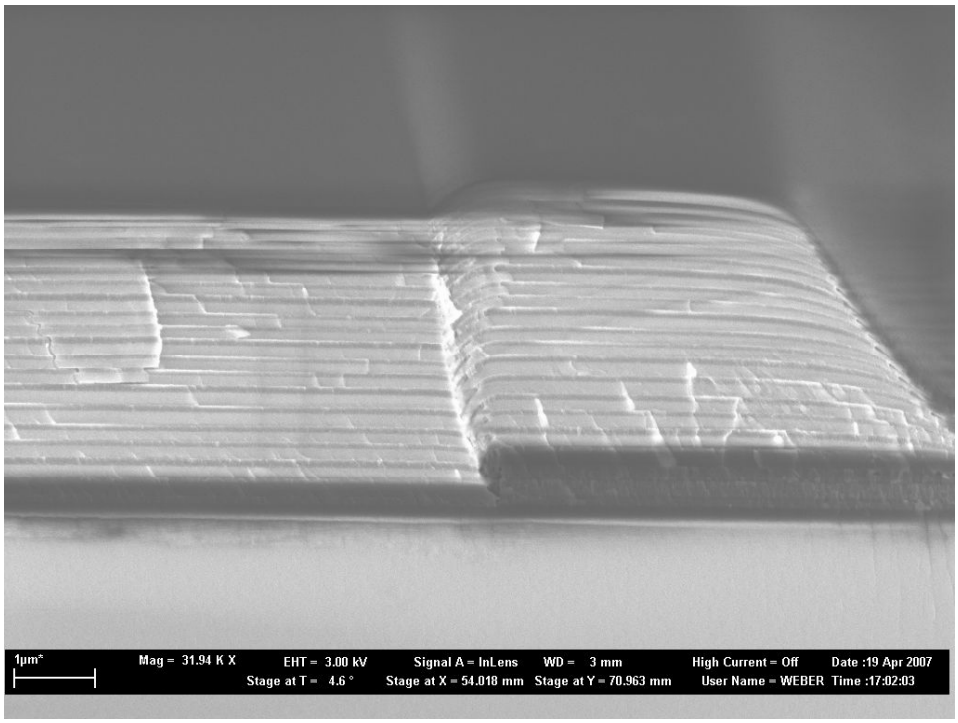
Optics:

New Tetrachroid beamsplitter - Schematics



- Optical RGB and NIR pixel co-registration device
- Microstructured cascaded dichroic beamsplitters
- Energy conservation due to spectral light splitting
- Metal interference filters
- Located between optics and CCDs

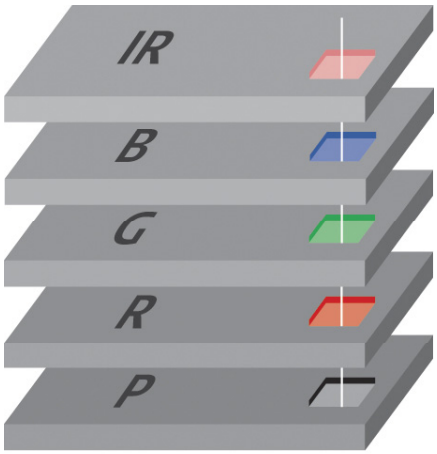
Optics:
New Tetrachroid beamsplitter – Cross-Section



- Colours have to be separated by filters close to the CCD line pairs
- Filter strips have to be 16 µm wide and perfectly straight
- Filter glass has to be mounted in close distance (40 µm) to the CCD surface

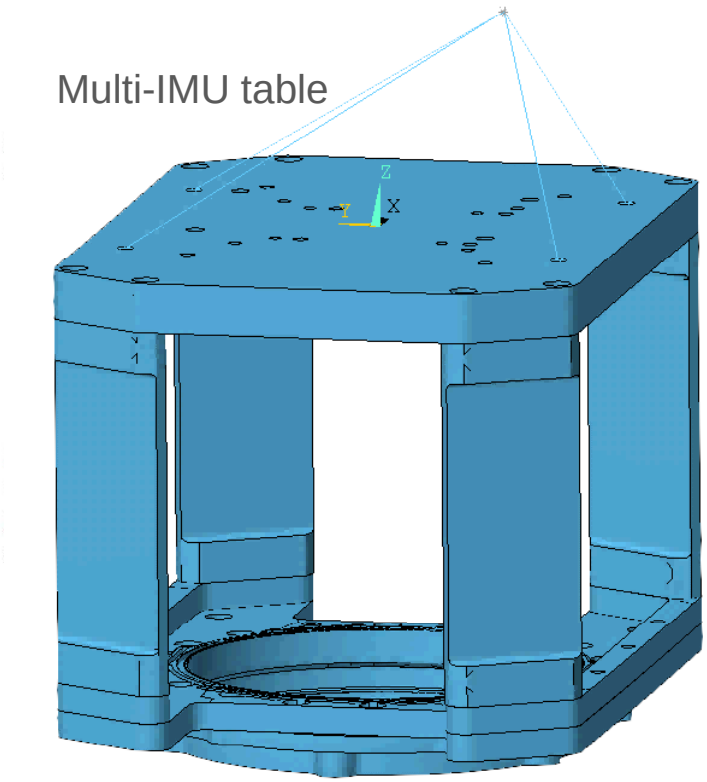
Optics:
New Tetrachroid beamsplitter - Benefits

- Perfectly co-registered R,G,B,N images
- All bands acquired at the same native resolution
- RGB and RGN composites with same resolution as the 3-line Pan images
- No Pan-sharpening required
- 5th band (Pan) from combined RGB bands
- Direct geo-referencing of all image data due to rigid connection of IMU, Focal plate, Tetrachroid and Optics



5-Band Imagery

Mechanics:
A new alloy for increased stability



- Focal plate made from an Al-Si alloy with high thermal conductivity and expansion of steel
- Central carrier (steel) holds lens system (steel) and focal plate
- Legs of IMU table allow central symmetric relative expansion of carrier and IMU table

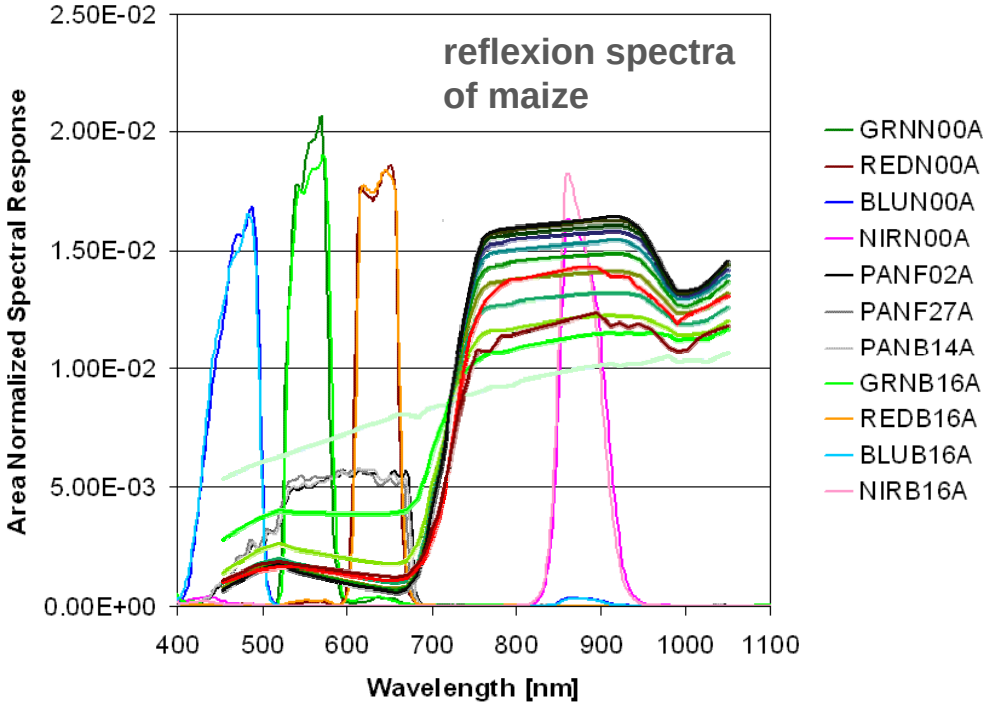
Raising the Bar for Multi-Band High-Resolution Airborne Imagery

Contents

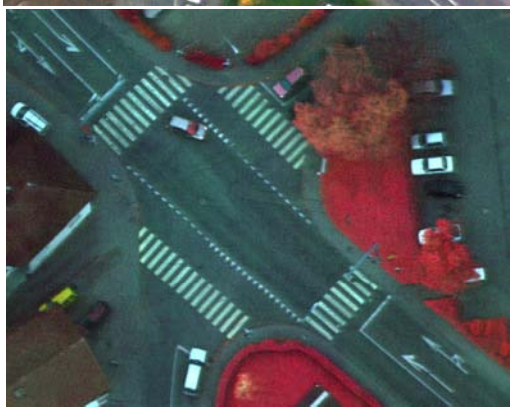
Further benefits of the technical progress

- Co-registered RGB and NIR for remote sensing
- Low image noise opens a wide field of applications
- Undisturbed imaging geometry allows a simple physical sensor model for in-situ self-calibration

Co-registered RGB and NIR for remote sensing, optimized for vegetation



Low image noise opens a wide field of applications



4 times increased sensitivity compared to 1st Generation sensors can yield faster ground speed or improved image quality

Longer flights during day and season

Data collecting on overcast days

Weather: overcast -> Equivalent sun-angle: 8°

GSD 5 cm

Ground Speed GS: 140 knots

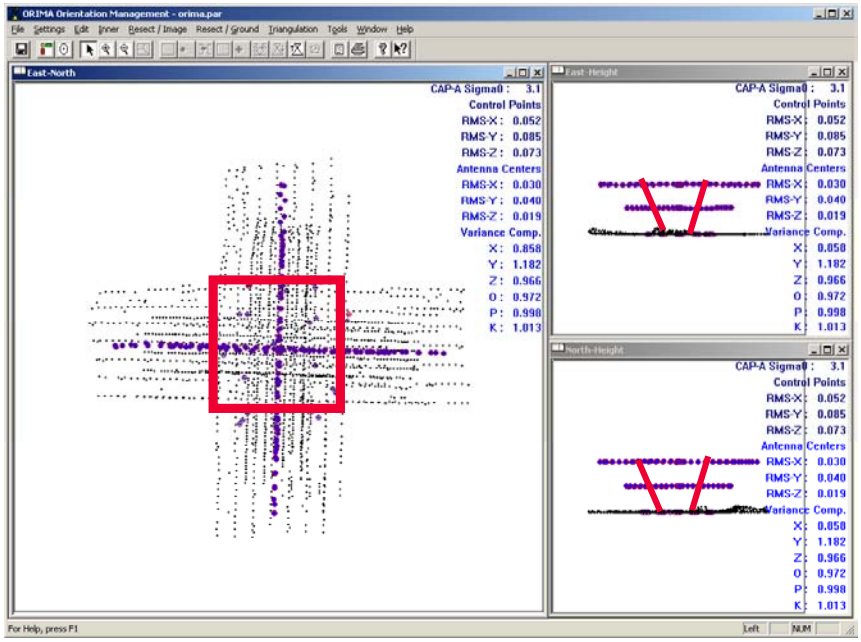
Date/Time: 1 Nov. 2006 / 3:20 p.m.

Latitude: 47° North

Sun-Angle: 13°

Undisturbed imaging geometry allows a simple physical sensor model for in-situ self-calibration

Cross-flight pattern at two altitudes allows:



In-situ flight calibration to compensate for many systematic error sources in the light path

- **Aerosol**
- **Air turbulence**
- **Optical window**
- **Cover glass**
- **Optics**
- **Filters**

Geometric and Radiometric Image Quality

Geometric Calibration

- Undistrubed image geometry due to mechanical stability of the IMU table, a single focal plate and a single temperature and pressure compenstated lens system
- Lab calibrations are insufficient to eliminate all systematic errors
- The In-situ Self-Calibration method offers
  - independence from manufacturers geometric lab calibration
  - allows in-situ calibration flights anywhere in the world
- In-situ Self-Calibration method gives flexibility to national certification entities

Quality of external orientation

Romanshorn test area – 5, 10, 20 cm GSD (July 2007)

		Ground Control [cm]	Check Points [cm]
GSD 5 cm	RMS-X	1.2	1.2
	RMS-Y	1.1	2.1
	RMS-Z	2.7	3.8
GSD 10 cm	RMS-X	1.7	3.4
	RMS-Y	1.3	3.4
	RMS-Z	1.6	8.7
GSD 20 cm	RMS-X	2.1	7.1
	RMS-Y	2.8	8.5
	RMS-Z	3.9	11.7

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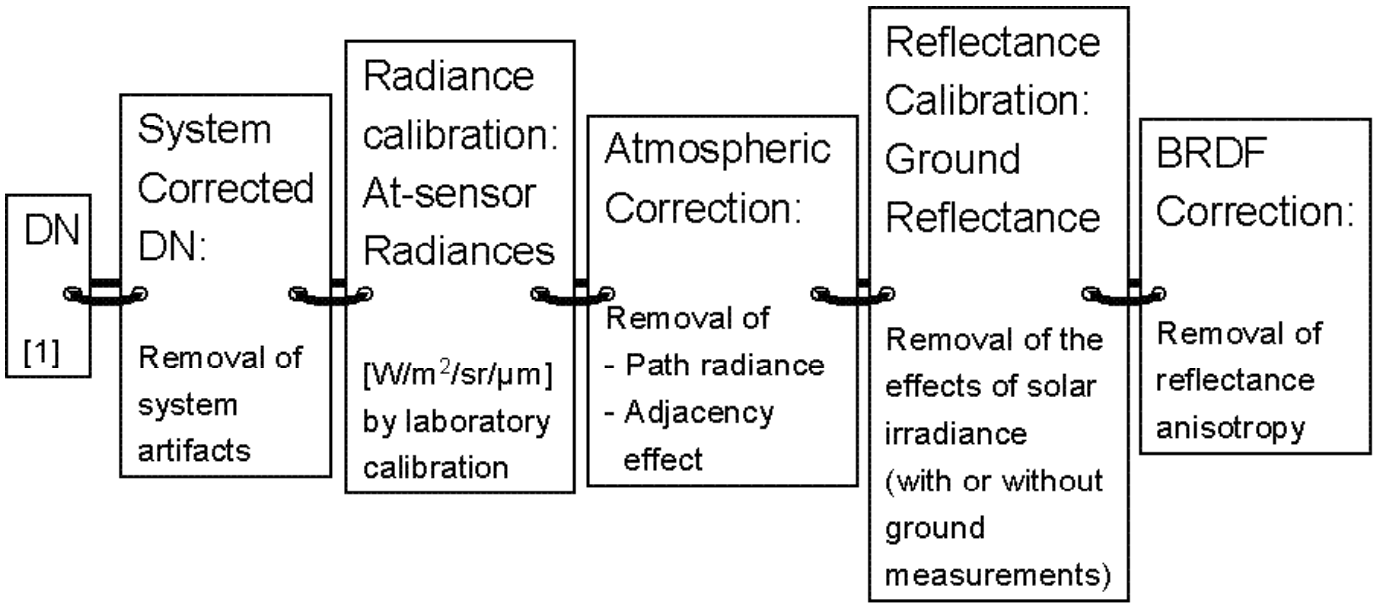
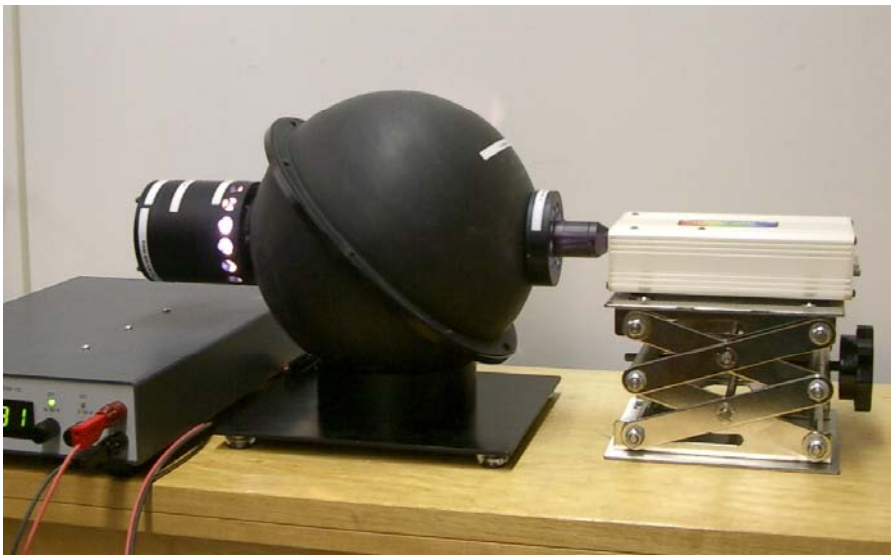
ADS40 Radiometric Processing Chain



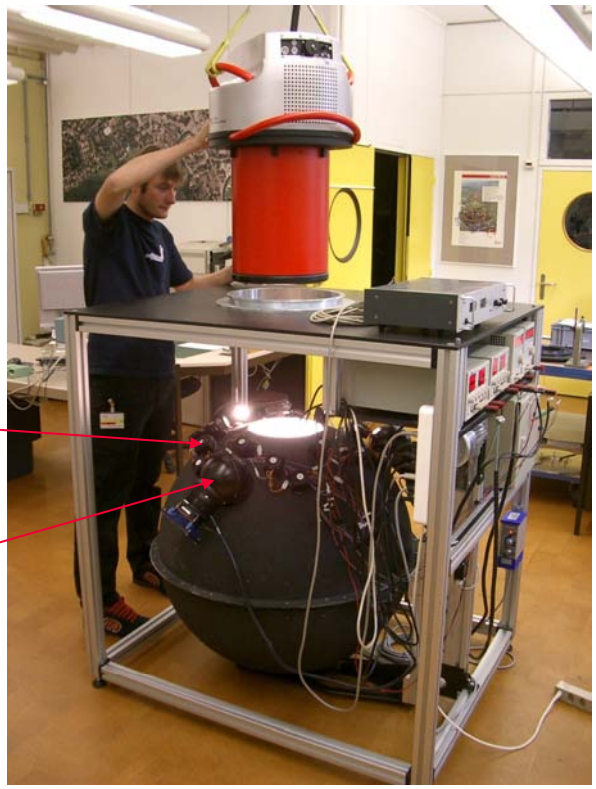
Absolute spectroradiometric calibration of the ADS40 sensor

Is best realized in a lab environment because light intensities can be made traceable to national standards



NIST Traceable Laboratory Light Source
with spectroradiometer

Calibrated Integrating Sphere



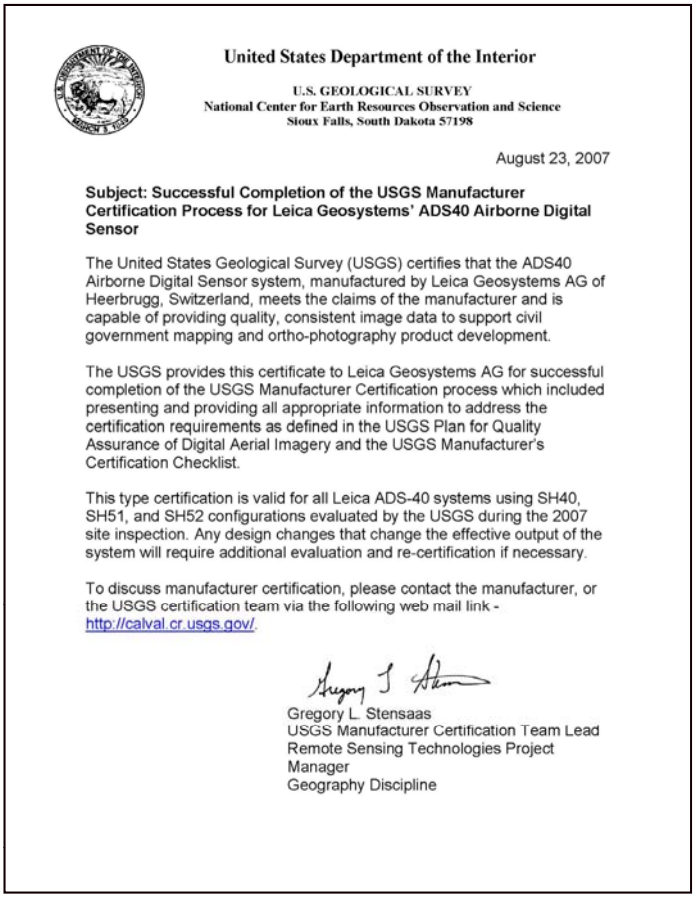
Blue LEDs

Calibrated Satellite sphere with Tungsten lamp

Summary on the absolute radiometric calibration

- Absolute radiometric calibration of digital cameras offers additional information and image normalization possibilities.
- After radiometric calibration is applied in GPro, 16 bit ADS40 image data differ only by a small factor from the corresponding spectral radiance value.
- Quantitative measurements for geology, agriculture, etc. are made possible.
- Laboratory calibration sites in Switzerland, USA and soon in Asia ensure a proper “global” calibration of all ADS40 sensors.

USGS Certification



United States Department of the Interior

U.S. GEOLOGICAL SURVEY
National Center for Earth Resources Observation and Science
Sioux Falls, South Dakota 57198

August 23, 2007

Subject: Successful Completion of the USGS Manufacturer Certification Process for Leica Geosystems' ADS40 Airborne Digital Sensor

The United States Geological Survey (USGS) certifies that the ADS40 Airborne Digital Sensor system, manufactured by Leica Geosystems AG of Heerbrugg, Switzerland, meets the claims of the manufacturer and is capable of providing quality, consistent image data to support civil government mapping and ortho-photography product development.

The USGS provides this certificate to Leica Geosystems AG for successful completion of the USGS Manufacturer Certification process which included presenting and providing all appropriate information to address the certification requirements as defined in the USGS Plan for Quality Assurance of Digital Aerial Imagery and the USGS Manufacturer's Certification Checklist.

This type certification is valid for all Leica ADS-40 systems using SH40, SH51, and SH52 configurations evaluated by the USGS during the 2007 site inspection. Any design changes that change the effective output of the system will require additional evaluation and re-certification if necessary.

To discuss manufacturer certification, please contact the manufacturer, or the USGS certification team via the following web mail link - http://calval.cr.usgs.gov/.

Gregory L. Stensaas
USGS Manufacturer Certification Team Lead
Remote Sensing Technologies Project Manager
Geography Discipline

Fulfilling the USGS Plan for Quality Assurance of Digital Aerial Imagery the ADS40 System obtained the USGS Certification for all of the three Sensor Heads:

SH40

SH51

SH52

Raising the Bar for Multi-Band High-Resolution Airborne Imagery

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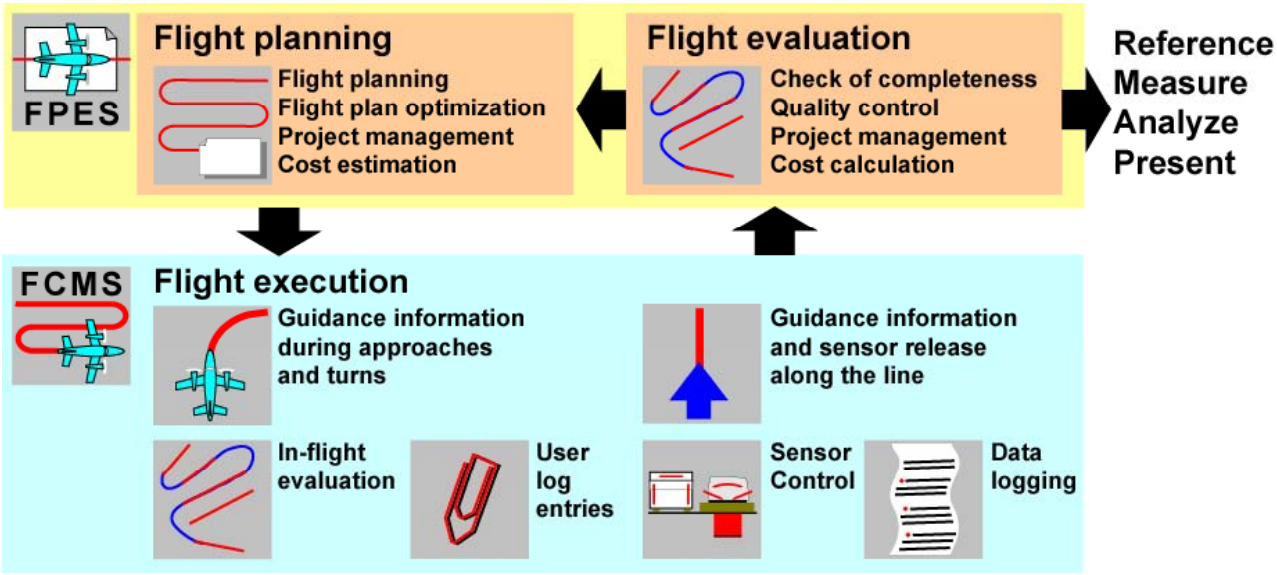
Summary of practical benefits of the progress made from 1st to 2nd Generaton ADS40

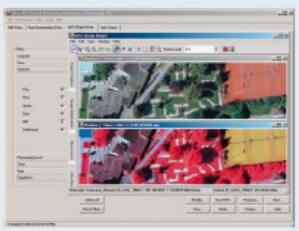
- 4 times more sensitivity
- Reduced volume of Sensor Heads SH51 / SH52
- Exchangeable IMU‘s
- Fringe-free Stereo images in equal native PAN, RGB and CIR
- Geometric in-situ Self-Calibration
- Absolute spectroradiometric calibration
- Independence from GNSS reference Stations (PPP technology)
- Upgrade path from SH40 to SH51 / SH52

Leica Geosystems' proven integrated workflow

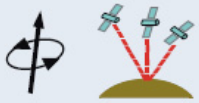
- FPES – Flight Planning & Evaluation Software
- FCMS - Flight & Sensor Control Management System



Leica GPro – ADS40 Ground Processing



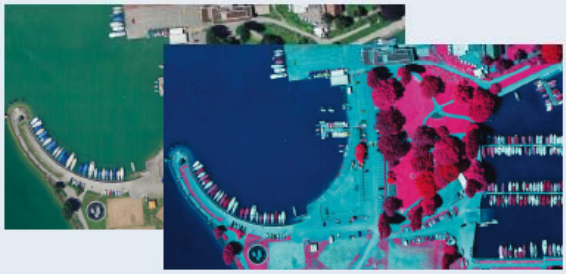
GPro
- Data Download
- Georeferencing
- Aerial Triangulation
- Image Rectification
- Orthophoto Generation



IPAS Pro
- Post Processing of GNSS/IMU Data

Data for
- DTM
- Mapping
- Revision
- Visualisation
- Image Analysis
- Classification

Image Deliverables



Post processing time (PHOWO 2003)

			Total time Workstations single	Total time Workstations eight	User action time
Capture	Flight	2,400 km², 20cm GSD 30 lines, each 40 km, 3 Pan and 4 MS Approximately 8 h flight at 130 knots			
Reference	Download	230 GB ADS data format = 940 GB image data	5 h	5 h	0.5 h
	Geo-referencing	Trajectory calculation geo-referencing of L0 images	2 h 3 h	2 h 3 h	1.5 h 0.5 h
	Rectification	FW, Nadir and BW panchromatic image strips from each flight line Automatic Point Measurement	36 h	5 h	0.5 h
	Aerial triangulation	Bundle Adjustment	36 h 12 h	5 h 12 h	0.5 h 1.5 h
Measure	Ortho photo	RGB or FCIR 2,400 km² (927 sq.mi)	60 h	9 h	5 h
Analyze	Feature extraction	Due to image strips slightly faster than in traditional workflow	154 h	41 h	10 h
Present	Fly-through	Similar to traditional workflow			

- when it has to be right

Leica Geosystems

Post processing time (PHOWO 2007)

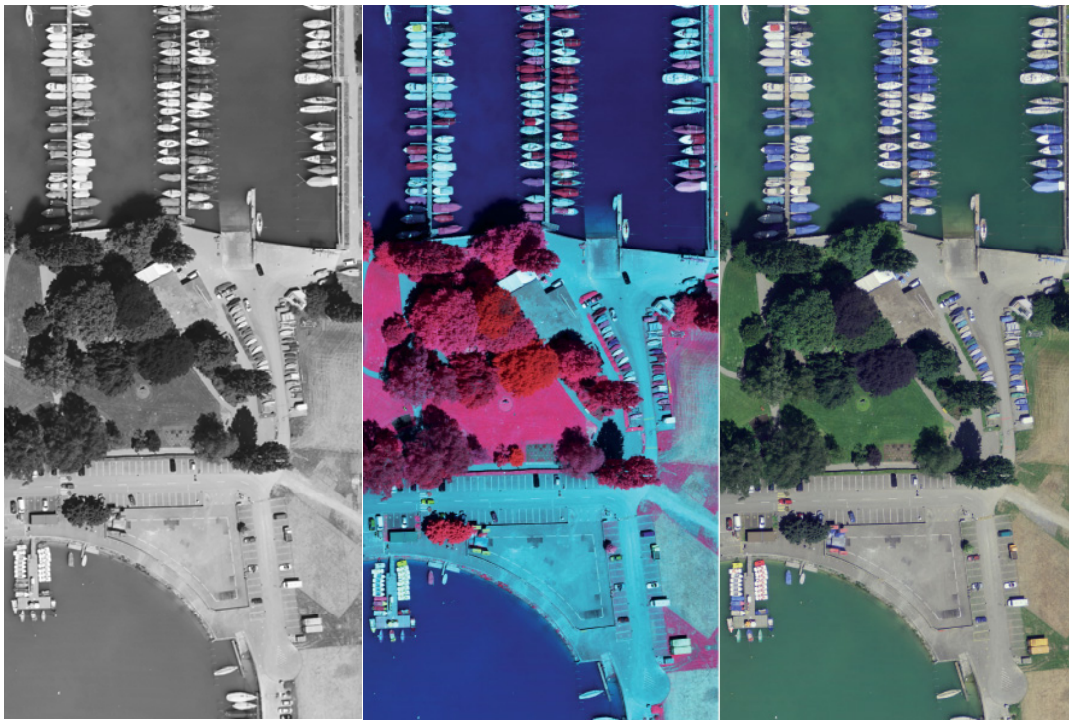
			Total time Workstations single	Total time Workstations eight	User action time
Capture	Flight	2,400 km², 20cm GSD 30 lines, each 40 km, 3 Pan and 4 MS Approximately 8 h flight at 130 knots			
	Download	230 GB ADS data format = 940 GB image data	4 h	4 h	0.5 h
Reference	Geo-referencing	Trajectory calculation geo-referencing of L0 images	2 h 2 h	2 h 2 h	1.5 h 0.5 h
	Aerial triangulation	Automatic Point Measurement Bundle Adjustment	8 h 12 h	3 h 12 h	0.5 h 5 h
Measure	Ortho photo	RGB or FCIR 2,400 km² (927 sq.mi)	44 h	6 h	1.5 h
			72 h	29 h	9.5 h
Analyze	Feature extraction	Due to image strips slightly faster than in traditional workflow			
Present	Fly-through	Similar to traditional workflow			

- when it has to be right

Leica Geosystems

ADS40 2nd Generation
Best Imagery

- PAN, RGB and RGN Stereo
- Equal Resolution
- No color fringes



Romanshorn
Bodensee
H = 1000m
GSD: 10cm

ADS40 2nd Generation
5cm GSD image

Achieved requirements for a truly multi-band, high-resolution camera – the bar has been raised

- High area coverage performance (FoV, Swath)
- High accuracy (spatial and radiometric)
- Equal resolution in all bands
- No Bayer array solution
- No Pan-Sharpening
- No model deformation due to image patching
- No model deformation caused by temperature & pressure changes in the optical system
- Full Stereo capability (PAN, RGB, CIR)

ADS40 2nd Generation Airborne Digital Sensor Best Imagery … Anytime … Anywhere

Thank you for your attention