



<b>11:00 - 12:00</b>	<b>Introducing IGI</b>
12:00 - 13:30	Lunch Break
<b>13:30 - 14:30</b>	<b>Sensor Systems</b>
<b>14:30 - 15:30</b>	<b>Mission Planning / Flight Guidance</b>
15:30 - 16:00	Coffee Break
<b>16:00 - 16:45</b>	<b>Georeferencing with GNSS/IMU</b>
<b>16:45 - 17:00</b>	<b>Questions / Discussion</b>

[www.igi-systems.com](http://www.igi-systems.com)



November 10<sup>th</sup>, 2008, Kreuztal

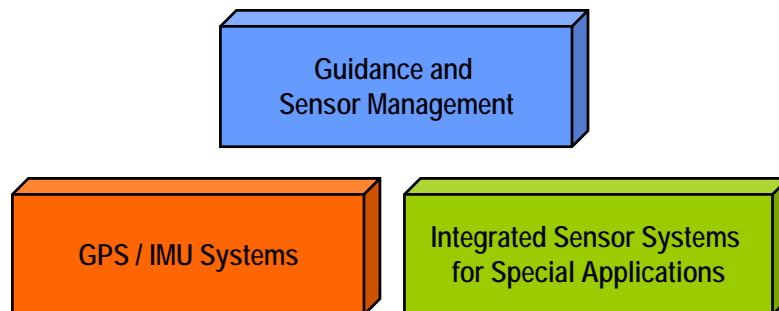
## IGI Product Spectrum

Jens Kremer  
IGI mbH  
57223 Kreuztal / Germany

[www.igi-systems.com](http://www.igi-systems.com)



**IGI mbH**  
Langenauer Str. 46  
57223 Kreuztal, Germany  
[www.igi-systems.com](http://www.igi-systems.com)



Guidance and  
Sensor Management

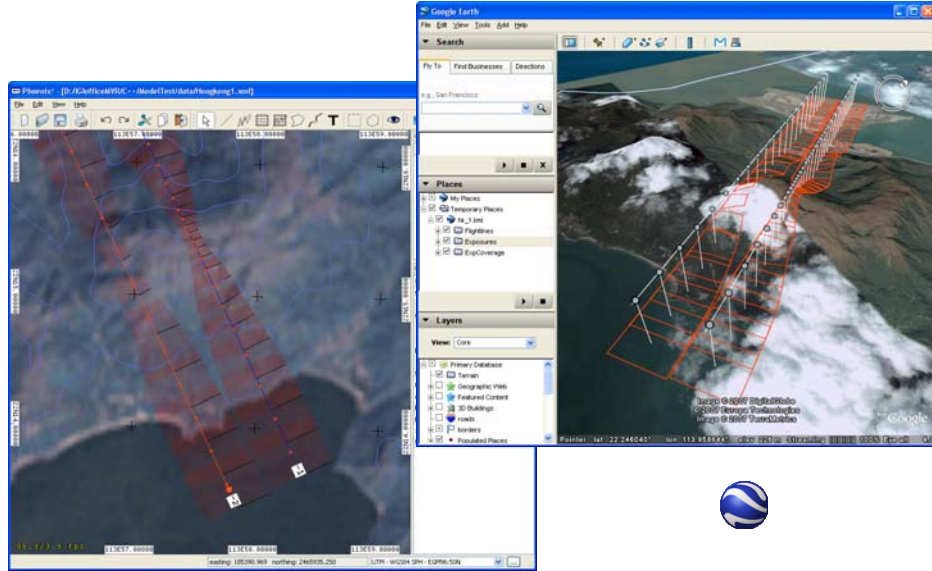
GPS / IMU Systems

Integrated Sensor Systems  
for Special Applications

**CCNS:  
Guidance and Sensor Management**

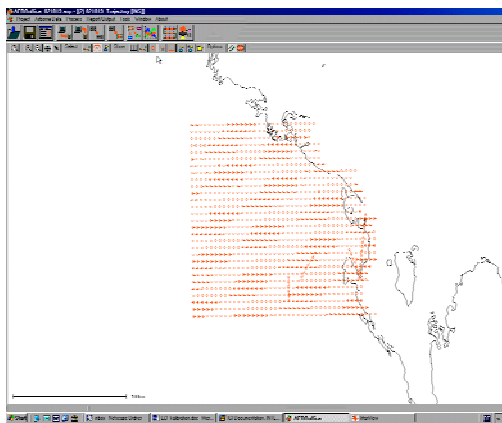


# Mission Planning and Documentation



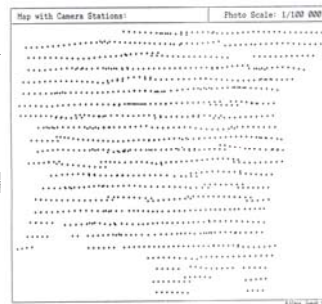
www.igi-systems.com

# Development in Aerial Survey



Today

1988



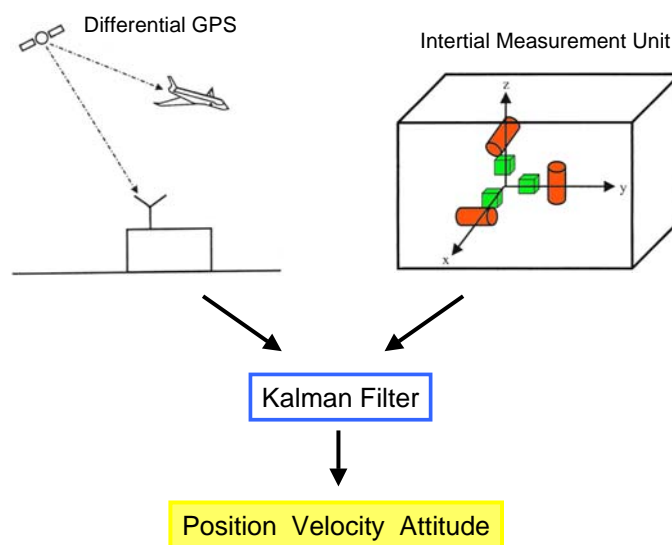
www.igi-systems.com

Guidance and  
Sensor Management

GPS / IMU Systems

Integrated Sensor Systems  
for Special Applications

## GPS/IMU Integration



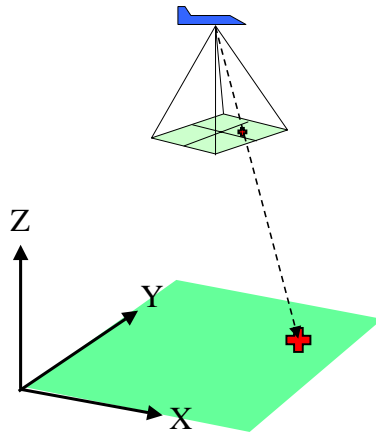
## Direct Georeferencing



### Georeferencing



connect information of an airborne sensor with a position in space



**Indirect** using the sensor data  
Example: AT

**Direct** NOT using the sensor data

- position
- attitude
- velocity ( e.g. SAR)

www.igi-systems.com

## AEROcontrol-IId

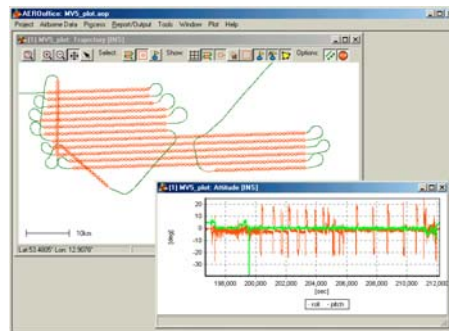


### Hardware

### Software



**AEROcontrol** computer unit with GPS receiver and IMU



**AEROoffice** software incl. GrafNav

www.igi-systems.com

## CCNS/AEROcontrol



[www.igi-systems.com](http://www.igi-systems.com)



Guidance and  
Sensor Management

GPS / IMU Systems

Integrated Sensor Systems  
for Special Applications

- LiteMapper
- DigiCAM
- StreetMapper

[www.igi-systems.com](http://www.igi-systems.com)

## LiteMapper - Components



max. pulse repetition rate: **240 kHz**  
max. range: **1800 m**  
number of targets / pulses: **unlimited** for digitized waveform



[www.igi-systems.com](http://www.igi-systems.com)

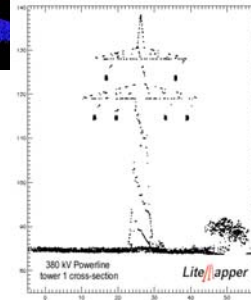
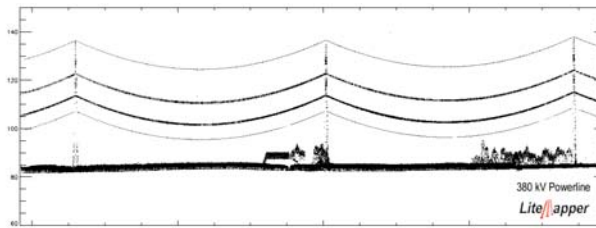
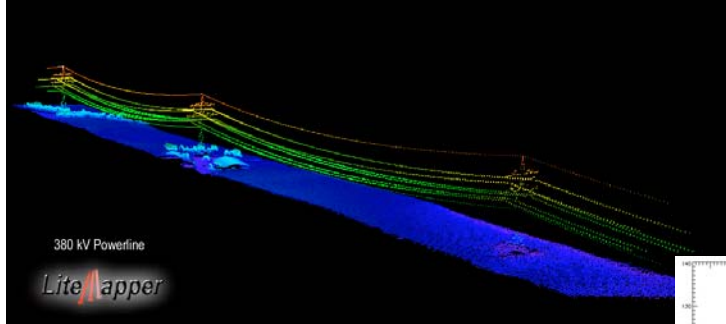
## Installation in a Bell 206 Jet Ranger



[www.igi-systems.com](http://www.igi-systems.com)

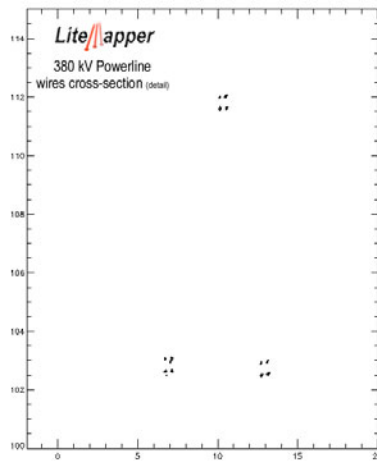
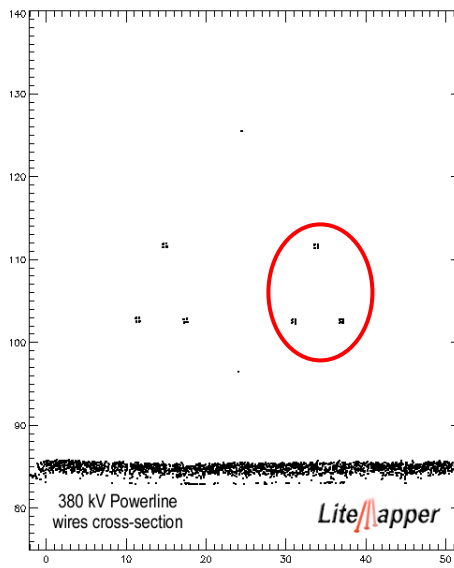


380KV Powerline  $h = 85m / v = 40kn$



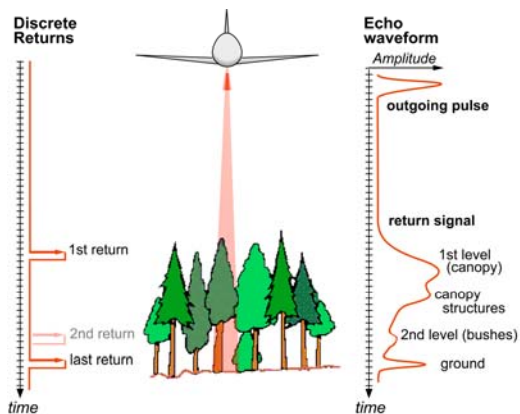
www.igi-systems.com

380KV Powerline  $h = 85m / v = 40kn$



www.igi-systems.com

waveform digitization

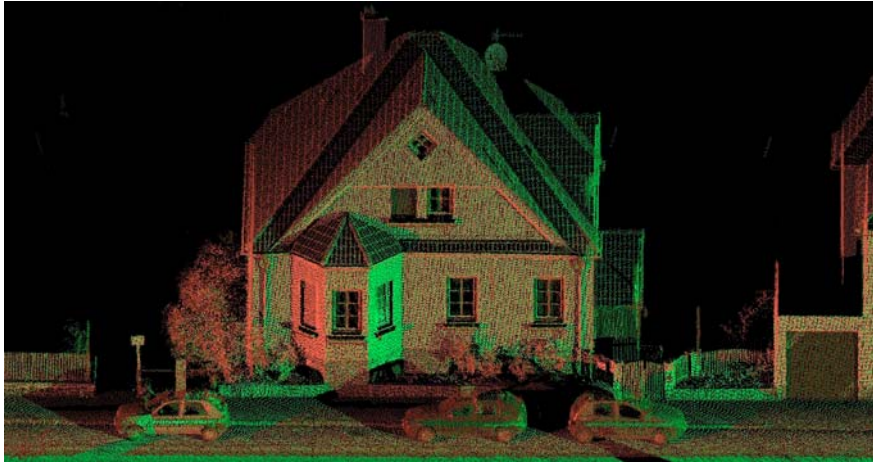


→ forestry and agriculture monitoring  
(vegetation height, canopy structure, biomass ...)



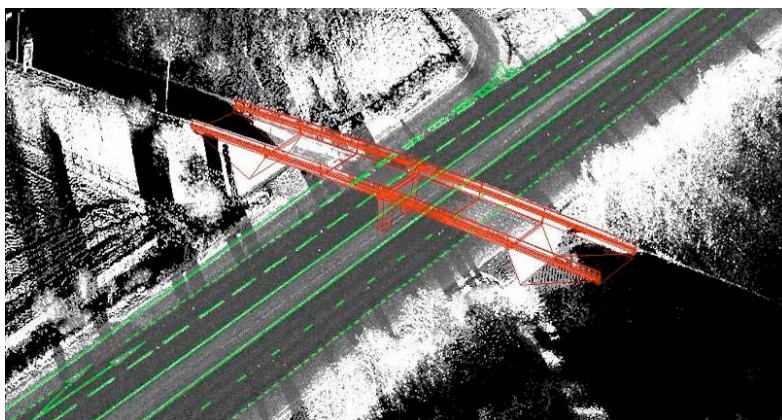
**Typical applications:**

- City modeling



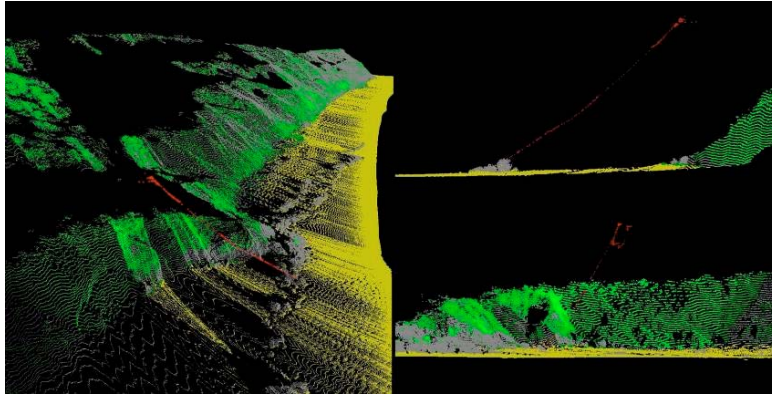
**Typical applications:**

- Highways

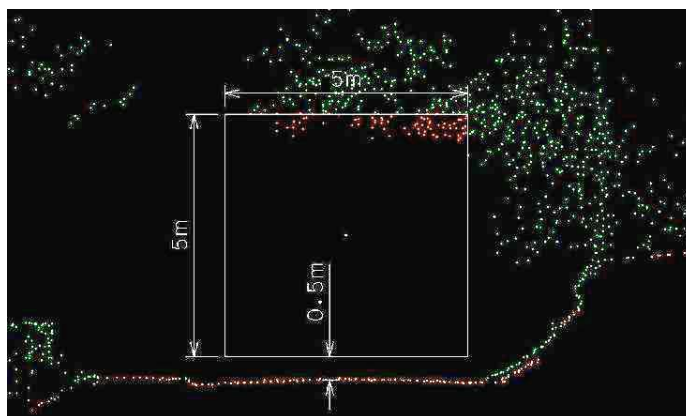


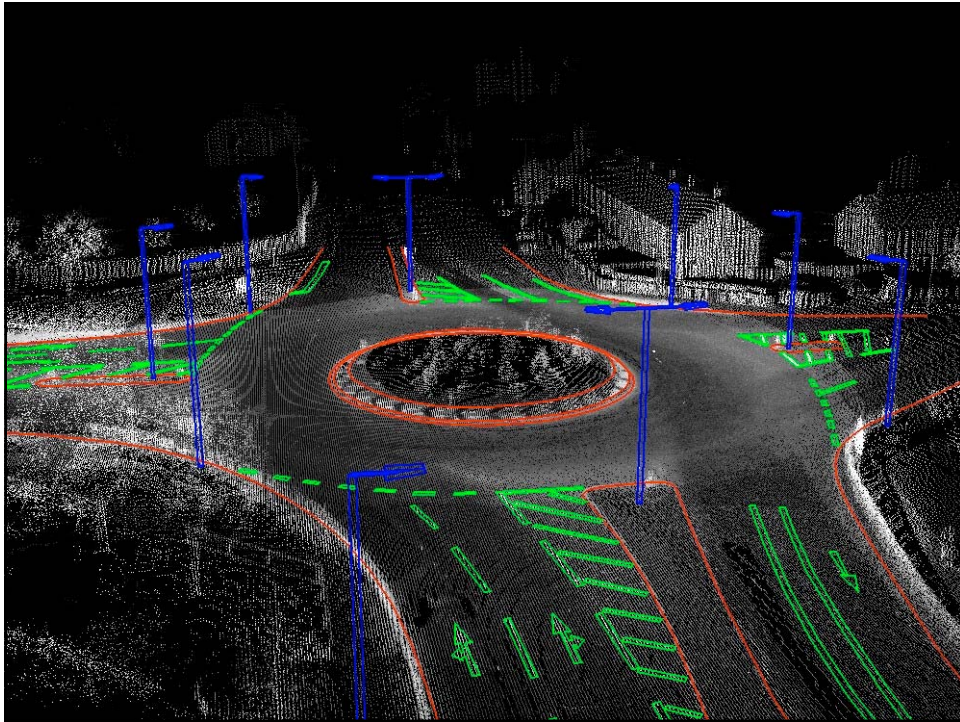
**Typical applications:**

- Coastal Surveys

**Typical applications:**

- High-load route planning



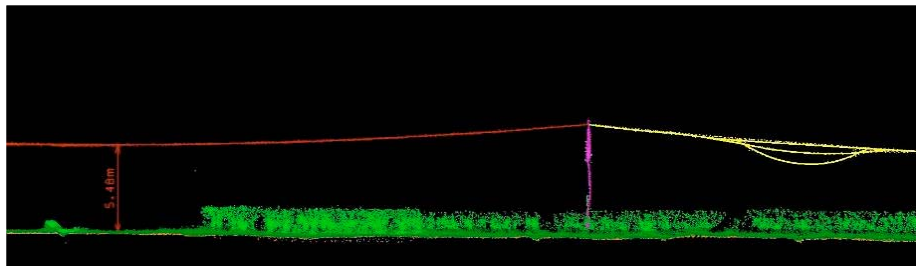


STREETMAPPER



**Typical applications:**

- Overhead Wire Surveys



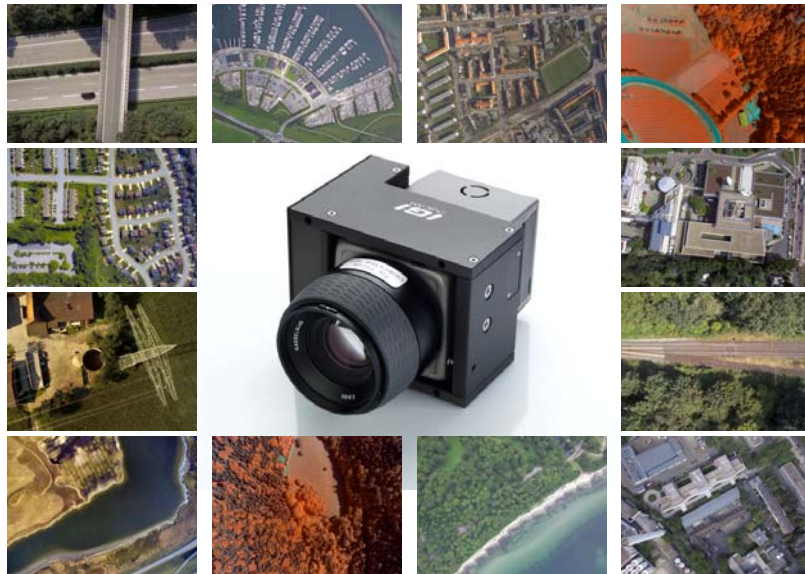
[www.igi-systems.com](http://www.igi-systems.com)



Next Steps:



## DigiCAM



## DigiCAM-H/39



39 Mpixel CCD back  
Control computer with two storage units  
Graphical User Interface with touch screen



www.igi-systems.com

## DigiControl GUI



SN: 05-0102

Hold Preview

Shutter

Aperture

Toggle Camera

Menu

Nr: —	Time: —	GSD: — m	Blur: — Pix
Shutter: — s	Aperture: —	GSD: — m	Blur: — Pix
Offline	████████████████████	GSD: --- m	Blur: --- Pix
Images: 23	Remaining: 846	Shutter: 1/250 s	Aperture: 4

www.igi-systems.com

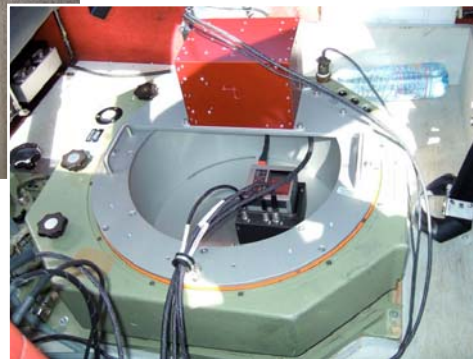


## DigiCAM Installation Examples



[www.igi-systems.com](http://www.igi-systems.com)

## DigiCAM Installation Examples



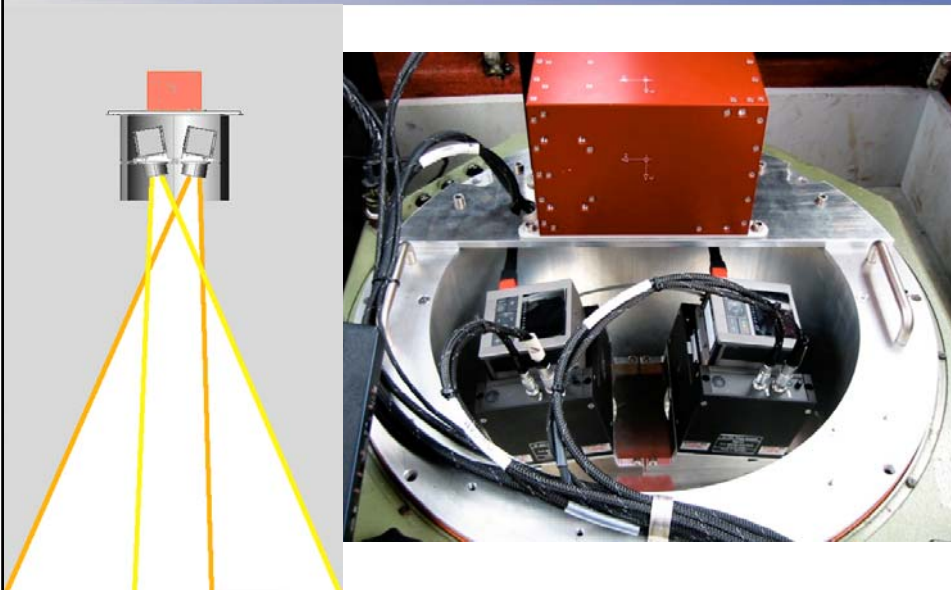
[www.igi-systems.com](http://www.igi-systems.com)

## DigiCAM Installation Examples



[www.igi-systems.com](http://www.igi-systems.com)

## Dual-DigiCAM



[www.igi-systems.com](http://www.igi-systems.com)

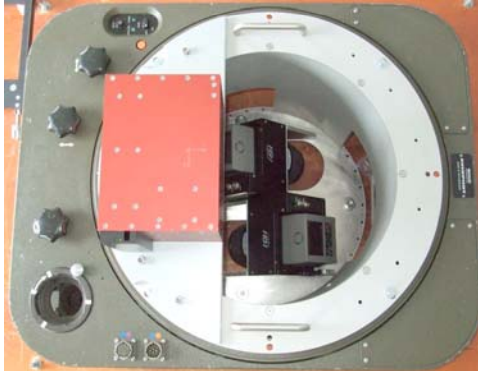
## Multiple DigiCAM - oblique



Multiple *DigiCAM* - oblique

4 x 45° (82mm)

2 x 45° (82mm)



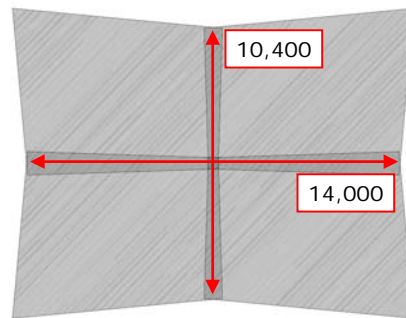
[www.igi-systems.com](http://www.igi-systems.com)



## Quatro-DigiCAM

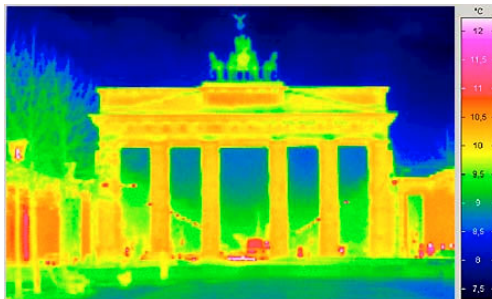


145 Mpixel



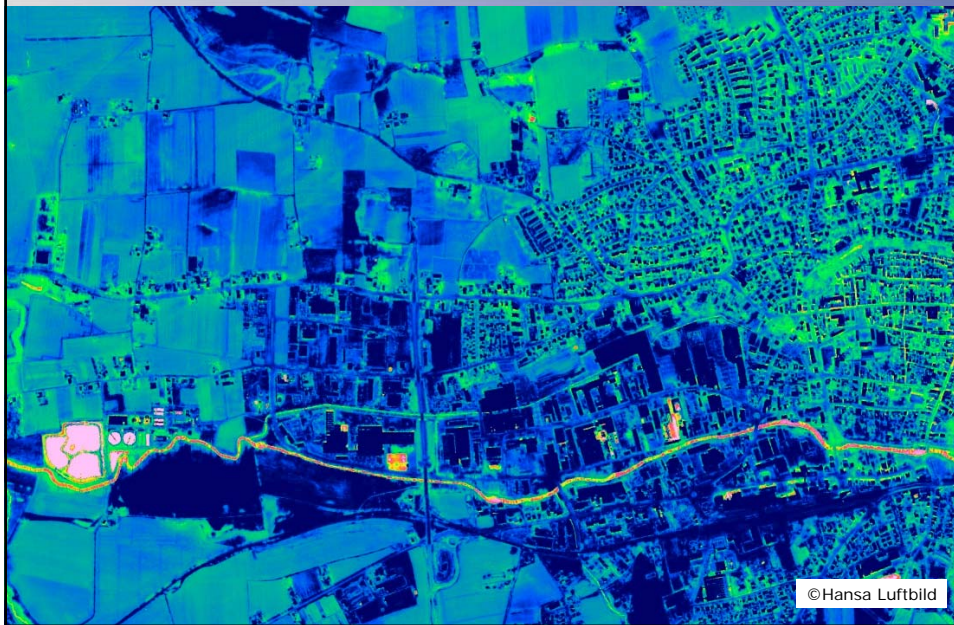
[www.igi-systems.com](http://www.igi-systems.com)

## Thermography

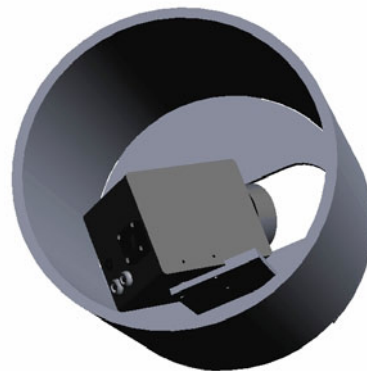


[www.igi-systems.com](http://www.igi-systems.com)

## Airborne Thermography



## New Developments - DigiTHERM



- 640 \* 480 pixel
- < 80mK resolution
- Direct Georeferencing
- operated in a stabilized mount

[www.igi-systems.com](http://www.igi-systems.com)

**Mission example "Stuttgart City"**

- GSD = 0.5m / h = 600m
- 6.5 km<sup>2</sup>
- 266 thermal images



Guidance and  
Sensor Management

GPS / IMU Systems

Integrated Sensor Systems  
for Special Applications

Guidance and  
Sensor Management

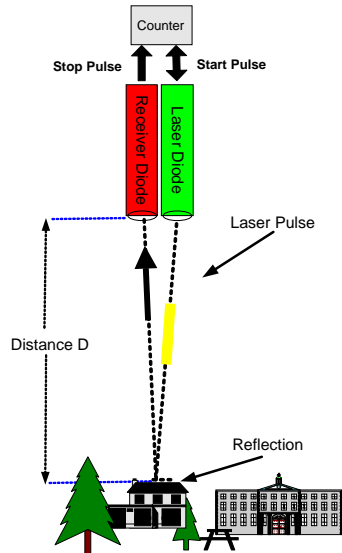
GPS / IMU Systems

Integrated Sensor Systems  
for Special Applications



- StreetMapper
- DigiCAM
- LiteMapper

## Laser Runtime Measurement

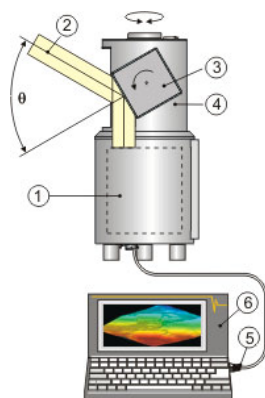


$$D = \frac{c \cdot t}{2}$$



[www.igi-systems.com](http://www.igi-systems.com)

## Static Laserscanning



[www.riegl.com](http://www.riegl.com)

[www.igi-systems.com](http://www.igi-systems.com)

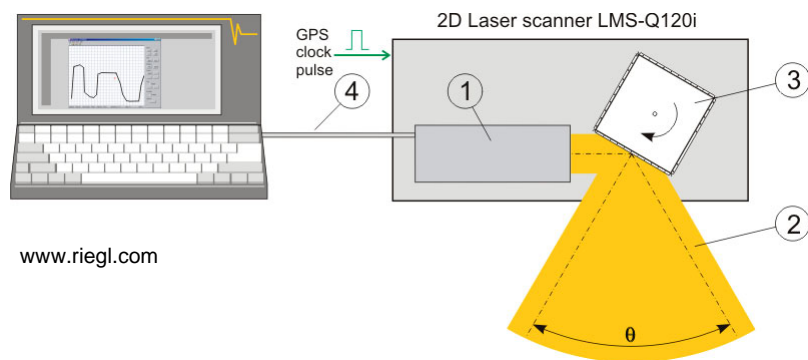


## Static Laserscanning



[www.igi-systems.com](http://www.igi-systems.com)

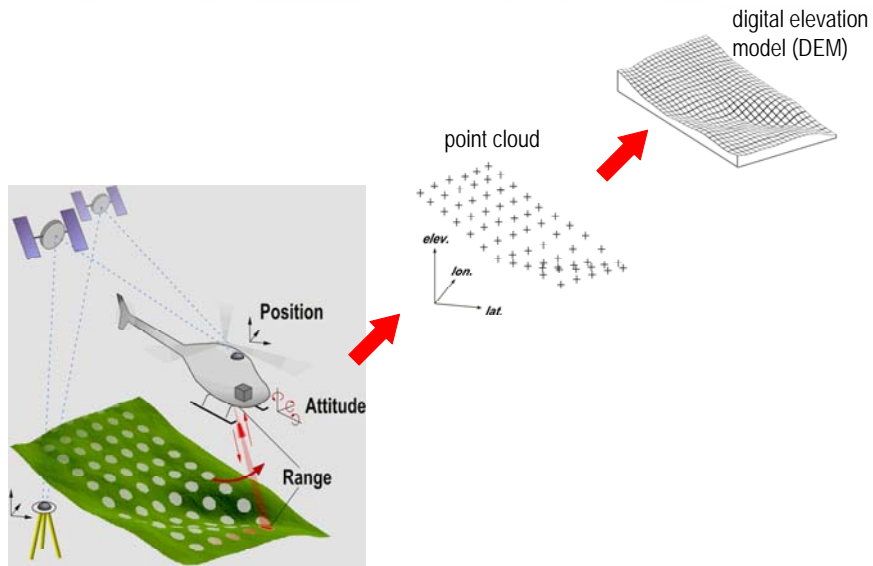
## Mobile Laserscanning



[www.riegl.com](http://www.riegl.com)

[www.igi-systems.com](http://www.igi-systems.com)

## Airborne LiDAR Mapping



[www.igi-systems.com](http://www.igi-systems.com)

## LiteMapper

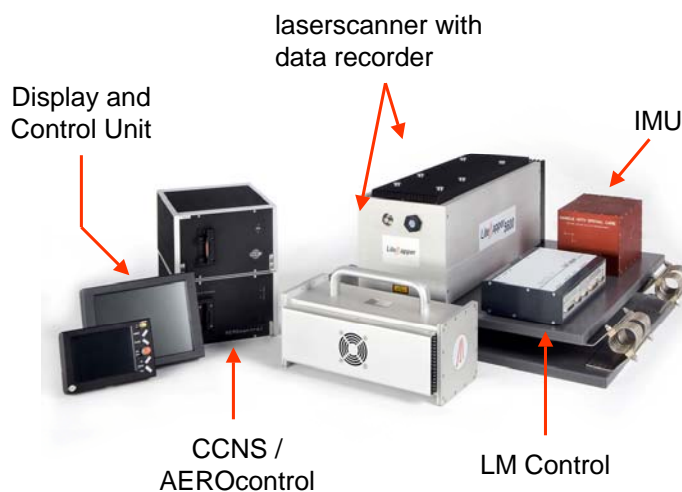


**LiteMapper** applications:

- ➔ infrastructure planning and maintenance  
(powerlines, pipelines, railroads, highways ...)
- ➔ high-accuracy flood-plain mapping
- ➔ high-resolution urban area mapping ...
- ➔ forestry and agriculture monitoring  
(vegetation height, canopy structure, plant health, biomass ...)

[www.igi-systems.com](http://www.igi-systems.com)

## LiteMapper - Components



[www.igi-systems.com](http://www.igi-systems.com)

## LiteMapper - Components

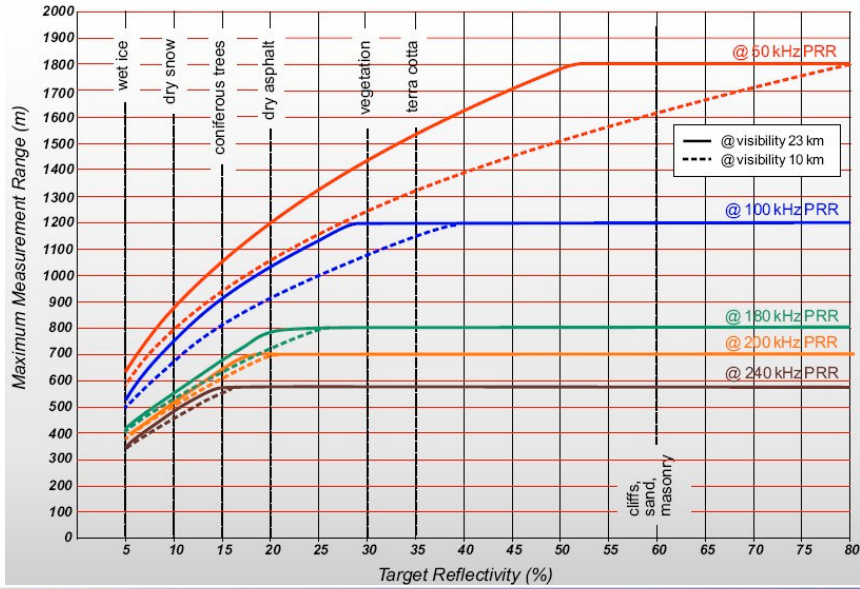


max. pulse repetition rate: **240 kHz**  
max. range: **1800 m**  
number of targets / pulse: **unlimited** for digitized waveform



[www.igi-systems.com](http://www.igi-systems.com)

## LiteMapper - Parameters



www.igi-systems.com

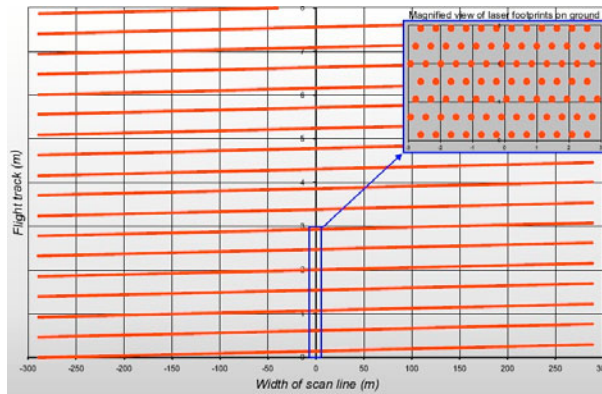
## LiteMapper - Parameters



PRR: 200kHz  
 scan speed: 120/sec  
 flying altitude: 1640ft. (500m)  
 flying speed: 108kt (200km/h)




point spacing in a line: 0.47m  
 distance between lines: 0.46m  
 line width: 577m  
 point density: 4.2pts/m<sup>2</sup>




www.igi-systems.com

## LiteMapper - Components



**Sensor Management System** 


The *LMcontrol* manages and controls the LIDAR unit during airborne missions. The high resolution touch screen display provides a comfortable graphical user interface.




**Airborne Laser Scanner** 

The following constellations are available:  
*LiteMapper 2400*: Riegl scanner LMS-Q240i  
*LiteMapper 5600*: Riegl scanner LMS-Q560  
*LiteMapper 5600i*: for the new Riegl scanner LMS-Q560i




**DigiCAM - Medium-format Airborne Digital Camera (option)** 

The *DigiCAM* system is based on a professional high-resolution camera with 39 Mega pixels. The system is available with color (RGB) or color-infrared (CIR) filters and a variety of calibrated lenses with different focal lengths. The *DigiCAM* integrates perfectly with the *LiteMapper* system.



**CCNS4 Computer Controlled Navigation System** 

The *CCNS4* is the guidance, positioning and sensor management system for aerial surveys with an integrated GPS receiver and antenna. The system is operated easily through the Command & Display Unit.



**LiteMapper**<sup>®</sup>  
 Airborne Lidar Terrain Mapping System


**AEROcontrol DGPS / IMU System** 

*AEROcontrol* is the solution for the precise determination of position and attitude of an aerial sensor. *AEROcontrol* is based on differential GPS (DGPS) and an Inertial Measurement Unit (IMU-tild) using fibre-optic gyros with a data rate of 256 Hz.



**IGIplan Mission Planning Software** 

- GoogleEarth™ format support
- Worldwide coordinate system support
- Raster & vector map support for common file formats
- Support for many DTM raster formats
- Drag and modify flight lines interactively
- Full support for IGI's CCNS4
- Video tutorials




**RIPROCESS, RIWORLD and RIANALYSE 560 Software** 

RIPROCESS is designed for automated correction of LIDAR data. RIANALYSE 560 for processing airborne laser scanner data and RIWORLD for coordinate transformation of airborne data.

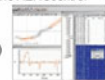
**TerraScan, TerraModeler & TerraPhoto (option)** 

**OrthoMaster & OrthoVista (option)** 

Additional software packages for manipulating, viewing and classifying LIDAR data are available from Terrasolid and inpho. The software supports creation of DTM/DSM and orthophotos.

**AEROoffice Post-Processing Software** 

*AEROoffice* is IGI's data handling and post-processing software for the *AEROcontrol* system. It provides all functions and tools necessary for handling Exterior Orientation (EO) calculation and quality control.



[www.igi-systems.com](http://www.igi-systems.com)

## Installation in a Bell 206 Jet Ranger



[www.igi-systems.com](http://www.igi-systems.com)

*Installation in a Bell 206 Jet Ranger*



[www.igi-systems.com](http://www.igi-systems.com)

*Installation in an AS 350*



[www.igi-systems.com](http://www.igi-systems.com)

## Installation in a Schweizer 333

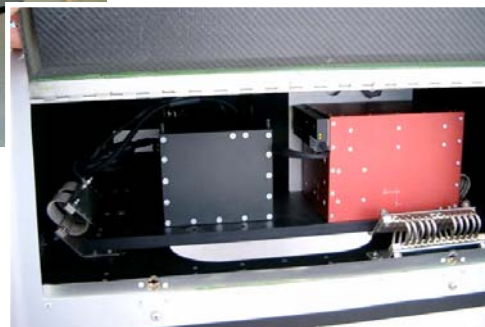


Chesapeake Bay Helicopters, Inc. / Chesapeake, VA



[www.igi-systems.com](http://www.igi-systems.com)

## Installation in a Schweizer 333



[www.igi-systems.com](http://www.igi-systems.com)

## Installation in a MI 8



[www.igi-systems.com](http://www.igi-systems.com)

## Installation in a fixed wing aircraft



[www.igi-systems.com](http://www.igi-systems.com)

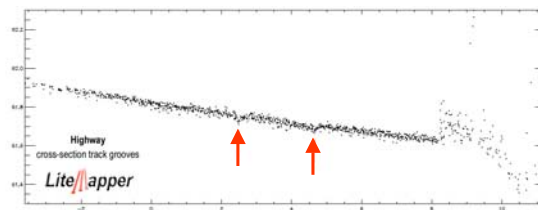
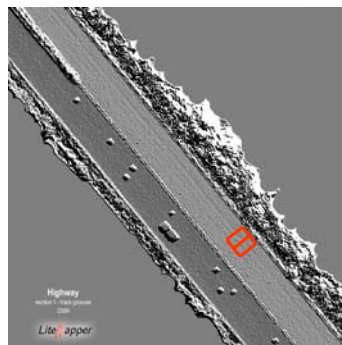


## Installation in a Cessna 207



www.igi-systems.com

## Project "Aahlen"



www.igi-systems.com

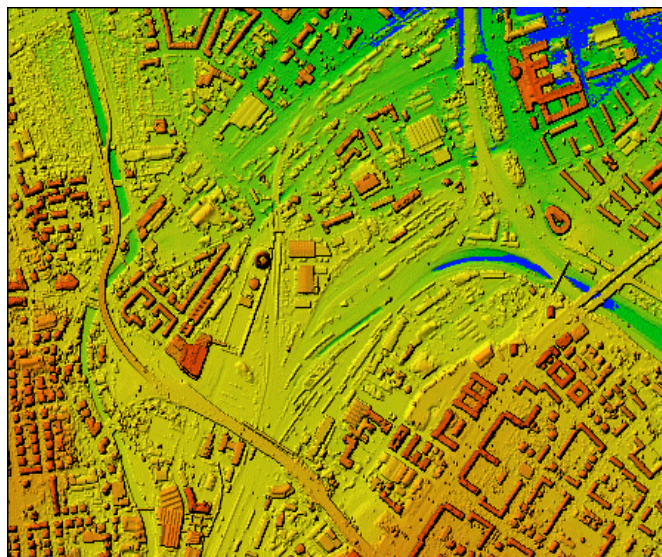
### Simulation of Elbe river water levels

**Project:** city of Dresden, Saxony, Germany

**DSM -**  
Digital Surface Model

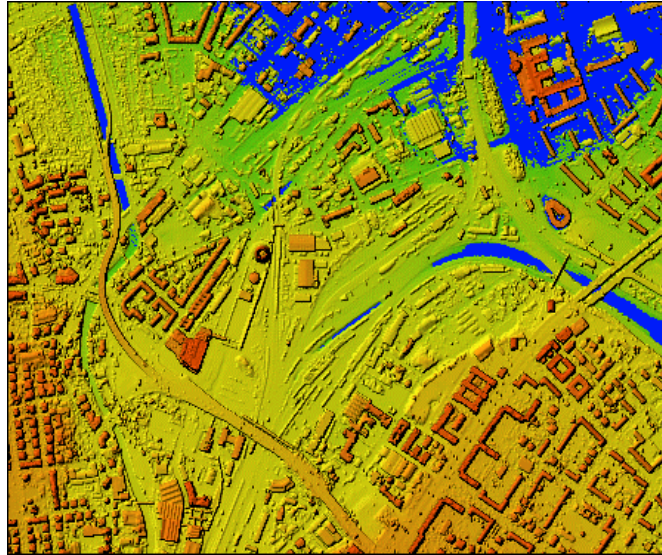
**Ground point spacing:**  
1 point/m<sup>2</sup> raster, approx.  
4 mio. points total

Images kindly provided by Milan Flug GmbH  
Image © Landestalsperrenverwaltung (LTV),  
Freistaat Sachsen, Germany



114 m

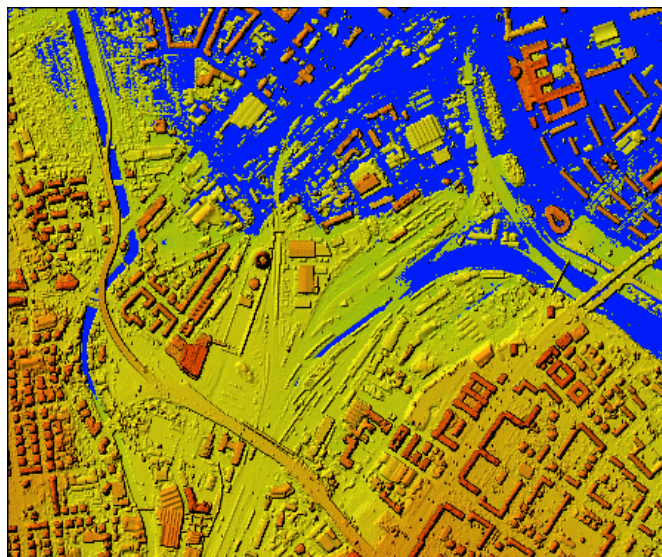
**Flood Risk Management**



116 m

[www.igi-systems.com](http://www.igi-systems.com)

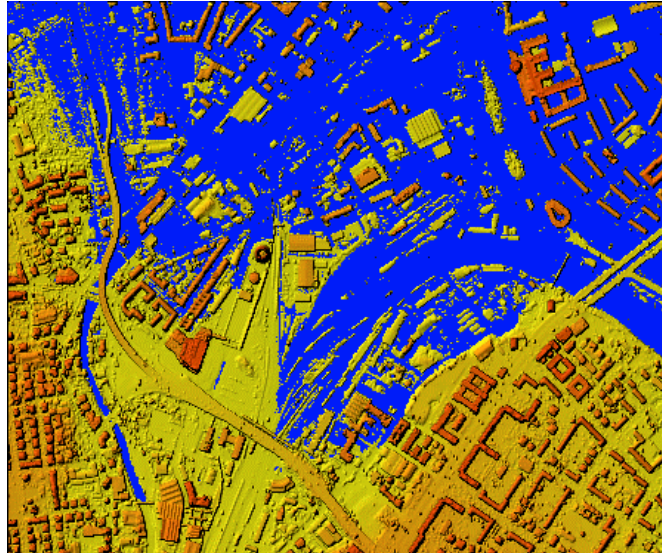
**Flood Risk Management**



118 m

[www.igi-systems.com](http://www.igi-systems.com)

## Flood Risk Management



120 m

[www.igi-systems.com](http://www.igi-systems.com)

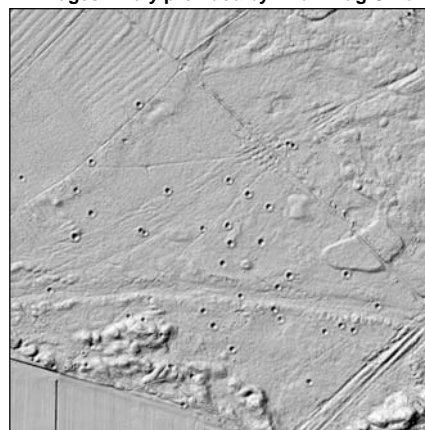
## Project: Ludwigslust



Images kindly provided by Milan Flug GmbH



DSM (Digital Surface Model)

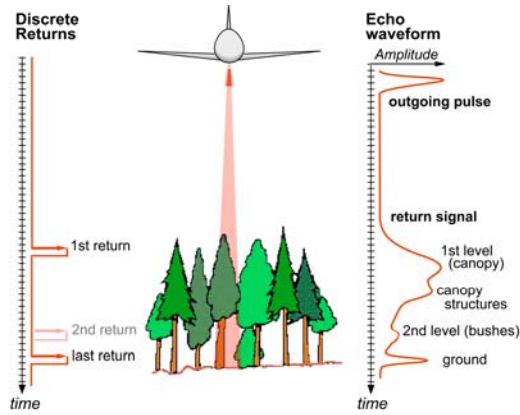


DTM (Digital Terrain Model)

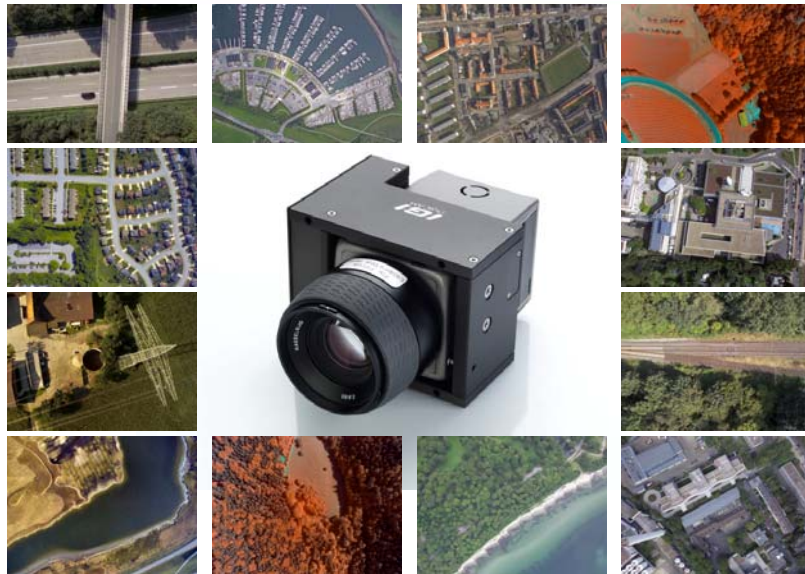
Bomb crater close to Ludwigslust, Germany.

[www.igi-systems.com](http://www.igi-systems.com)

waveform digitization



→ forestry and agriculture monitoring  
(vegetation height, canopy structure, biomass ...)



## DigiCAM



### Corridor mapping

- Power lines
- Pipelines
- Roads
- Rail tracks

### Small to mid size projects

### Rapid response applications

[www.igi-systems.com](http://www.igi-systems.com)

## DigiCAM-H/39

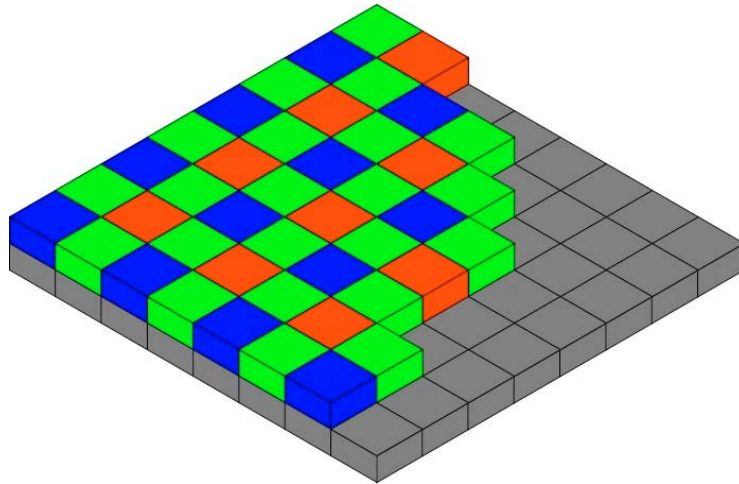


- 39 Mpixel CCD back
- Control computer with two storage units
- Graphical User Interface with touch screen



[www.igi-systems.com](http://www.igi-systems.com)

## Bayer Pattern



[www.igi-systems.com](http://www.igi-systems.com)

## DigiCAM-H/39 Design



[www.igi-systems.com](http://www.igi-systems.com)

## Lens Options I



- Exchangeable lenses with bayonet mount
- Integrated electronic shutter (central shutter)
- Exchangeable filters for RGB and CIR mode (optional)
- Lenses from 28mm to 300mm available



[www.igi-systems.com](http://www.igi-systems.com)

## Lens Options II



[www.igi-systems.com](http://www.igi-systems.com)



## DigiControl Storage Unit



### Hard disk units

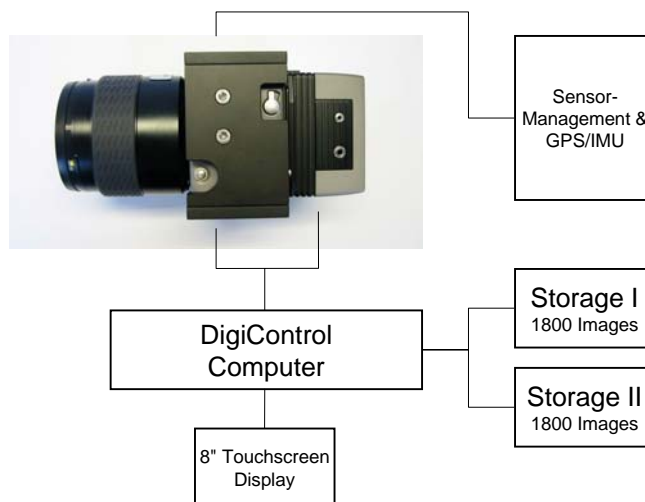
- 250 GB
- min. 4000 images
- 3000m recommended height limit

### Flash memory units

- 128 GB
- min. 2000 images
- no height limitation

[www.igi-systems.com](http://www.igi-systems.com)

## DigiCAM-H/39 - System Design



[www.igi-systems.com](http://www.igi-systems.com)

## Graphical User Interface



The screenshot displays the IGI graphical user interface. On the left, a large window shows a live aerial view of a city with a prominent central tower. To the right of the view is a control panel with several sections:

- SN: 05-0102**: A green histogram or sensor data plot.
- Main Buttons**: A vertical stack of four buttons: "Hold Preview" (with a grey circle icon), "Shutter" (with a green circular arrow icon), "Aperture" (with a camera lens icon), and "Toggle Camera" (with a camera icon).
- Menu**: A blue button with a hand cursor icon.

Below the main view, there are two rows of status information:

Nr: --	Time: --
Shutter: -- s	Aperture: --

Below this, a battery level indicator (a bar with 10 segments) is shown next to the text "Offline". To the right of the battery indicator, the following parameters are displayed:

GSD: --- m	Blur: --- Pix
Images: 23	Remaining: 846
Shutter: 1/250 s	Aperture: 4

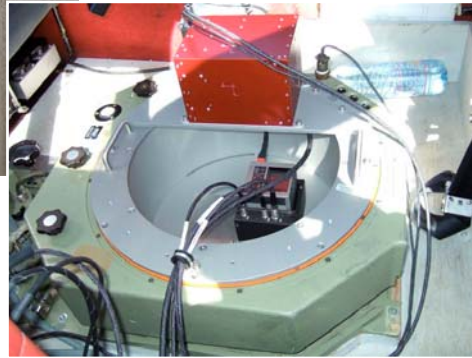
[www.igi-systems.com](http://www.igi-systems.com)

## DigiCAM Installation Examples



[www.igi-systems.com](http://www.igi-systems.com)

## DigiCAM Installation Examples



[www.igi-systems.com](http://www.igi-systems.com)

## Image Mosaic



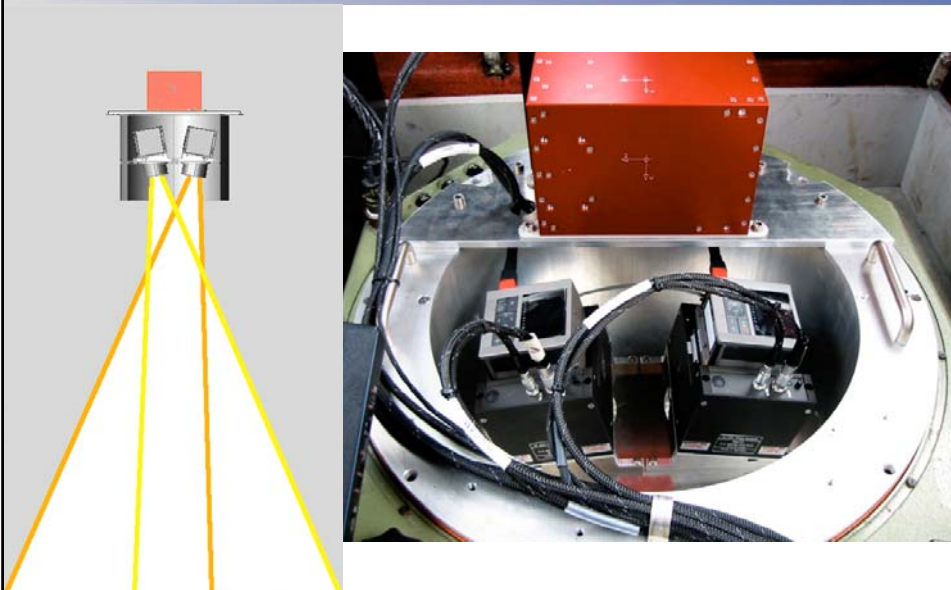
[www.igi-systems.com](http://www.igi-systems.com)

## DigiCAM Installation Examples



[www.igi-systems.com](http://www.igi-systems.com)

## Dual-DigiCAM



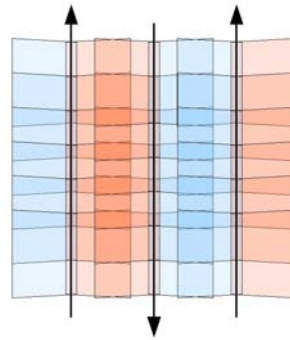
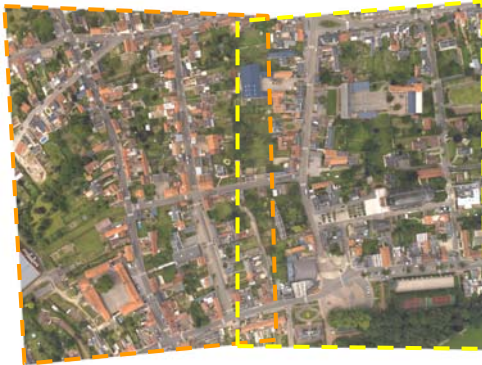
[www.igi-systems.com](http://www.igi-systems.com)

## Dual-DigiCAM



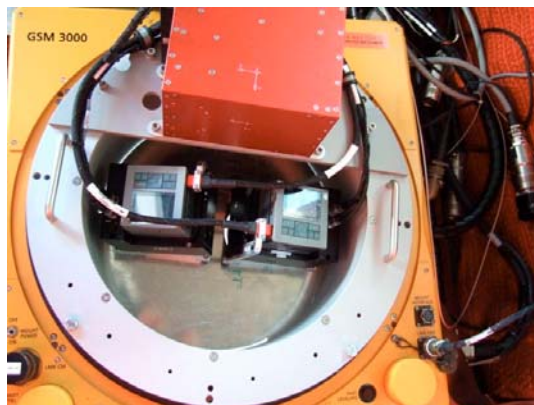
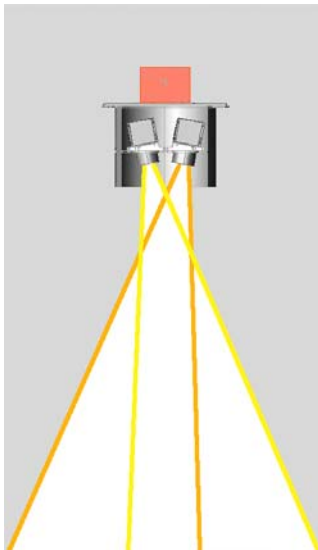
Total image size: 10,400 x 7,216 pixel (74 Mpixel)

- One exposure = two separate photos



[www.igi-systems.com](http://www.igi-systems.com)

## Dual-DigiCAM

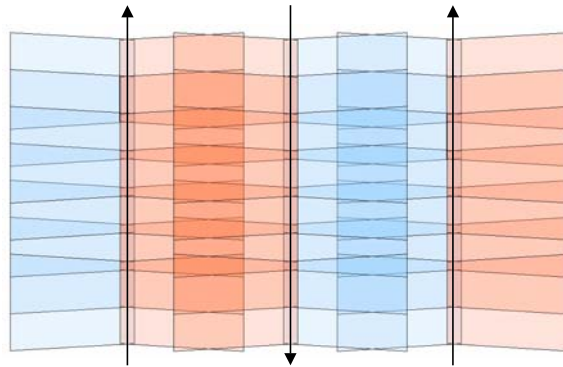


[www.igi-systems.com](http://www.igi-systems.com)

## Dual-DigiCAM



Total image size: 14,000 x 5,412 pixel (75 Mpixel)



[www.igi-systems.com](http://www.igi-systems.com)

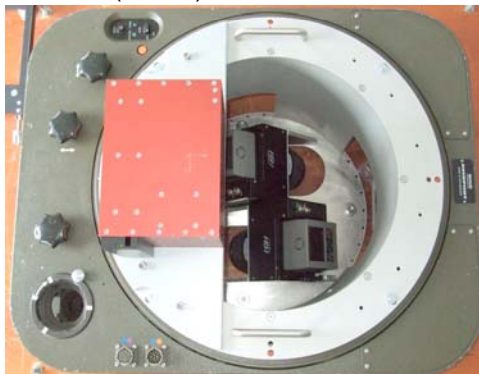
## Multiple DigiCAM - oblique



Multiple *DigiCAM* - oblique

4 x 45° (82mm)

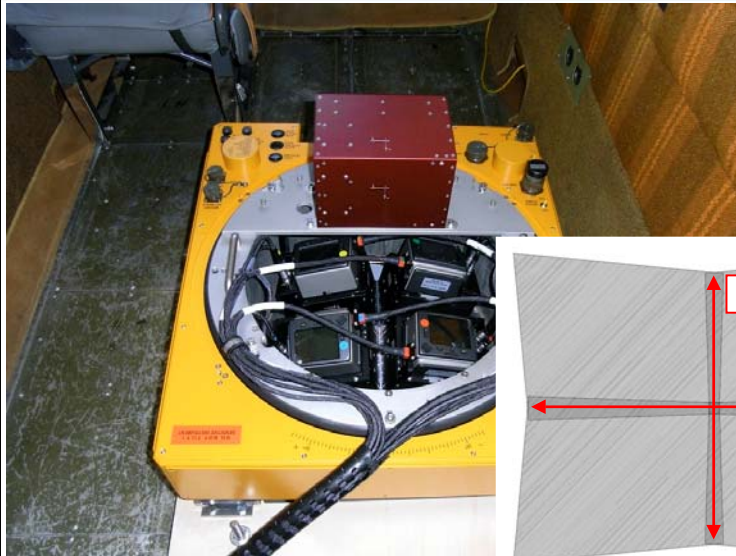
2 x 45° (82mm)



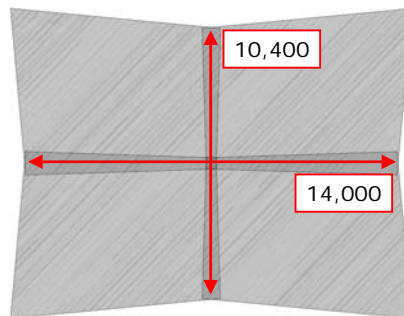
[www.igi-systems.com](http://www.igi-systems.com)




### Quatro-DigiCAM



145 Mpixel



[www.igi-systems.com](http://www.igi-systems.com)



[www.igi-systems.com](http://www.igi-systems.com)



Nov 10<sup>th</sup>, 2008, Kreuztal

Georeferencing with  
*AEROcontrol* GPS/IMU data

Jens Kremer  
IGI mbH  
57223 Kreuztal / Germany

Guidance and  
Sensor Management

GPS / IMU Systems

Integrated Sensor Systems  
for Special Applications

Motivation - Which accuracies do we need?

Why GPS and IMU?

GPS/IMU integration

The AEROcontrol system

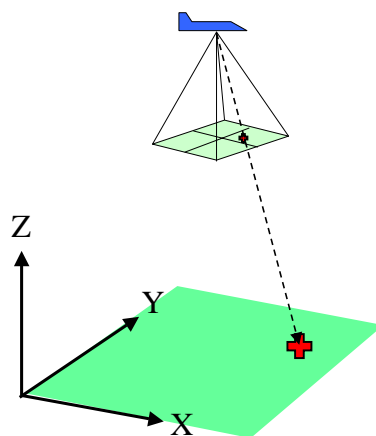
How to use AEROcontrol results for Georeferencing

Examples

## Direct Georeferencing

Georeferencing →

connect information of an airborne sensor with a position in space



**Indirect** using the sensor data  
Example: AT

**Direct** NOT using the sensor data

- position
- attitude
- velocity ( e.g. SAR)

### Accuracy : What do we need?

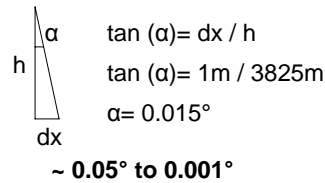
**Position Attitude**



As good as the aspired accuracy of the final result

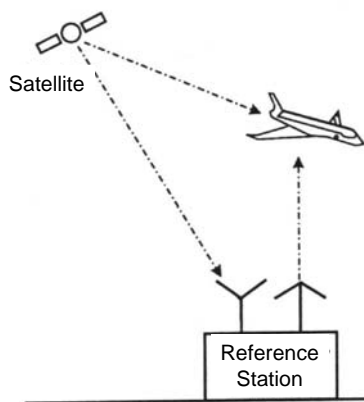
~ **cm to m**

Good enough to reach cm to m accuracy on the ground:  
e.g. TOP10DK  
image scale: 1:25000 (3825m)



GPS: ~5-10m

Differential GPS using phase and doppler measurements:



Possible accuracy :  
a few cm (kinematic!)

- Dependent on:**
- Distance from the base station
  - Satellite configuration (number and position of the satellites)
  - Reception conditions

**Rate 1 - 20 Hz**

**No attitude measurement**  
(antenna array:  
5m distance, 1 cm  $\Delta$ pos:  
 $\Delta\alpha > 0.1^\circ$ )

## Inertial Navigation



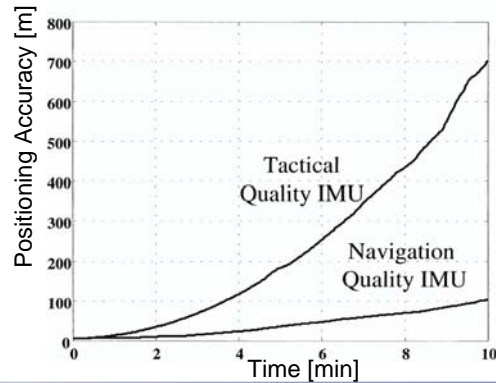
High data rates: > 50 Hz

Attitude measurement as good as you like ( ... price?! )

“Dead reckoning system”

All sensors are imperfect => increasing attitude and position error:

e.g. accelerometer bias  $a_b$  => position error =  $1/2 a_b t^2$

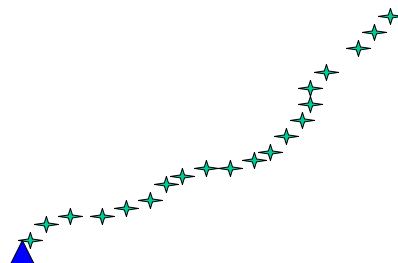


www.igi-systems.com

## GPS/IMU Integration

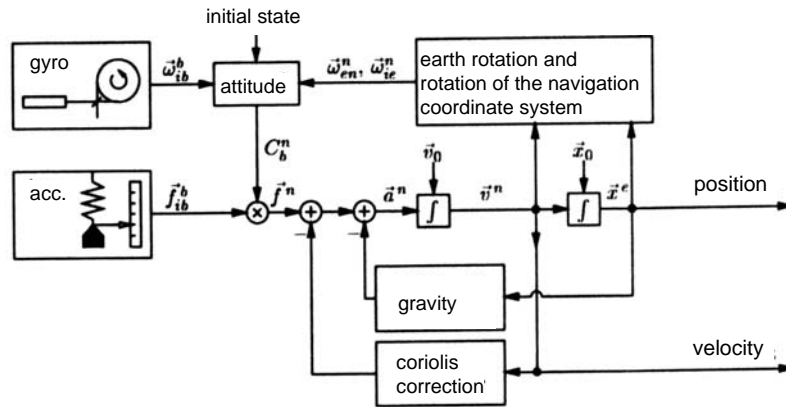


1. Calculate initial position, attitude and velocity (the **initial state**)
2. Calculate the **actual state** with the IMU data (“strapdown algorithm”)



www.igi-systems.com

## “Strapdown Algorithm”



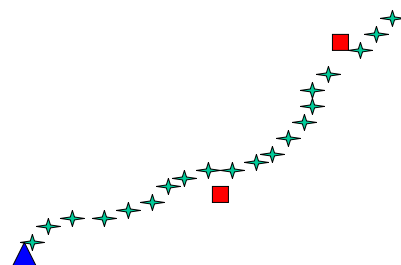
e.g. 256 Hz

www.igi-systems.com

## GPS/IMU Integration



1. Calculate initial position, attitude and velocity (the **initial state**)
2. Calculate the **actual state** with the strapdown algorithm
3. When GPS **measurements** occur: use Kalman Filter to estimate **optimal state**, including IMU properties



**state vector**

**x:** pos, att, vel, IMU properties

**measurement vector**

**y:**  $\Delta$ pos,  $\Delta$ vel

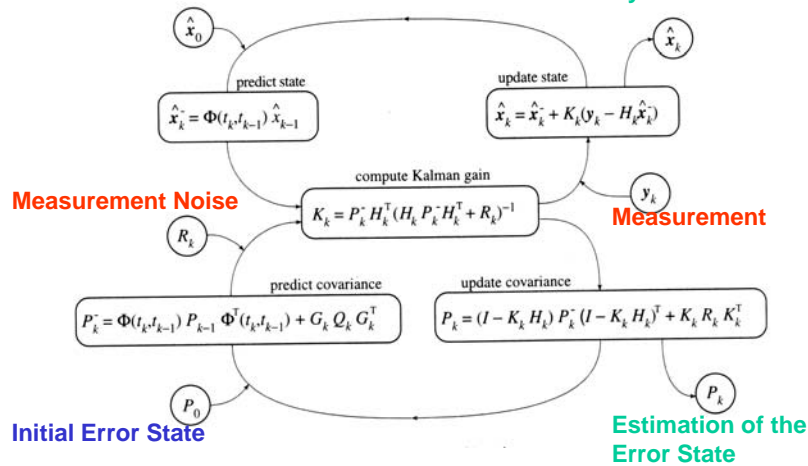
www.igi-systems.com

## Kalman Filter



Initial System State

Estimation of the System State



e.g. 2 Hz

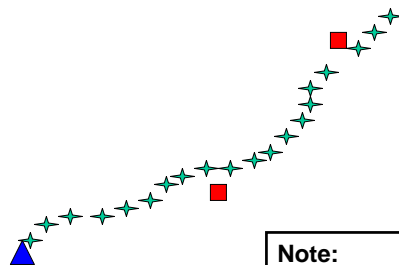
www.igi-systems.com

## GPS/IMU Integration



1. Calculate Initial Position, Attitude and Velocity (the **initial state**)
2. Calculate the **actual state** with the strapdown algorithm
3. When GPS **measurements** occur: use Kalman Filter to estimate **optimal state**, including IMU properties

Live Demo!

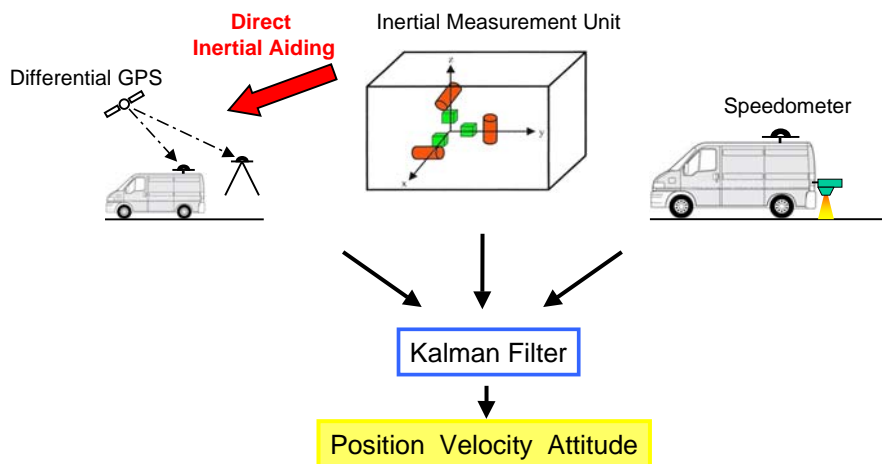
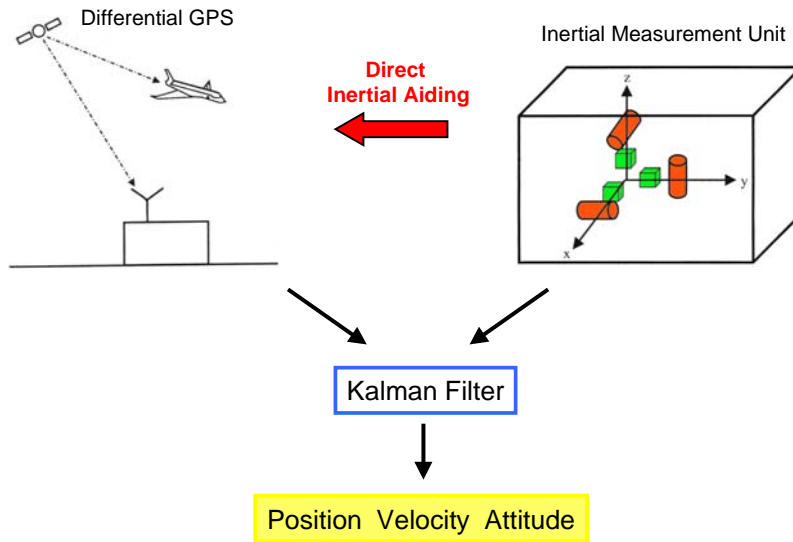


**state vector**  
 $x$ : pos, att, vel, IMU properties

**measurement vector**  
 $y$ :  $\Delta$ pos,  $\Delta$ vel

**Note:**  
 forward- backward calculation and smoothing  
 can improve the result significantly!

www.igi-systems.com



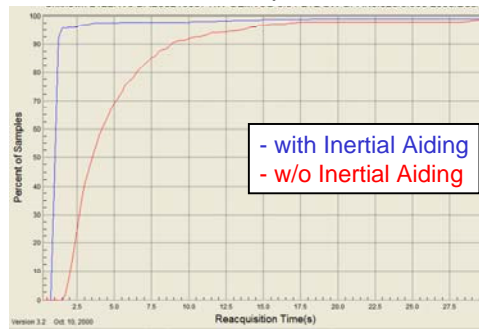
## Direct Inertial Aiding



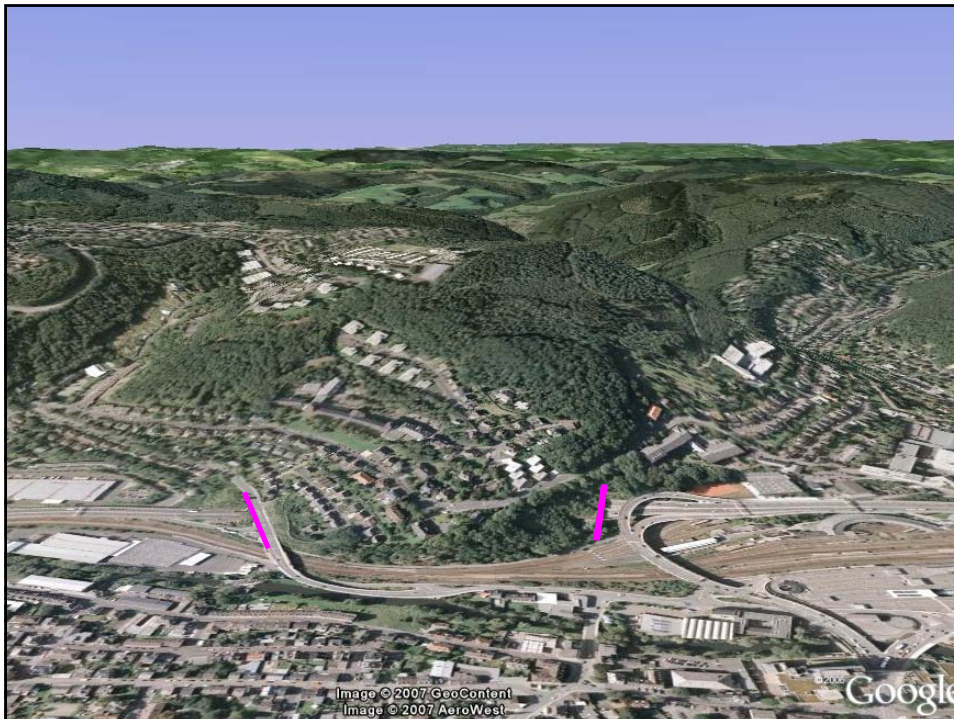
TERRAcontrol-IIId with internal  
NovAtel OEMV-3 receiver



GPS L1 reacquisition time

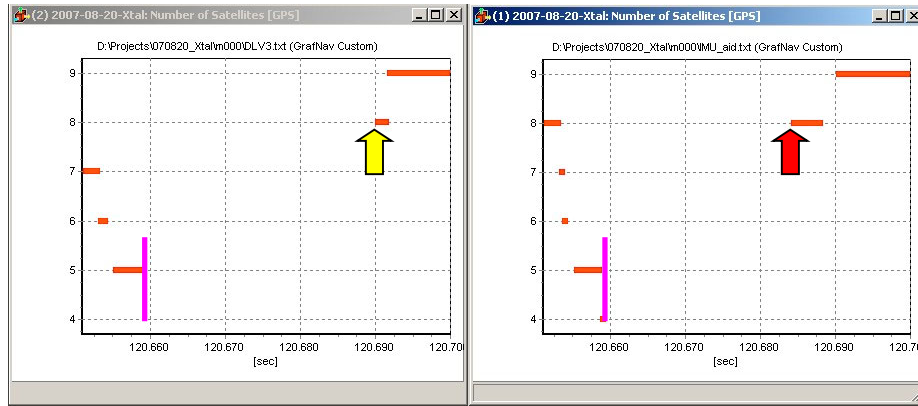


www.igi-systems.com





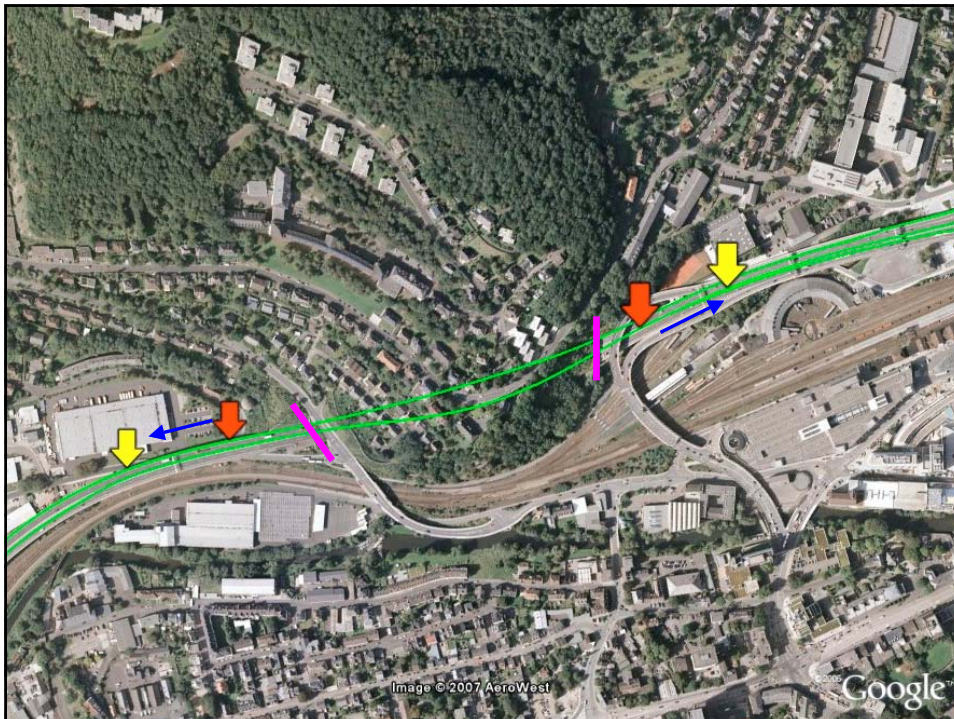
# Direct Inertial Aiding



without inertial aiding

with inertial aiding

[www.igi-systems.com](http://www.igi-systems.com)

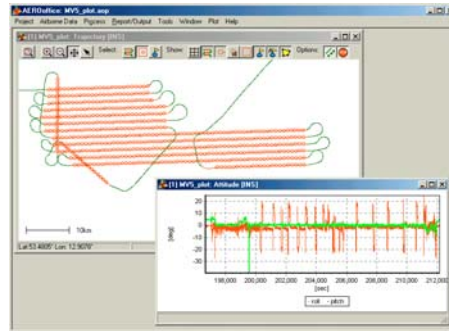


**Hardware**

**Software**

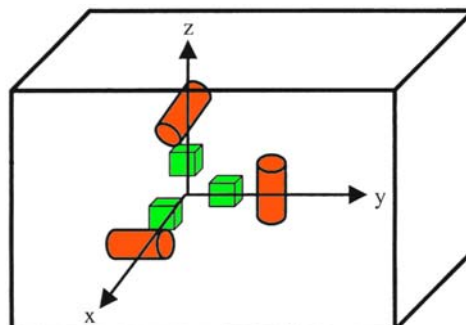


**AEROcontrol** computer unit with GPS receiver and IMU



**AEROoffice** software incl. GrafNav

- Three accelerometers
- Three gyroscopes

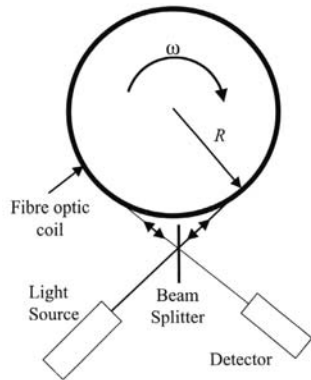


➡ Measurement of the motion in all three axes.

# IMU - Inertial Measurement Unit



## ➡ IMU with fiber-optic gyros

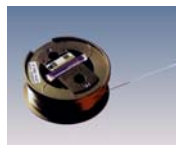


www.igi-systems.com

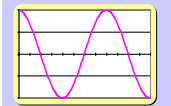
# Fiber Optic Gyros



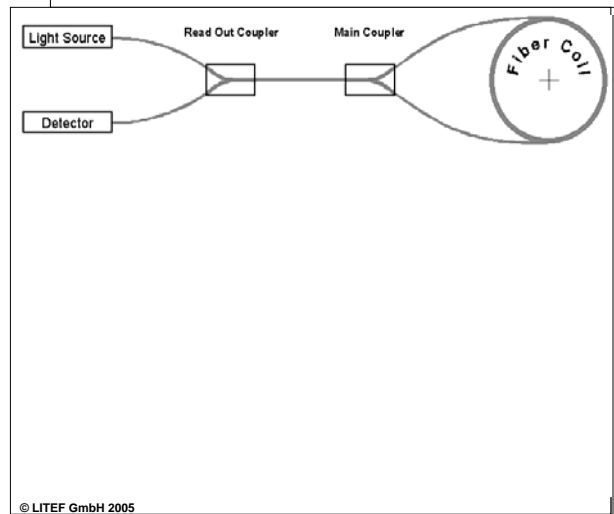
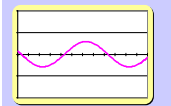
## The Fiber Optic Gyro Principle



### 1. no Rotation



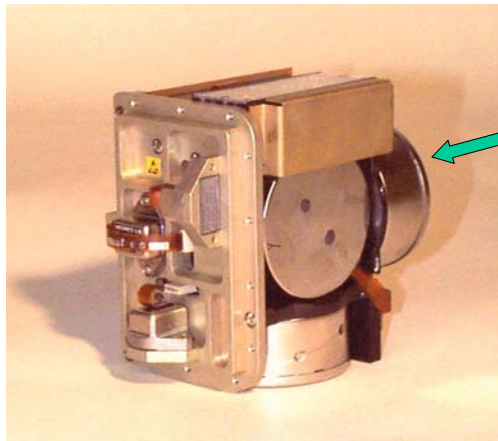
### 2. with Rotation



© LITEF GmbH 2005

www.igi-systems.com

## IGI IMU-IId



500m optical fiber

AEROcontrol IMU - IId  
with fiber optic gyros

**Drift:** 0.1°/h  
**Noise:** 0.02°/ SQRT(h)  
**Rate:** 128 or 256 Hz

[www.igi-systems.com](http://www.igi-systems.com)

## GPS Receiver



### NovAtel OEMV-3

- 72 channels
- triple frequency
- optional OMNISTAR HP
- optional GLONASS



[www.igi-systems.com](http://www.igi-systems.com)

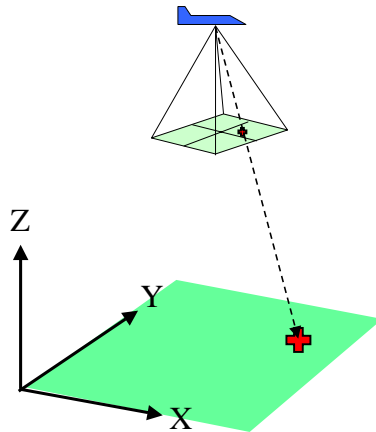
## Direct Georeferencing



### Georeferencing



connect information of an airborne sensor with a position in space

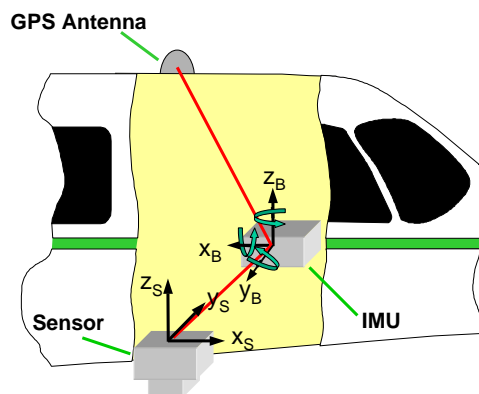


**Indirect** using the sensor data  
Example: AT

**Direct** NOT using the sensor data  
position  
attitude  
velocity (e.g. SAR)  
at the correct time!  
correct sensor model

www.igi-systems.com

## System Calibration



- Exact synchronization
- The lever-arms have to be taken into account
- Careful measurement of the attitude of the IMU
- Correct sensor model at the data collection time



**Calibration**

www.igi-systems.com

## System Calibration



### Calibration



#### IMU Calibration

- IMU properties
- at the IMU provider
- IGI: 2 years

#### Sensor Calibration

- focal length
- principal point
- angle encoder
- ...
- Calibration lab
- camera: 2 years
- or selfcalibration

#### Misalignment Calib.

- angle offset
- position offset
- calibration field or mission area
- after system modification

www.igi-systems.com

## DG or ISO ?



Position and Attitude  
from GPS/IMU



Georeferenced  
Image Data

### DG

#### Direct Georeferencing

Direct use of calibrated GPS/IMU data to georeference image data.

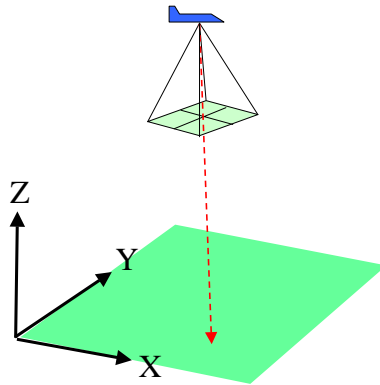
### ISO

#### Integrated Sensor Orientation

Extended aerial triangulation with GPS/IMU data as additional input.

www.igi-systems.com

## Direct Georeferencing

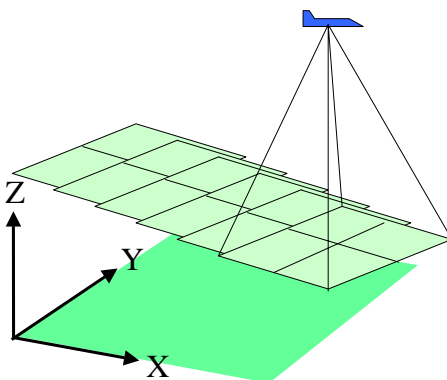


No GCPs and no AT  
Very fast

Need for calibration  
No redundancy  
Limited accuracy

[www.igi-systems.com](http://www.igi-systems.com)

## Integrated Sensor Orientation

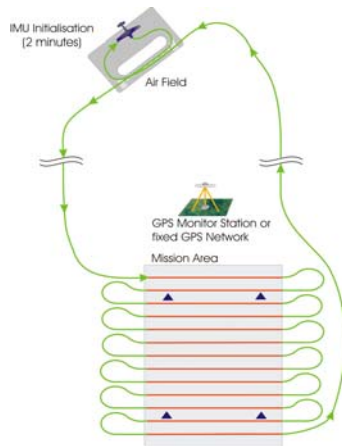


Need for AT of the mission area

No extra calibration  
Redundant measurement  
Accuracy not limited by GPS or IMU

[www.igi-systems.com](http://www.igi-systems.com)

## Integrated Sensor Orientation



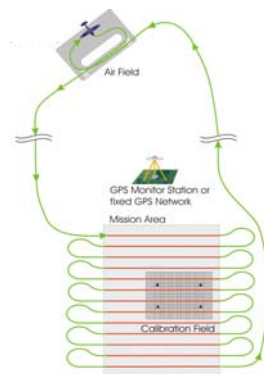
- extended AT for the mission area
- GPS/IMU results are used as additional measurements

- without any ground control
- with 1 GCP
- with some GCPs

- no need to determine calibration parameters explicitly

[www.igi-systems.com](http://www.igi-systems.com)

## Direct Georeferencing I



- extended AT for a small part of the mission area

- without any ground control
- with 1 GCP
- with some GCPs

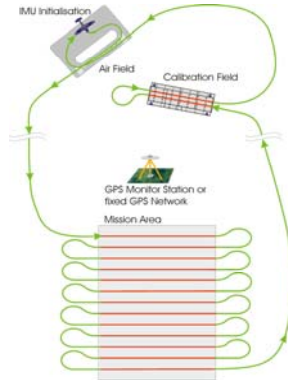
[www.igi-systems.com](http://www.igi-systems.com)



## Direct Georeferencing II



- use calibration from an other area (e.g. flown at an other day)

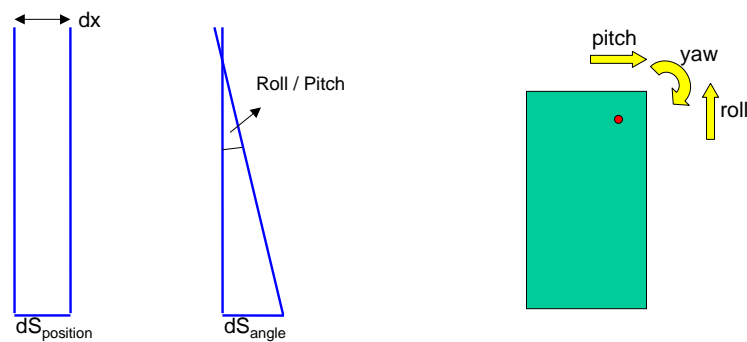


www.igi-systems.com

## DG or ISO ?



Displacement of a pixel from position and attitude errors:



### Example:

Aerial photo mission for large scale maps

flying height ~500m

$\tan 0.004^\circ * 500\text{m} = 3.5\text{cm}$

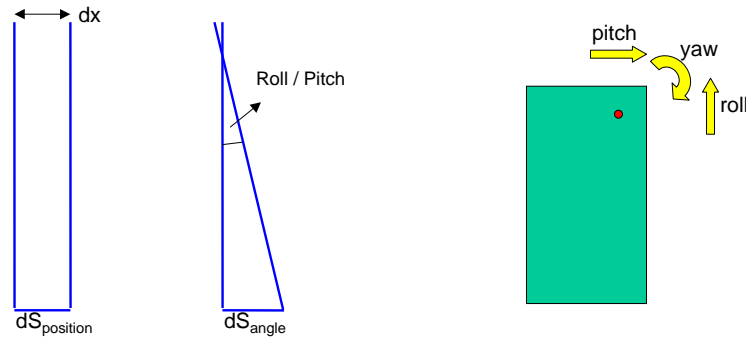
dGPS accuracy ??

www.igi-systems.com

## DG or ISO ?



Displacement of a pixel from position and attitude errors:



**Example:**

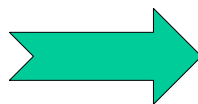
DMC with 12 $\mu$ m pixels and 120mm focal length  
 $\tan 0.004^\circ * 120\text{mm} \approx 8\mu\text{m}$   $\rightarrow$  1RMS angle error < 1 Pixel

www.igi-systems.com

## DG or ISO ?



Position and Attitude  
from GPS/IMU



Georeferenced  
Image Data

### DG

**D**irect **G**eoreferencing

Direct use of calibrated GPS/IMU data to georeference image data.

small to medium scale mapping, orthophotos

- largest savings possible

### ISO

**I**ntegrated **S**ensor **O**rientation

Extended aerial triangulation with GPS/IMU data as additional input.

medium to large scale mapping

- highest accuracy
- no extra boresight calibration

www.igi-systems.com



The optimal choice of the georeferencing workflow (and calibration) is the key to a (commercially) successful operation of an aerial camera/GPS/IMU system.

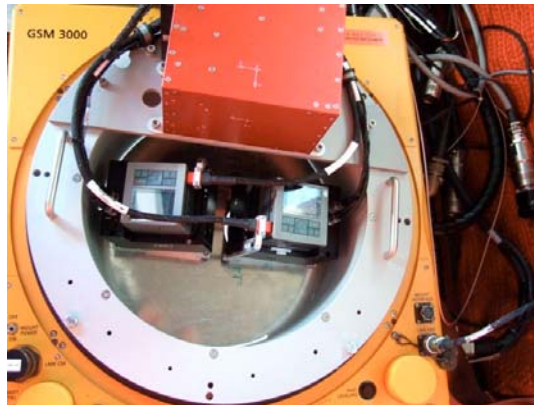
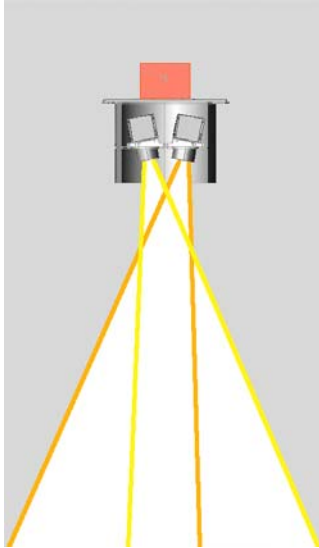
## Mission Examples

**DG:** Dual-DigiCAM ifp / IGI

**ISO:** strip project, RWS highway

**DG:** UltraCam block project "Wesco"

## Dual DigiCAM



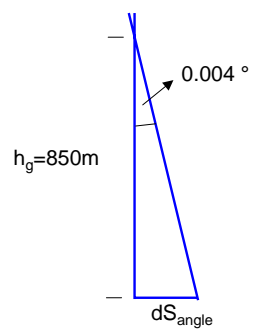
[www.igi-systems.com](http://www.igi-systems.com)

## Example: Direct Georeferencing



- optimal GPS conditions (GPS accuracy  $\leq 5$  cm)
- good lever arm determination

Estimation of the angle- and position accuracy:



$$dS_{\text{angle}} \approx \tan 0.004^\circ \cdot 850\text{m} = 6 \text{ cm}$$

$$dS_{\text{position}} \approx 5 \text{ cm}$$

[www.igi-systems.com](http://www.igi-systems.com)

## 071219 - Vaihingen Enz



19.12.2007  
Weser Bildmessflug



Cessna 206  
(single engine)

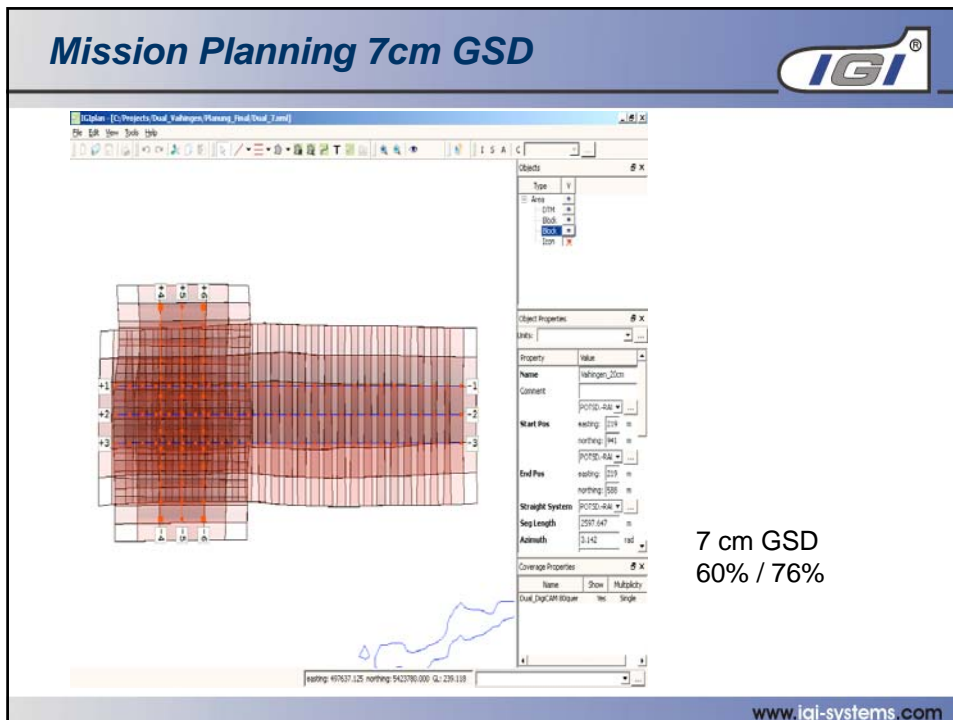
[www.igi-systems.com](http://www.igi-systems.com)

## Weather Conditions



[www.igi-systems.com](http://www.igi-systems.com)

## Mission Planning 7cm GSD



## Direct Georeferencing Results



Vers.	GCP #	ChP #	$\sigma_0$ [ $\mu\text{m}$ ]	RMS [m]		
				$\Delta\text{East}$	$\Delta\text{North}$	$\Delta\text{Up}$
<b>DG</b>	0	65	4.08	0.045	0.075	0.130
AT no	32	33	1.50	0.033	0.070	0.134
AT 44	32	33	1.41	0.022	0.037	0.088
AT io	32	33	1.47	0.022	0.039	0.096

Table 5: Absolute accuracy from check point analysis for GSD 7cm block.

Results were presented at the XXI ISPRS Congress 2008 in Beijing.

## Integrated Sensor Orientation



### Aerial photography of a track

AT:  
The roll angle is difficult to get,  
the yaw angle is well known.

Consequence:  
additional parallel lines  
a high number of GCP's

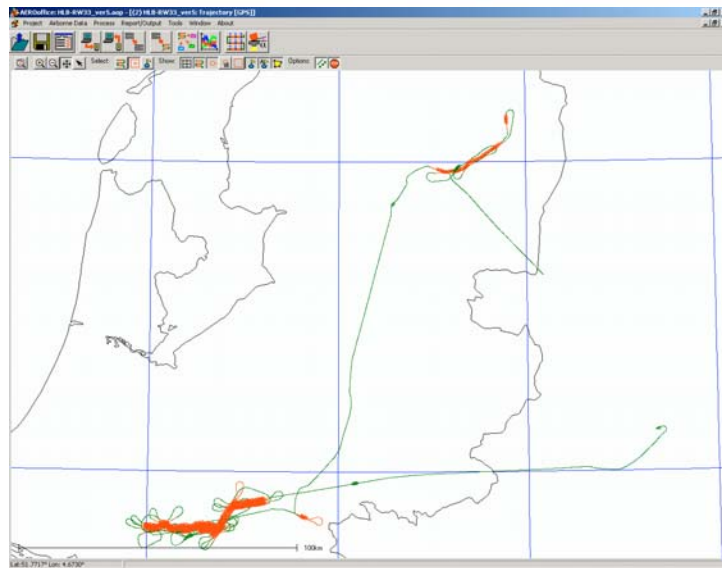


GPS/IMU: The roll angle is very well known, the yaw angle is more difficult to get.

For a single strip, the AT and GPS/IMU complement one another very well.

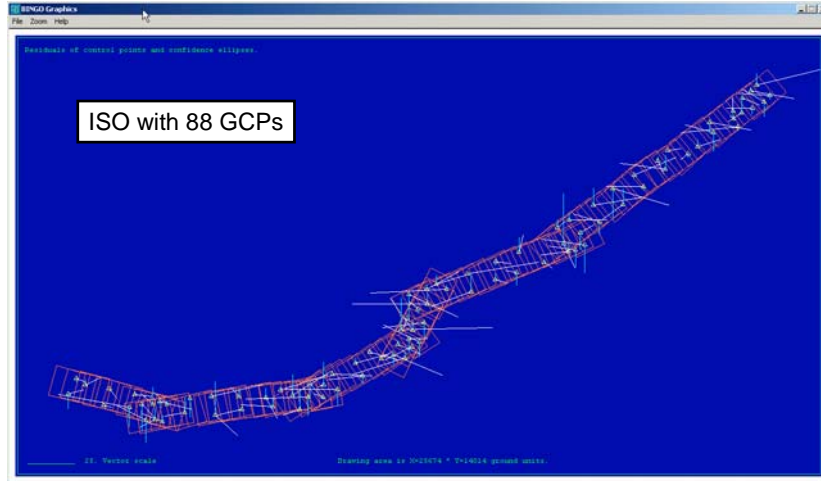
[www.igi-systems.com](http://www.igi-systems.com)

## Integrated Sensor Orientation



[www.igi-systems.com](http://www.igi-systems.com)

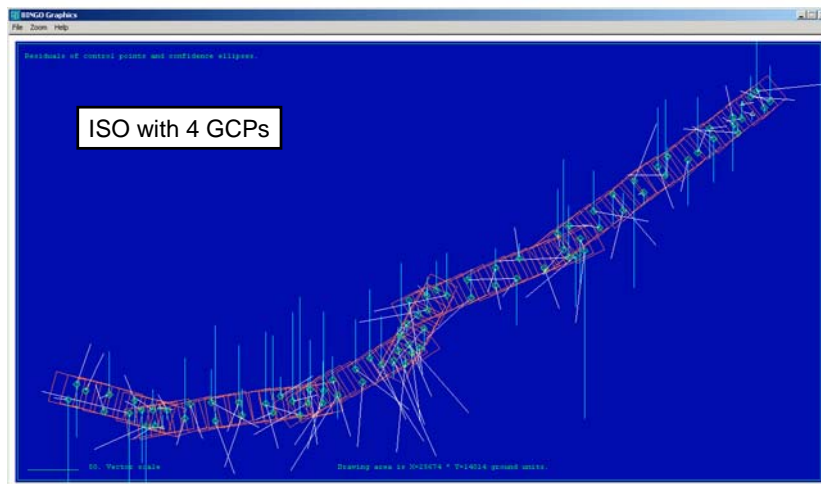
## Integrated Sensor Orientation



SIGMA 0 = 4.07 (1/1000)  
 RMS control point residuals: 18. 6. 7. (1/1000)  
 Max. control point residuals: 49. 17. 27. (1/1000)

www.igi-systems.com

## Integrated Sensor Orientation

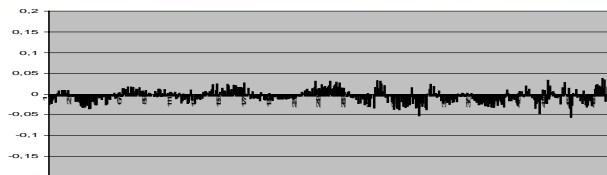


SIGMA 0 = 3.94 (1/1000)  
 RMS control point residuals: 12. 2. 7.  
 Max. control point residuals: 15. 2. 12.  
 RMS of check point residuals: 32. 38. 50.

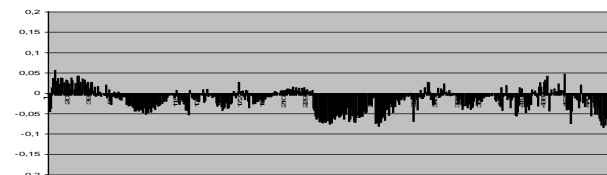
www.igi-systems.com



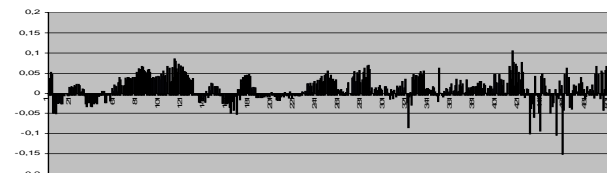
## Integrated Sensor Orientation



X [east]  
RMS: 1.5 cm



Y [north]  
RMS: 2.7 cm



Z [height]  
RMS: 3.0 cm

[www.igi-systems.com](http://www.igi-systems.com)



Aerial photography mission flown for



Date: *September 21st 2006*

Area: *Tsuruma (near Tokyo)*

Camera: *ULTRACAM<sub>D</sub>*

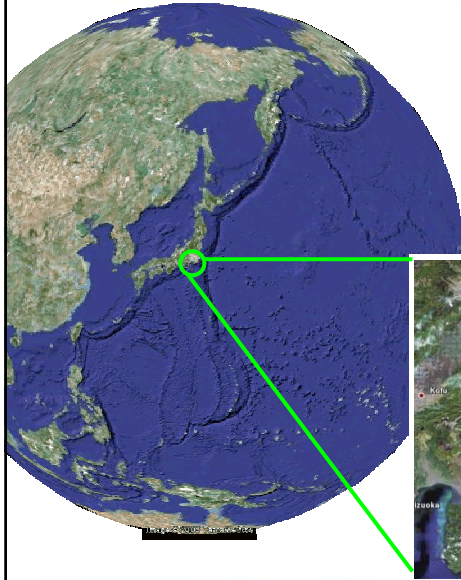
Camera mount  
leveling: *AEROcontrol*

Guidance and  
precise positioning: *CCNS/AEROcontrol*

Data processing: *MATCH-AT and AEROoffice*

[www.igi-systems.com](http://www.igi-systems.com)

## WESCO: Mission Area



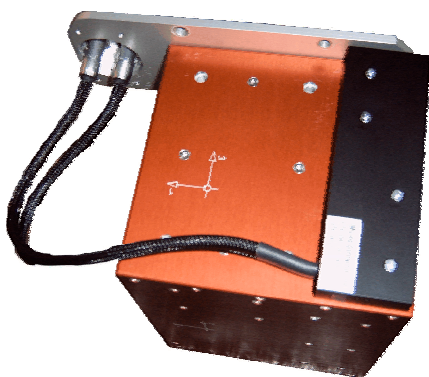
Greater Tokyo Area  
Airport of departure:  
Chofu Airport

17 sqkm



www.igi-systems.com

## WESCO: IMU Installation



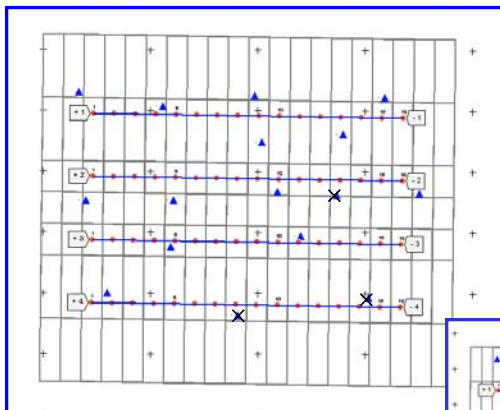
www.igi-systems.com

## WESCO: Camera and GPS Antenna



[www.igi-systems.com](http://www.igi-systems.com)

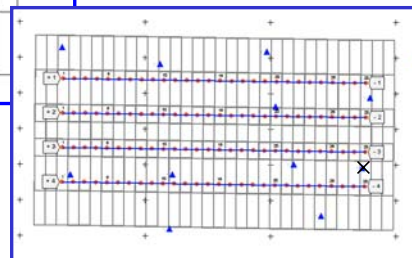
## WESCO: Flight Planning



GSD: 15cm  
Block: 4\*16 Images  
Overlap: 80% / 60%

13 Ground Control Points

GSD: 7cm  
Block: 4\*28 Images  
Overlap: 80% / 60%



[www.igi-systems.com](http://www.igi-systems.com)

## WESCO: Flight Mission

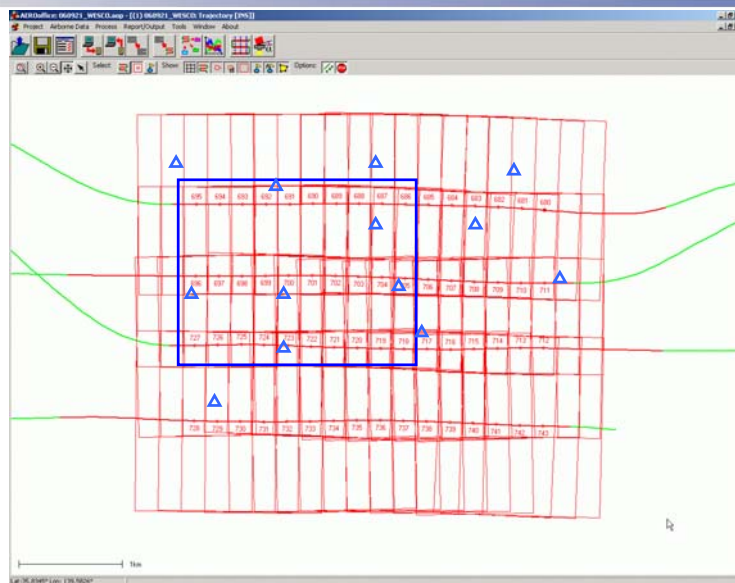


September 21st 2006



www.igi-systems.com

## WESCO: Misalignment Calibration I

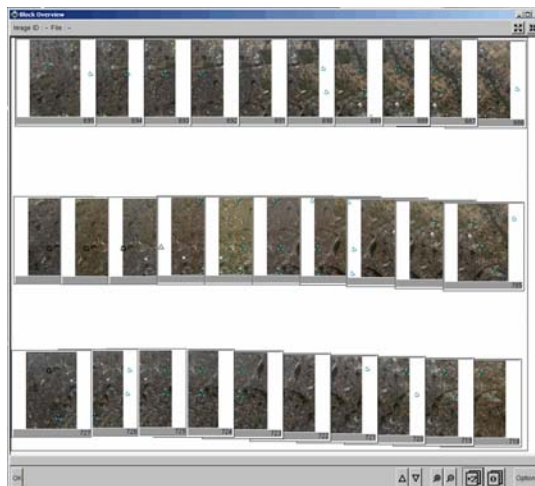


www.igi-systems.com

## WESCO: Misalignment Calibration II



Automatic tiepoint generation with INPHO MATCH-AT



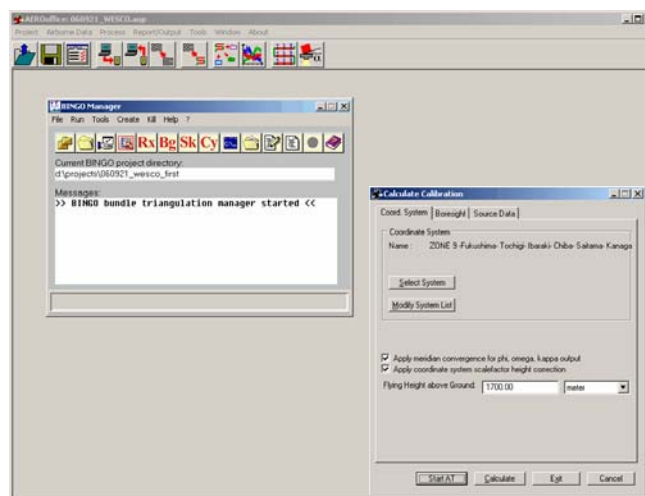
www.igi-systems.com

## WESCO: Misalignment Calibration III



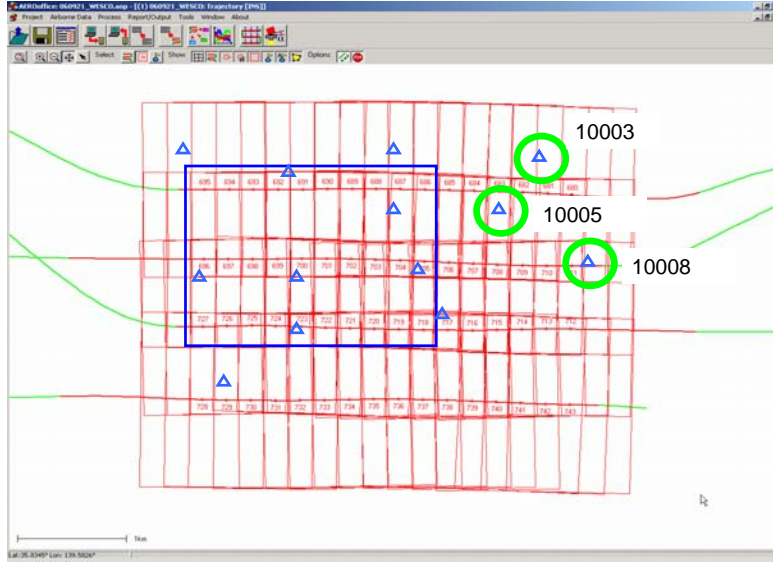
Misalignment calibration inside AEROoffice

$\Delta\omega\phi\kappa < 0.004^\circ$




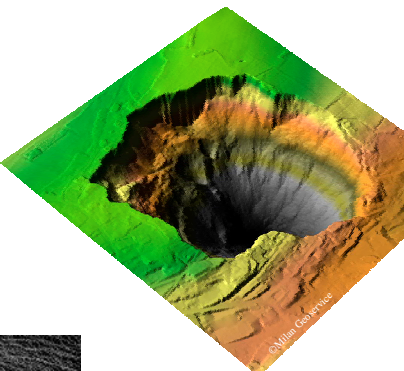

www.igi-systems.com

# WESCO: Direct Georeferencing



www.igi-systems.com





[www.igi-systems.com](http://www.igi-systems.com)