UAS photogrammetry for high precise point positioning of linear objects

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EuroCOW 2016
EPFL Lausanne, Feb 11, 2016

Inspection drones – UAV engineering

senseFly eXom

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Possible Scenario
Water canal shore

Requirements

- proof of annual, **horizontal changes** in the order of 2-15 mm / anno, with two cases
  - changes in the range of 2 mm / anno → **stable embankment**
  - changes of 15 mm / anno → **landslide**

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Possible Scenario
Water canal shore

Challenges

- **Strip geometry**, only about 10m strip width
- Vegetation / water → flight corridor, **matching**
- **Very high accuracy** (up to better than 5mm)
- **Very high resolution**

Accuracy Estimation
Normal Case of Stereo-Photogrammetry

$$\sigma_X = \sigma_Y = m_b \cdot \sigma_x = \frac{GSD}{\Delta pix} \cdot \sigma_x$$

$$\sigma_x = 5\mu\text{m}$$

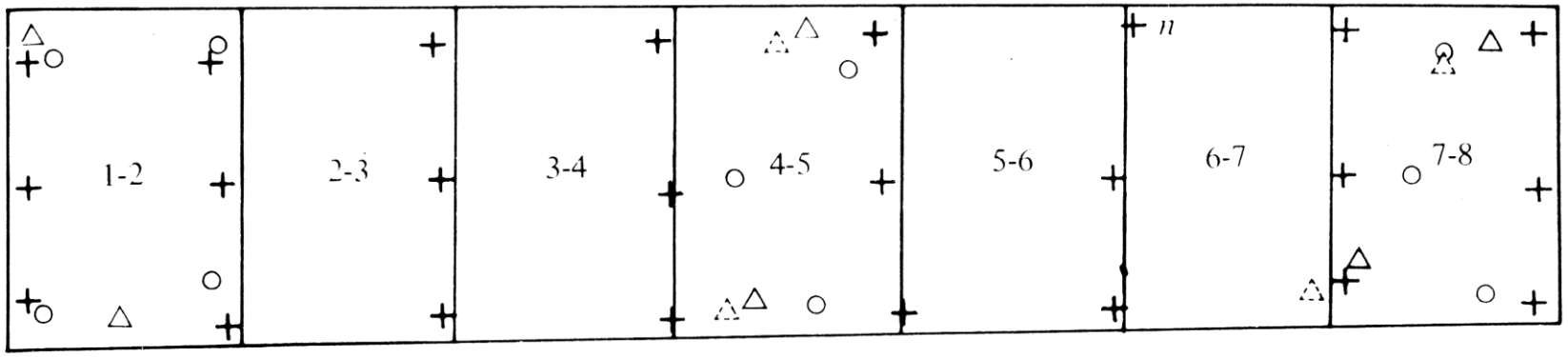
$$\Delta_{pix} = 5\mu\text{m}$$

$$h_g = c \cdot m_b = c \cdot \frac{GSD}{\Delta pix}$$

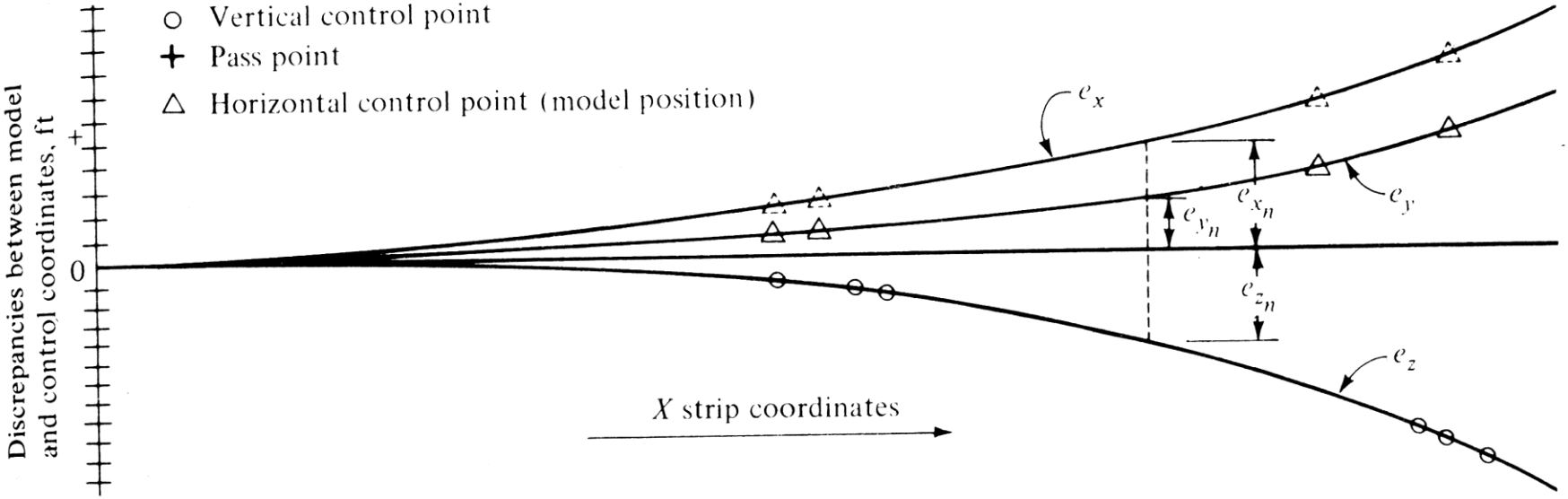
		c=0,050	0,035	0,028	0,02	0,01
	hg= 100	0,01000	0,01429	0,01786	0,02500	0,05000
σ=5mm	**50**	0,00500	0,00714	0,00893	0,01250	0,02500
	25	0,00250	0,00357	0,00446	0,00625	0,01250
	10	0,00100	0,00143	0,00179	0,00250	0,00500
	5	0,00050	0,00071	0,00089	0,00125	0,00250
	4	0,00040	0,00057	0,00071	0,00100	0,00200
	3	0,00030	0,00043	0,00054	0,00075	0,00150
	2	0,00020	0,00029	0,00036	0,00050	0,00100
	1	0,00010	0,00014	0,00018	0,00025	0,00050
	0,5	0,00005	0,00007	0,00009	0,00013	0,00025

Theoretical Accuracy (equals to GSD here) [m]

Strip triangulation – History



△ Horizontal control point (true position)
○ Vertical control point
+ Pass point
△ Horizontal control point (model position)



Simulation: Case 1 - Nadir view

	Nadir image parameters
Camera	3000 x 4000 pix @ 5 μm pixel size
Focal length	35 mm (opening angle ~40 deg)
GSD	3.5 mm
Flying height a.g.	25 m
Coverage per image	10.7 (cross flight) x 14.3 (in flight) m² Large side in flight direction
Base length	2.9 m @ p = 80%
#images	351 Images @ 1000 m strip length
Image point accuracy (tie points)	$\sigma_{x'}$**=5 μm** – 1 pixel (Option 1) $\sigma_{x'}$**=2 μm** – 0.4 pixel (Option 2)
Accuracy stereo model Sigma X, Y Sigma Z	 3.5 mm 30.2 mm (B/Z = 0.116)

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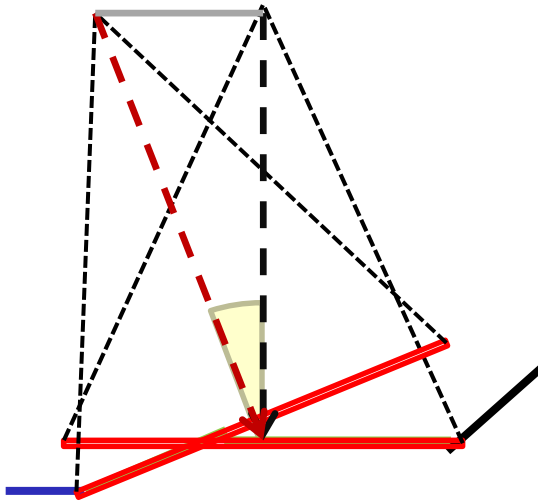
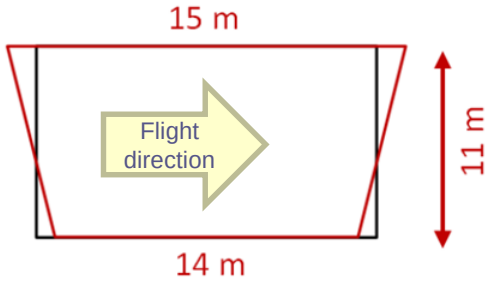
Simulation: Case 2 - Nadir + Oblique view

	Oblique image parameters
Camera	3000 x 4000 pix @ 5 μm pixel size
Focal length	35 mm (opening angle ~40 deg)
GSD	3.5 mm Nadir 3.5 – 3.8 mm Oblique
Flying height a.g.	25 m
Coverage per image	Trapezoidal (ca. 11 m x 14.5 m)
Base length	2.9 m @ „p = 80%“ Large side in flight direction
#images	351 Images @ 1000 m strip length
point accuracy (tie points)	$\sigma_{x'}$**=5 μm** – 1 pixel (Option 1) $\sigma_{x'}$**=2 μm** – 0.4 pixel (Option 2)





10deg oblique angle
(side looking)

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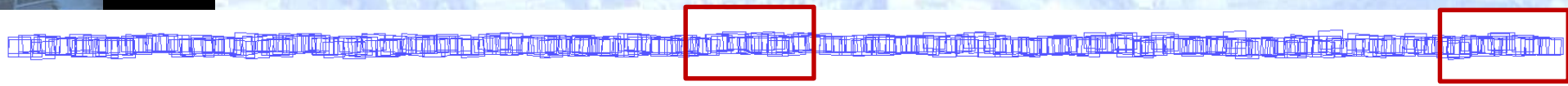
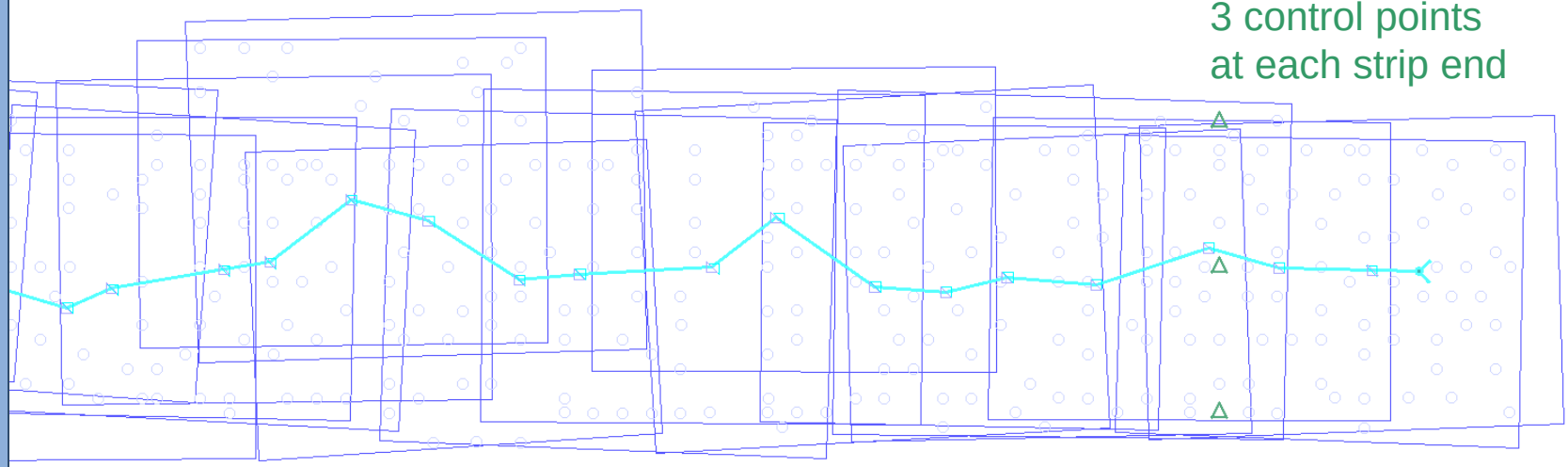
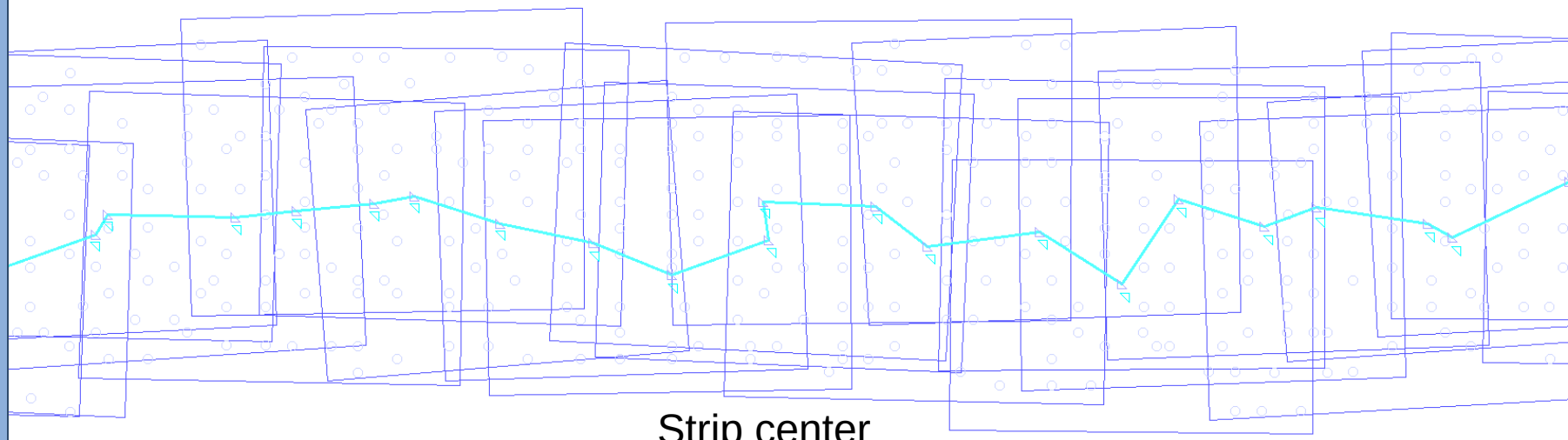
Simulation: Case 1 - Nadir view





End of strip



Strip center

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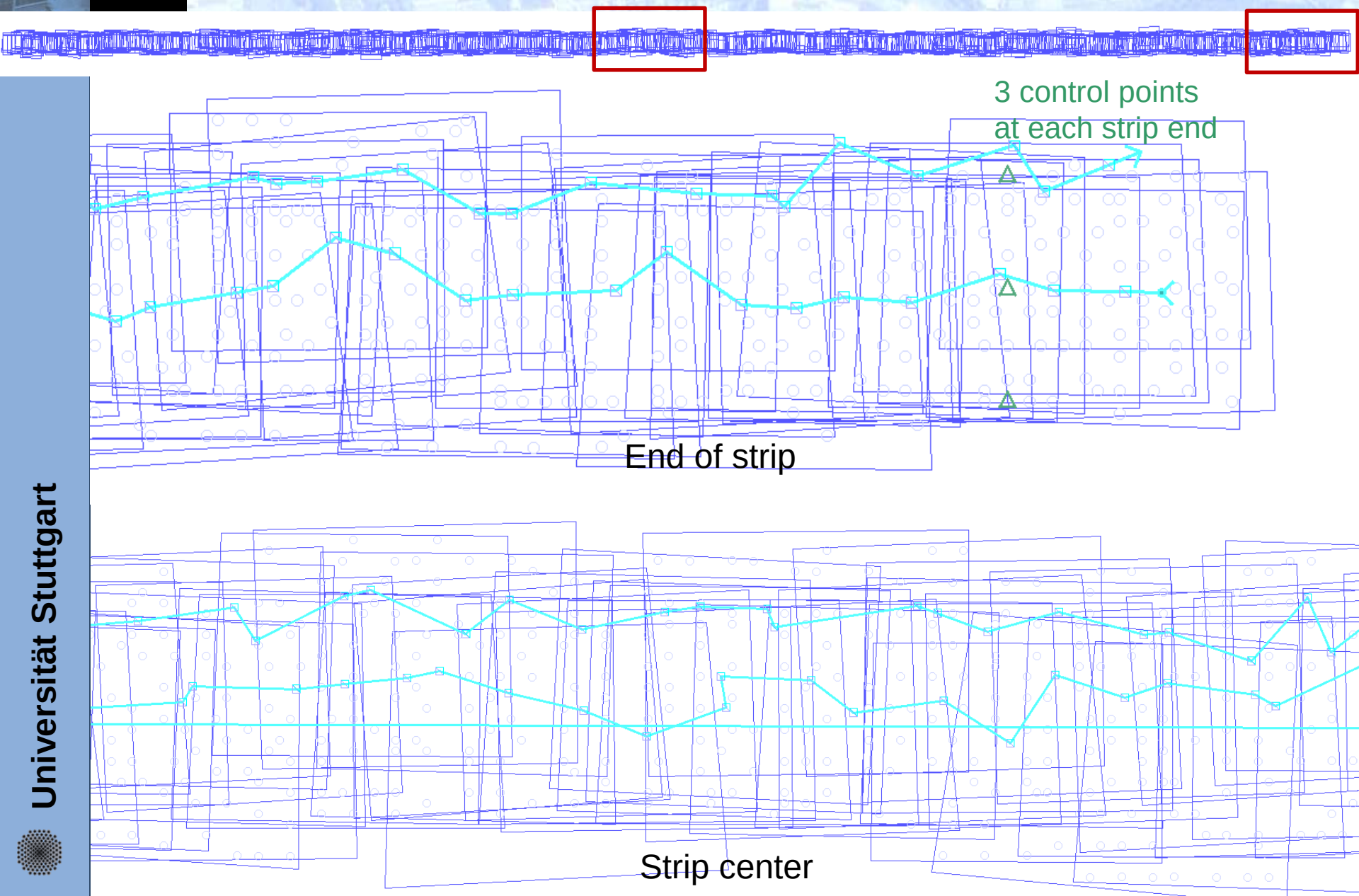
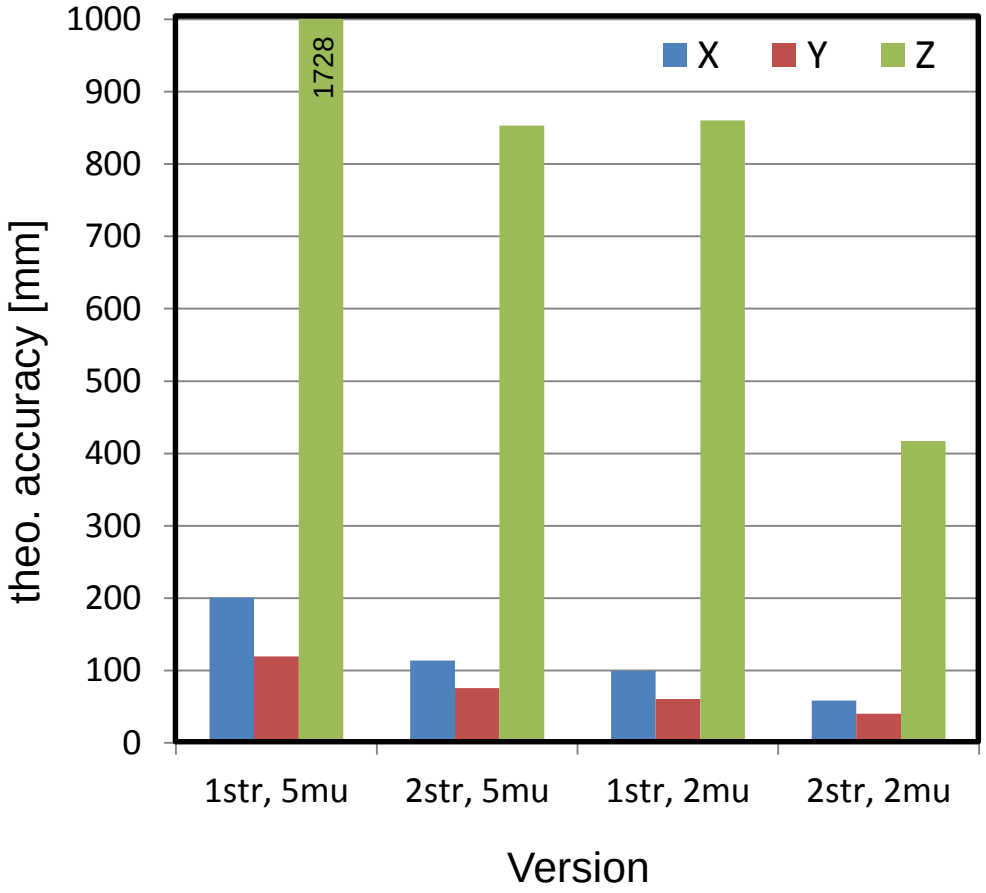
Simulation: Case 2 - Nadir + Oblique view



Simulation results (I)
Theoretical accuracy in object space

AT based on **control points only**



GSD 3.5mm

GCP only

Additional integrated GNSS/inertial sensor for direct EO measurement

Example GNSS/inertial board

Applanix APX-15 UAV

Product Information

http://www.applanix.com/media/downloads/products/specs/APX-15%20UAV_Data_Sheet.pdf

PERFORMANCE SPECIFICATIONS[2] (RMS ERROR)
Unmanned Airborne Vehicle Applications

	SPS	DGPS	RTK[4]	Post-Processed[5]
Position (m)	1.5 - 3.0	0.5 - 2.0	0.02 - 0.05	0.02 - 0.05
Velocity (m/s)	0.05	0.05	0.02	0.015
Roll & Pitch (deg)	0.04	0.03	0.03	0.025
True Heading[3] (deg)	0.30	0.28	0.18	0.080

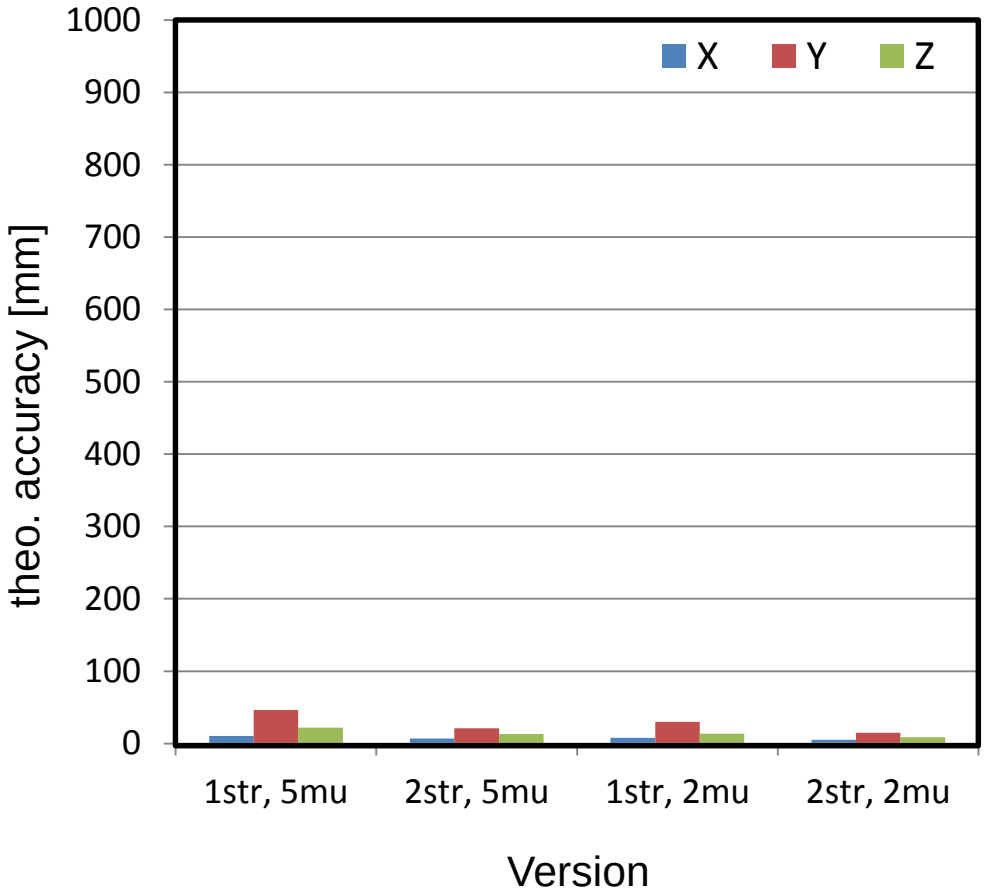
Assumptions in Simulation

0.04m

0.025deg

Simulation results (II)
Theoretical accuracy in object space

AT based on **control points + GNSS perspective centres**



GSD 3.5mm

GCP +
GNSS Pos.

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Simulation results (II)
Theoretical accuracy in object space

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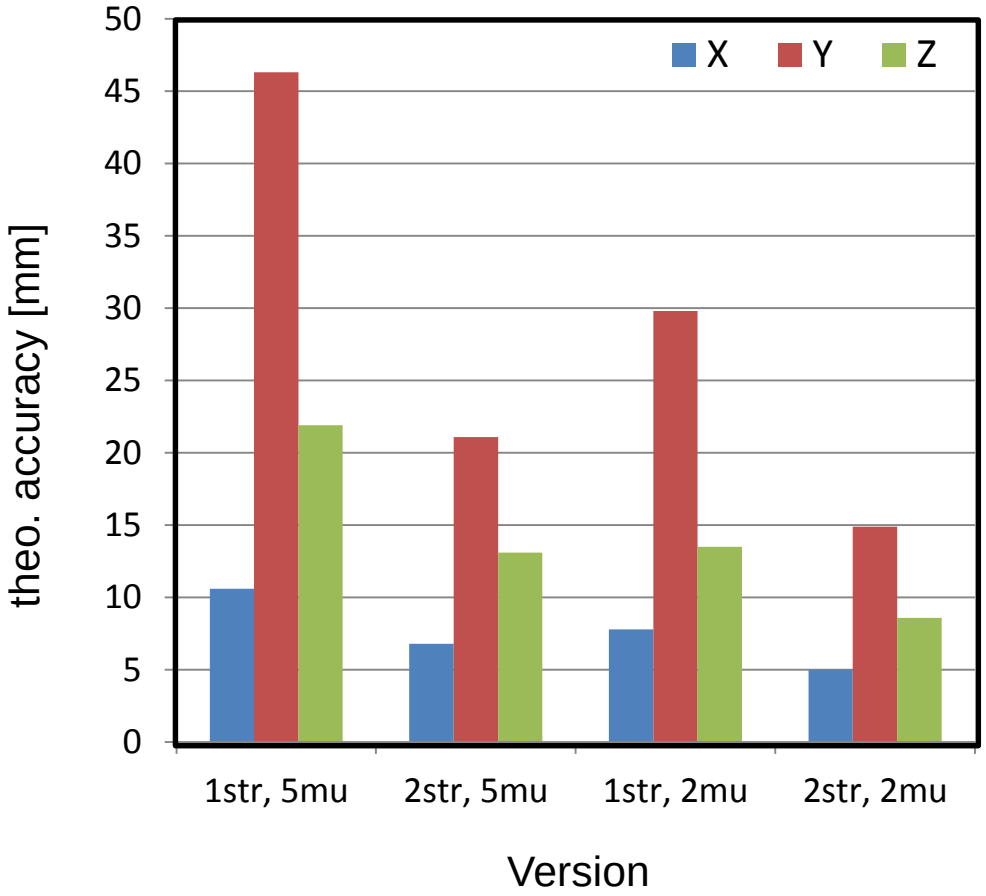

GSD 3.5mm

GCP +
GNSS Pos.

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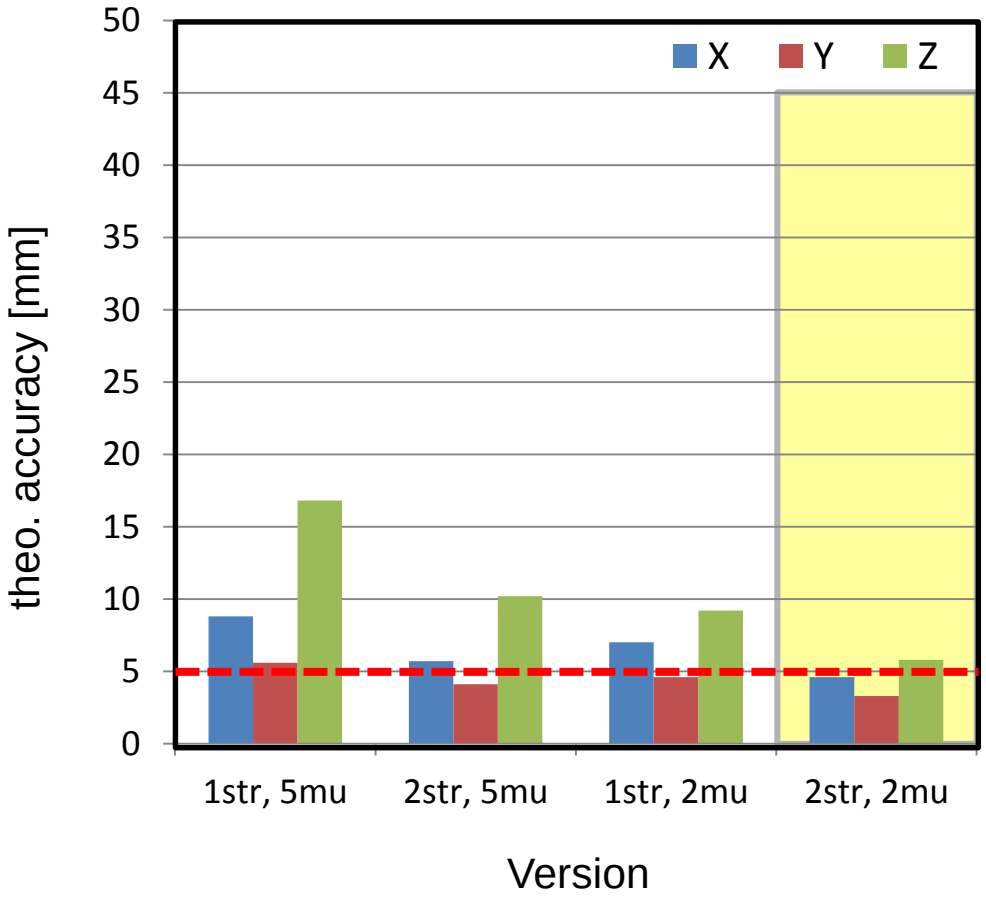
Simulation results (III)
Theoretical accuracy in object space

AT based on **control points + full GNSS/inertial EO params**



GSD 3.5mm

GCP + GNSS/ inertial full EO

5mm accuracy demand

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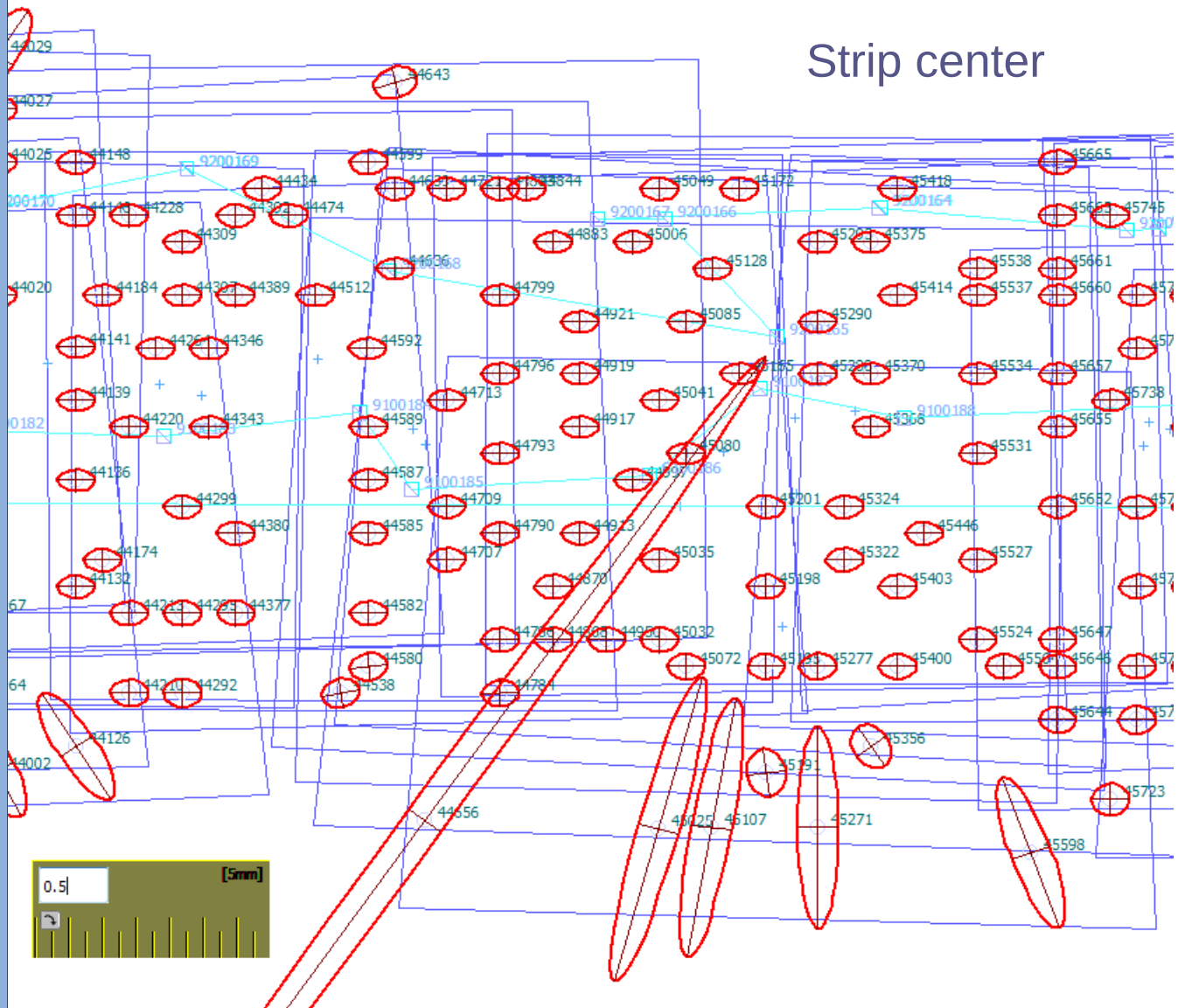
Simulation results (III)
Error ellipses



GSD 3.5mm

GCP + GNSS/
inertial full EO

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Results from Simulations

The **required theoretical horizontal accuracy** of σ_{xy} = 5mm **can be reached** from a flying height above ground of 25meters at a GSD of 3.5mm!

BUT

several **challenges** have to be solved

Challenge 1
Image quality / camera resolution

Fixed Wing: Canon Ixus **vs.** **Ricoh GXR + Zeiss Biogon**

GSD (nom.)	**4.487cm**
PSF	0.504 pix
GSD_{FWHM}	5.343 cm
Factor	1.19

GSD (nom.)	**4.942cm**
PSF	0.395 pix
GSD_{FWHM}	4.615 cm
Factor	0.93

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Challenge 1
Image quality / camera resolution

Copter: Sony Alpha 7R, 50mm lens

GSD (nom.)	**0.390 cm**
PSF	0.570 pix
GSD_{FWHM}	0.523 cm
Factor	1.34

DSC04840

GSD (nom.)	**0.378 cm**
PSF	0.517 pix
GSD_{FWHM}	0.460 cm
Factor	1.22

DSC06675

Notice: ISO 1000

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Challenge 2
Image point accuracy / Tie point transfer

- automatic tie point measurement in the range of 1/3 pic (refined SIFT (LSM on top)
- dense tie point assignment (multiple links) in the vegetation (grass land)

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Image point accuracy / Tie point transfer

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- possible coded markers to maximum pixel accuracy (automatically) for permanent check / control points

- Number of required signalized points / (reference) accuracy of the control points
- Reference systems / coordinate transformation

Challenge 3
Overall system calibration

- camera stability
  - geometric calibration, cannot be solved from in-situ calibration as there is only one strip geometry block (most likely)
- GNSS / inertial system
  - assumed accuracy only available with accurate determination of the spatial and temporal eccentricities between GNSS / IMU / camera.
  - can theoretical GNSS/inertial accuracy obtained in operational environment
- synchronization
  - precise time synchronization of all involved components required. In particular, integration of the camera
  - shutter

Friday, April 8, 2016, starting 14:00 h
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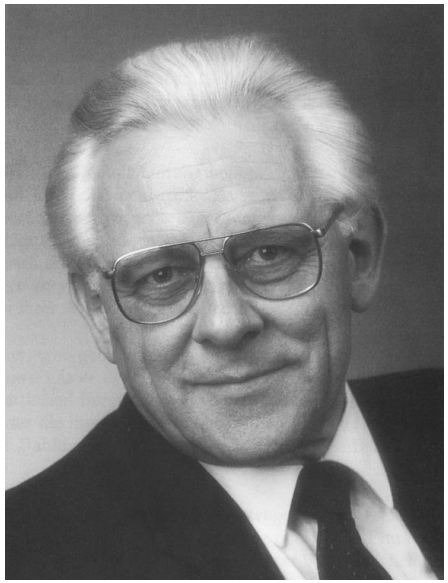
50 Jahre ifp
Institut für Photogrammetrie der Universität Stuttgart



1966 – 1992

1992 – 2016

2016 –

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