

# Photogrammetric Evaluation of Multi-Temporal Fixed Wing UAV Imagery

UAVg, ETHZ

16.9.2011

Prof. Dr. Eberhard Gülch

Hochschule für Technik  
**Stuttgart**

University of Applied Sciences

# Contents

- ◆ **PAMS (Personal Aerial Mapping System)**
  - Description
  - Experiences from flight missions and preparation tasks
  - PAMS UAV Evaluation Software
  - Established link to Trimble INPHO Digital Photogr. Software
- ◆ **Empirical investigations**
  - Flight lines and image quality
  - Direct georeferencing
  - Ground control available
  - Comparisons
- ◆ **Conclusions**



(Germanics, 2010)

# PAMS - Description

## ◆ Smart Plane (Sweden)

- Micro UAV
- [http://www.smartplanes.se/plane\\_e.html](http://www.smartplanes.se/plane_e.html)

## ◆ 1.2m span-width

- Fuselage and 2 wings (detachable)

## ◆ Weight about 1.1 kg

- incl. Battery pack and payload 200gr

## ◆ Electric motor

- 200W with Li-Po Battery Pack
- Average speed 14-15m/s
- Flight mission 45-60 min.



(Germanics, 2010)

# Electronic components and sensors

## ◆ Electronic components

- Autopilot, digital receiver 2.4 GHz, data link, tracker

## ◆ Sensors

- IXUS 70
  - 7 Mpixel and 160 g
  - About 500 images on 2 GB mem.card
  - Shutter speed up to 1/1000
  - Test field calibration
  - Full control on camera functions
- GPS
- IR-Sensors
  - Attitude determination
  - Stabilized flight conditions



# Flight modes – Visual flight only

## ◆ Manual Mode

- Emergency
- Trim test

## ◆ Auto 1 Mode

- Start and Landing
- Stable flight conditions due to IR sensors

## ◆ Auto 2 Mode

- Approaches automatically base position after start
- Autonomous photogrammetric flight mission
- Plane returns afterwards to base position

# Preparation

## ◆ Setting up PAMS

- 1-2 persons in 10 min
  - Plane assembly
  - Mounting camera
  - Installing battery pack
  - Connecting cables (5)
  - Trim control



(SmartPlanes, 2010)

## ◆ Setting up ground station

- Netbook
- Radio antenna

# PAMS – Ground station SW

## ◆ Flight planning

- On-site (re-usable)
- Area parameters (Dimension and orientation of rectangle)
- Flight height
- Camera ID
- Park position

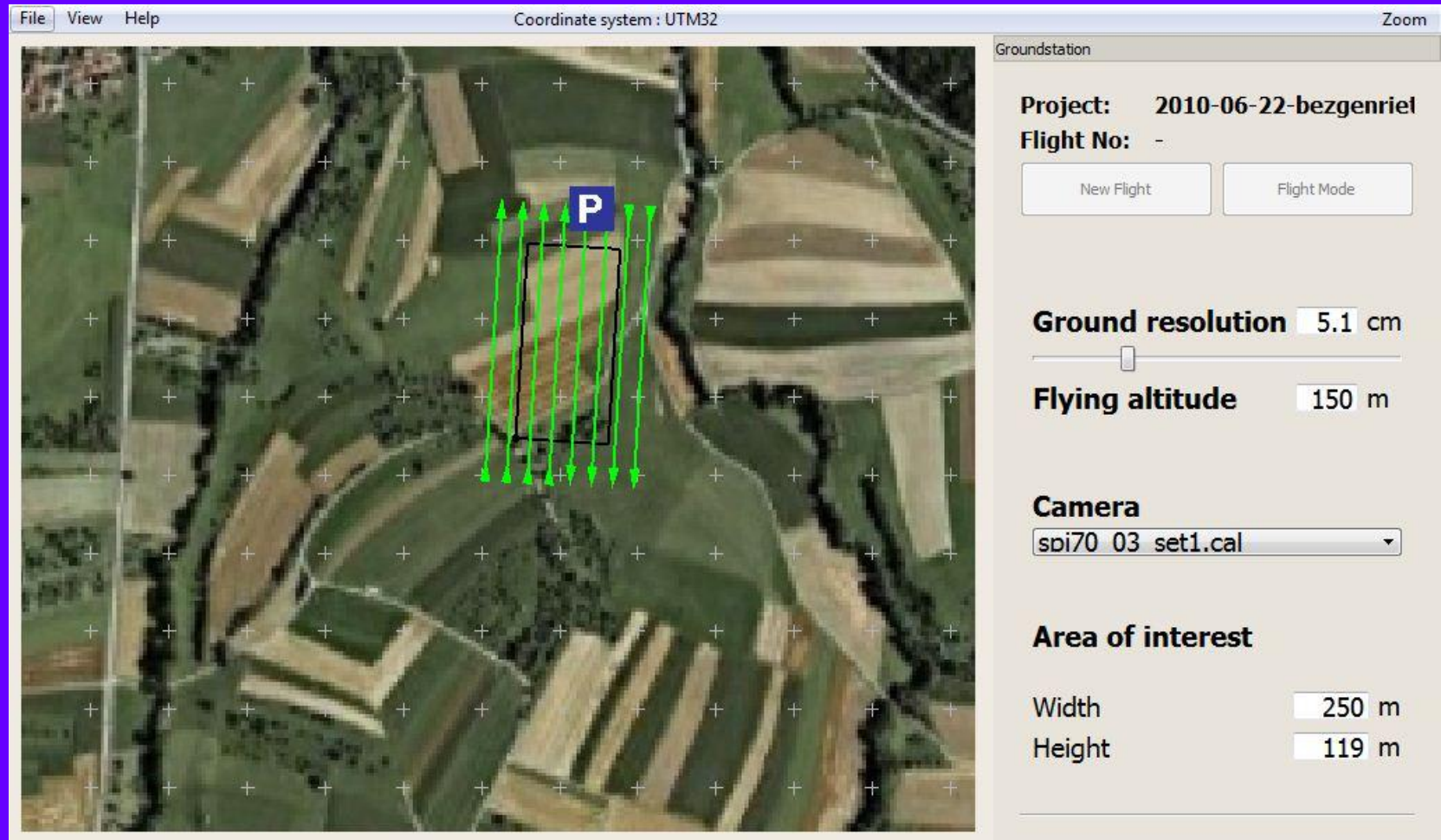
## ◆ Flight control

- Status of GPS, Radiolink, Camera, Battery
- Speed above ground
- Wind speed and direction
- Flight mode (Auto2, Auto1, Manual)
- Actual position, flight path and % of fixed flight

## ◆ Flight documentation

- Monitoring of all flight parameters

# Ground Station – Flight planning



The screenshot displays a flight planning application window. The main area is a satellite map with a grid of white crosses. A black rectangular area is drawn on the map, with a blue square containing a white 'P' at its top center. From the bottom edge of this rectangle, seven vertical green arrows point upwards, indicating a flight path. The right-hand side of the window contains a control panel titled 'Groundstation' with the following settings:

- Project:** 2010-06-22-bezgenriel
- Flight No:** -
- Buttons:** 'New Flight' and 'Flight Mode'
- Ground resolution:** 5.1 cm (with a slider below it)
- Flying altitude:** 150 m
- Camera:** spi70 03 set1.cal (dropdown menu)
- Area of interest:**
  - Width:** 250 m
  - Height:** 119 m

# Flight control and parameters

## ◆ Flight control

- Actual position
- Planned path
- Planned turn for next strip
- % of mission done

## ◆ Parameters

Preparation time	About 10 min (2 persons)
Flight planning	Area 119x250 m <sup>2</sup> Nominal GSD 4.6cm
Start	Auto mode 1
Photogrammetric flight mission	Flight time 5 min 39 sec 88 images Average speed 14.61 m/s Average wind speed (4.11m/s)
Landing	Auto mode 1

# PAMS – Evaluation software

## ◆ AirMosaic Software on Netbook/PC

### ◆ Stage 1: Quality control

- Per image
  - Speed
  - Angular speed
  - Exposure
  - Image quality parameter

### ◆ Stage 2: QuickMosaic

- Geotagged aerial images
- Quality control on site
  - Completeness and image quality

# BezF6 - QuickMosaic



(10-06-08, BezF6)

# PAMS – Evaluation software

## ◆ Stage 3: AirMosaic

- „Coarse“ orthomosaik (georeferenced imagery) from AT/DSM/Ortho process in image pyramids
- Provision of meta data (can be used to link to HFT INPHO Software Suite)

## ◆ Stage 4: only by Germanics

- 2nd level ground processing software for DSM/Ortho

# BezF6 – AirMosaic



(10-06-08, BezF6)

# Link to Trimble Inpho Software

- ◆ IO from flight protocol
- ◆ EO from AT protocol by AirMosaic Software
  - Case 0: all OK
  - Case 1: Missing EO but file exists
  - Case 2: Missing EO and missing file
- ◆ Generation of Inpho project file

	BezF1	BezF6	BezF7
	March 23, 2010	June 8, 2010	
Case 1	10	4	0
Case 2	0	9	13

# Empirical evaluations

- ◆ **Test data sets**
- ◆ **Flight lines and image quality**
- ◆ **Direct georeferencing**
- ◆ **Ground control available**
- ◆ **Comparisons to other ground data**

# Overview on test data sets

	BezF1	BezF6	BezF7
Day	March 23, 2010	June 8, 2010	
Strips	14	8	8
Images/strip	10	13	10
Images Available	140	88	68
Direction	E-W	N-S	N-S
Height	200m	150m	150m
Area (plan)	219x343 m <sup>2</sup>	119x250 m <sup>2</sup>	119x250 m <sup>2</sup>
End-lap	80% (planned) 70% (planned)		
Side-lap			
Time	11min57sec	5 min 39sec	5min 21sec

# Overview on test data sets



BezF1



BezF6



BezF7

# Bezgenriet – Sample image



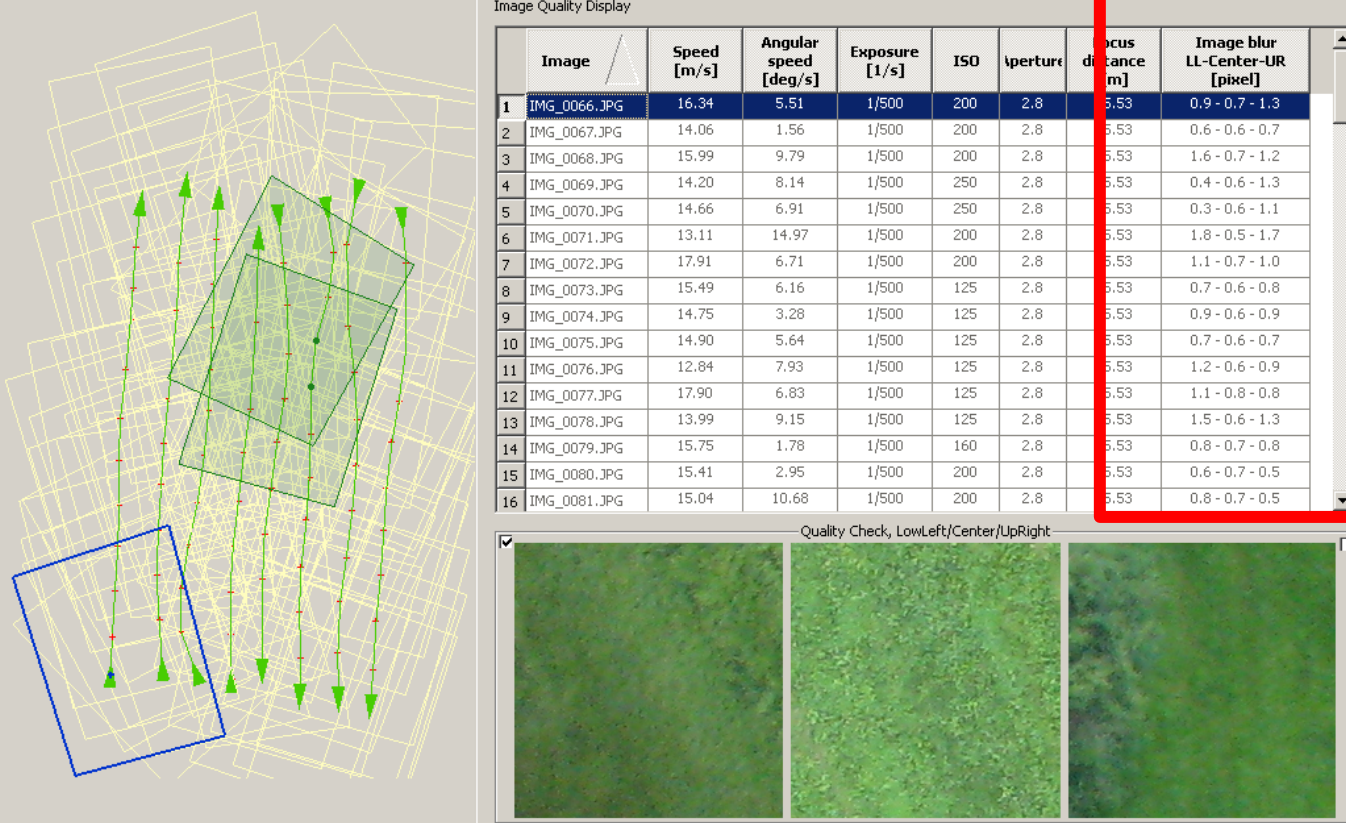
(10-06-08, Flight BezF6)

# Flight lines and image quality

UAS AirMosaic - [X:\Backup\Pams\_Data\2010-06-08-bezgenriet\flights / 6]

File Help

UAS AirMosaic  
2010-06-08-bezgenriet / 6



**Quality Check**

Image Quality Display

Image	Speed [m/s]	Angular speed [deg/s]	Exposure [1/s]	ISO	Aperture	Focus distance [m]	Image blur LL-Center-UR [pixel]
1 IMG_0066.JPG	16.34	5.51	1/500	200	2.8	5.53	0.9 - 0.7 - 1.3
2 IMG_0067.JPG	14.06	1.56	1/500	200	2.8	5.53	0.6 - 0.6 - 0.7
3 IMG_0068.JPG	15.99	9.79	1/500	200	2.8	5.53	1.6 - 0.7 - 1.2
4 IMG_0069.JPG	14.20	8.14	1/500	250	2.8	5.53	0.4 - 0.6 - 1.3
5 IMG_0070.JPG	14.66	6.91	1/500	250	2.8	5.53	0.3 - 0.6 - 1.1
6 IMG_0071.JPG	13.11	14.97	1/500	200	2.8	5.53	1.8 - 0.5 - 1.7
7 IMG_0072.JPG	17.91	6.71	1/500	200	2.8	5.53	1.1 - 0.7 - 1.0
8 IMG_0073.JPG	15.49	6.16	1/500	125	2.8	5.53	0.7 - 0.6 - 0.8
9 IMG_0074.JPG	14.75	3.28	1/500	125	2.8	5.53	0.9 - 0.6 - 0.9
10 IMG_0075.JPG	14.90	5.64	1/500	125	2.8	5.53	0.7 - 0.6 - 0.7
11 IMG_0076.JPG	12.84	7.93	1/500	125	2.8	5.53	1.2 - 0.6 - 0.9
12 IMG_0077.JPG	17.90	6.83	1/500	125	2.8	5.53	1.1 - 0.8 - 0.8
13 IMG_0078.JPG	13.99	9.15	1/500	125	2.8	5.53	1.5 - 0.6 - 1.3
14 IMG_0079.JPG	15.75	1.78	1/500	160	2.8	5.53	0.8 - 0.7 - 0.8
15 IMG_0080.JPG	15.41	2.95	1/500	200	2.8	5.53	0.6 - 0.7 - 0.5
16 IMG_0081.JPG	15.04	10.68	1/500	200	2.8	5.53	0.8 - 0.7 - 0.5

Quality Check, LowLeft/Center/UpRight

easting: 545551.85  
northing: 5390216.13

# Flight lines and image quality

## ◆ Flight lines

- Different pattern (ice cleaning)
- Strong kappa rotations
- Moderate to strong omega and phi rotations
- Effect on image quality due to partly high angular speed

## ◆ Image Quality

- Manual check in ground processing software
- Only center and 2 image corners
- Blur might occur also in other parts of the image due to vegetation movement etc.

# Image quality

- ◆ **Improved support to user by applying BlurMetric Matlab SW (Bao 2009)**
  - Measure for whole image (0=Good to 1=Bad)
  - Traffic light approach supports selection by operator



OK

Moderate

Not OK

# Flight mission - experiences

## ◆ 2 Operators, if novice users

- Easier start
- Allows visual control and check on ground station

## ◆ External conditions

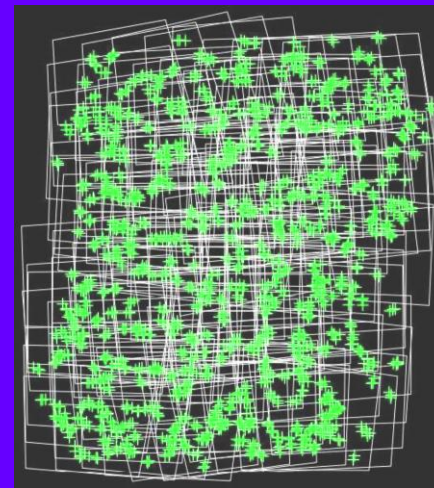
- Wind moderate or low
- Turbulences reduce image quality dramatically, even if flight lines are still quite good
- If cloud cover above flight height is too dense
  - IR sensors might not work properly
  - Problems with image quality and long exposure times
  - Check for sufficient start and landing strip

# Direct georeferencing - AT

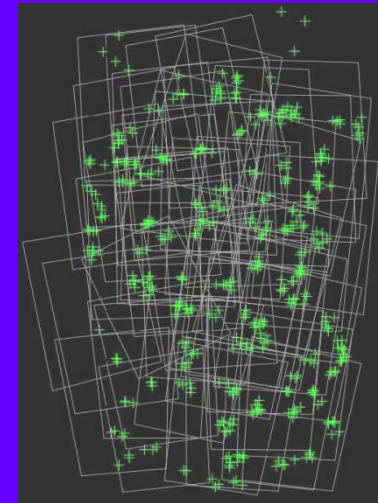
- ◆ Parameter selection adapted
- ◆ No manual tie points added

Point density	dense
TPC pattern:	3x3 or 4x4
Start at overview level:	6
Stop at overview level:	1 or 0
Size of tie-point area:	45 Pixel
Parallax bound:	15 Pixel
LSM/FBM correlation coeff.	90%-93%

- ◆ Differences in AT tie point distribution and flight lines

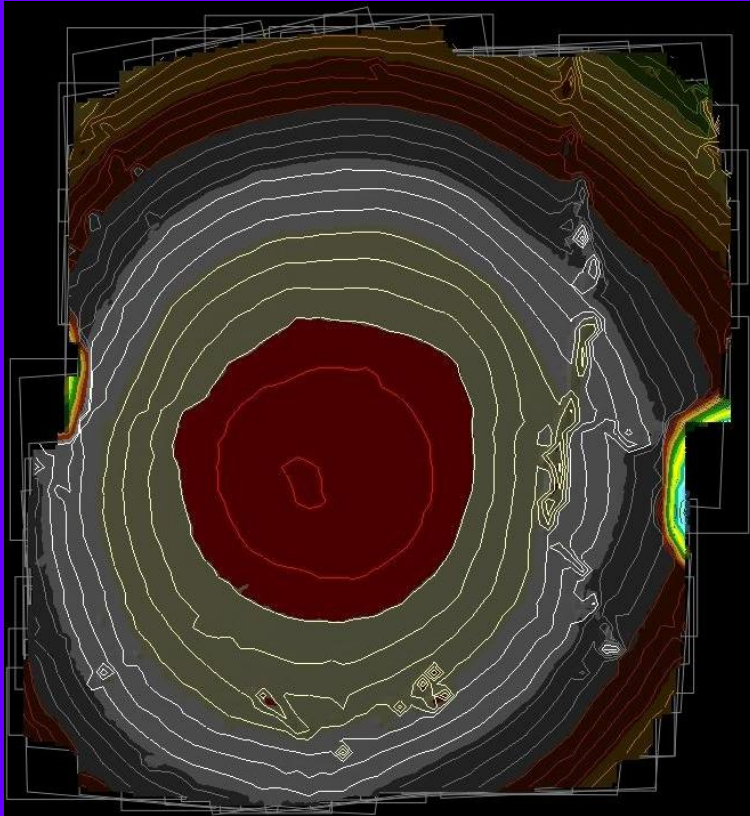


BezF1

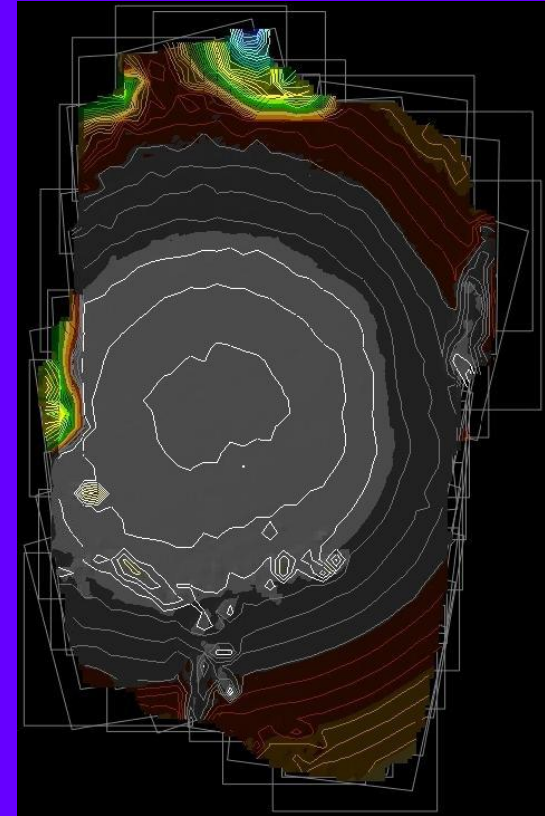


BezF7

# Direct georeferencing – DSM



BezF1



BezF6.

The “dome” in the center is erroneous. Contour interval 2.5m.

Potential source: Camera calibration effects

# Ground control available - AT

BezF1	E [m]	N [m]	H [m]
GCP min $\sigma_0 = 4.0 \mu\text{m}$	0.12	0.11	0.41
GCP moderate $\sigma_0 = 4.1 \mu\text{m}$	0.11	0.10	0.38

Sigma naught and SDEV at terrain points

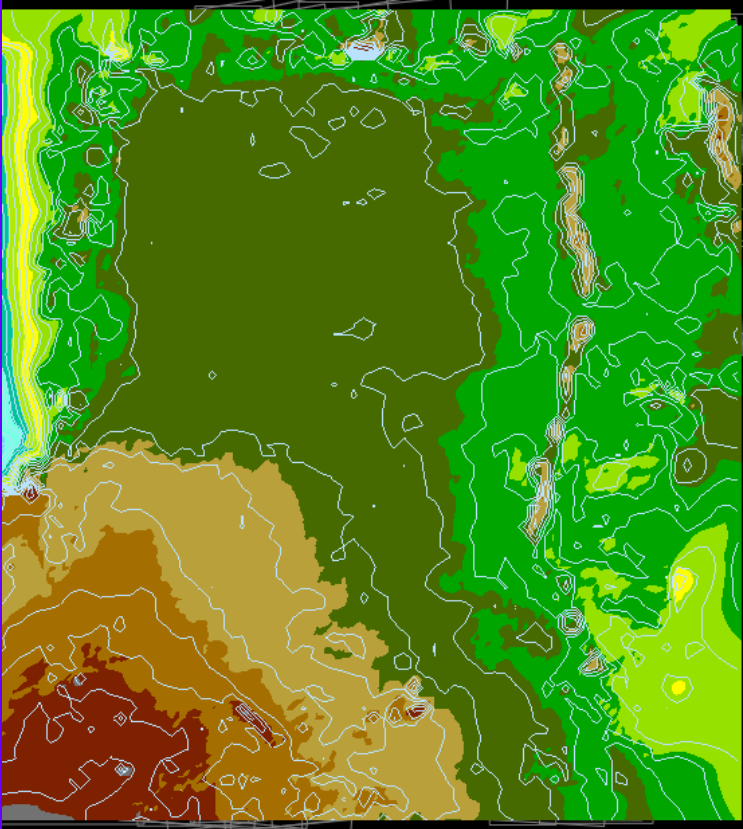
GCP min: 4 points

GCP moderate: 10 points

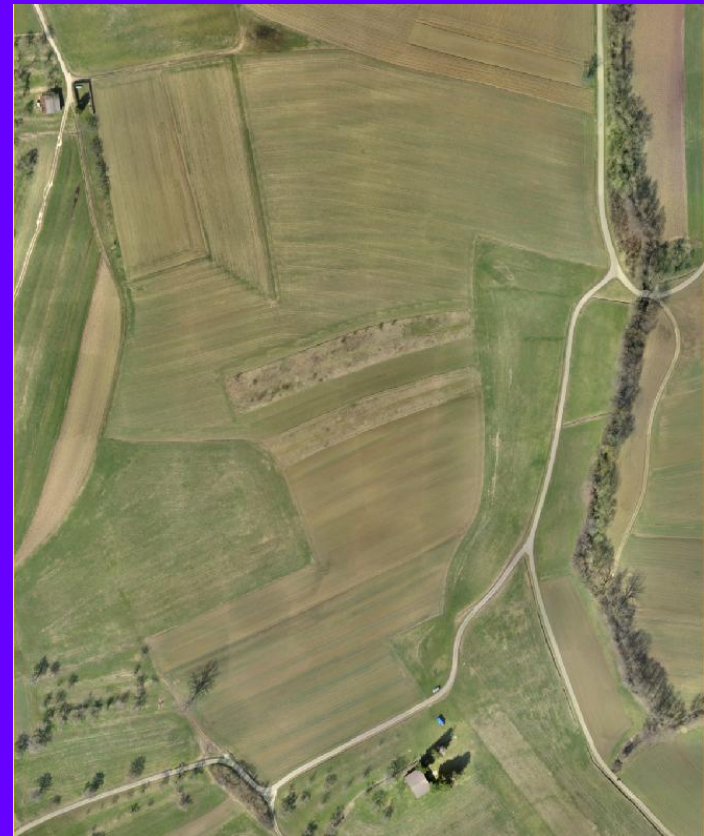
- ◆ **Internal accuracy quite OK, but should be further improved**
- ◆ **4 GCPs do already produce quite good results**
- ◆ **Diff. at some check points up to 1m**
  - no signals used
  - quality of check point definition
  - needs clarification

# Ground control available

DSM (BezF1, with moderate # of GCPs)



Orthomosaik (BezF1, with moderate # of GCPs)



# Comparisons

## ◆ Among flights on same area (no GCP)

- Strong shifts of several m even on flights of same day and same flight plan (F6-F7)
- Also scale differences observed
- Potential sources: flight conditions and/or unstable calibration of camera



## ◆ 2 flights to other data

Point 9011 (UTM32N)	E [m]	Diff. to GPS[m]	N [m]	Diff. to GPS[m]
BezF1-no GCP	545727.06	14.72	5389787.88	15.41
OpenStreetMap	545709.97	-2.37	5389771.59	-0.88
Google Maps	545709.99	-2.35	5389771.52	-0.95
GPS	545712.34	-	5389772.47	-
BezF1 moderate	545712.25	-0.09	5389772.57	0.10

# Conclusions

## ◆ UAVs offer new opportunities

- For local applications
- Combination of blocks for larger areas
- Can be extended to other sensors (CIR, Thermal)

## ◆ Not to forget

- It is NO replacement for classical photogrammetric flights
- Moderate to high dependency on external conditions
- Absolute NEED for GCPs on ground

# Future Work

- ◆ **Further analyses of accuracy and reliability**
  - Test field flights with self-calibration
  - Stability of camera calibration
  - Another camera?
- ◆ **Planned flights for local application areas**
  - Border zones of villages with orchards
  - Forest stands

# Acknowledgements

- ◆ **Germanics GmbH, Schorndorf**

- [www.germatics.com](http://www.germatics.com)

- ◆ **Smartplanes Schweden**

- [http://www.smartplanes.se/plane\\_e.html](http://www.smartplanes.se/plane_e.html)

- ◆ **HFT Students**

- Dipl.-Ing. (FH) S. Brinker

- B.Eng. M. Ziegler