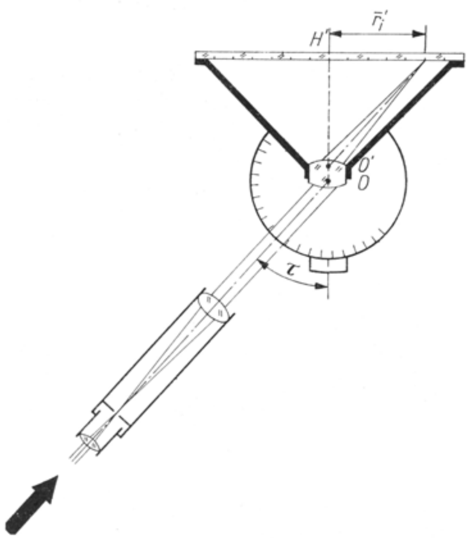
Calibration and validation of digital airborne cameras

Michael Cramer
Universität Stuttgart – Institut für Photogrammetrie (ifp)
Geschwister-Scholl-Str. 24D
D-70174 Stuttgart / Germany
phone ++49 711 121 4118, fax ++49 711 121 3297
michael.cramer@ifp.uni-stuttgart.de

EuroSDR

EuroCOW 2006
Castelldefels, 27-01-2006

Part I

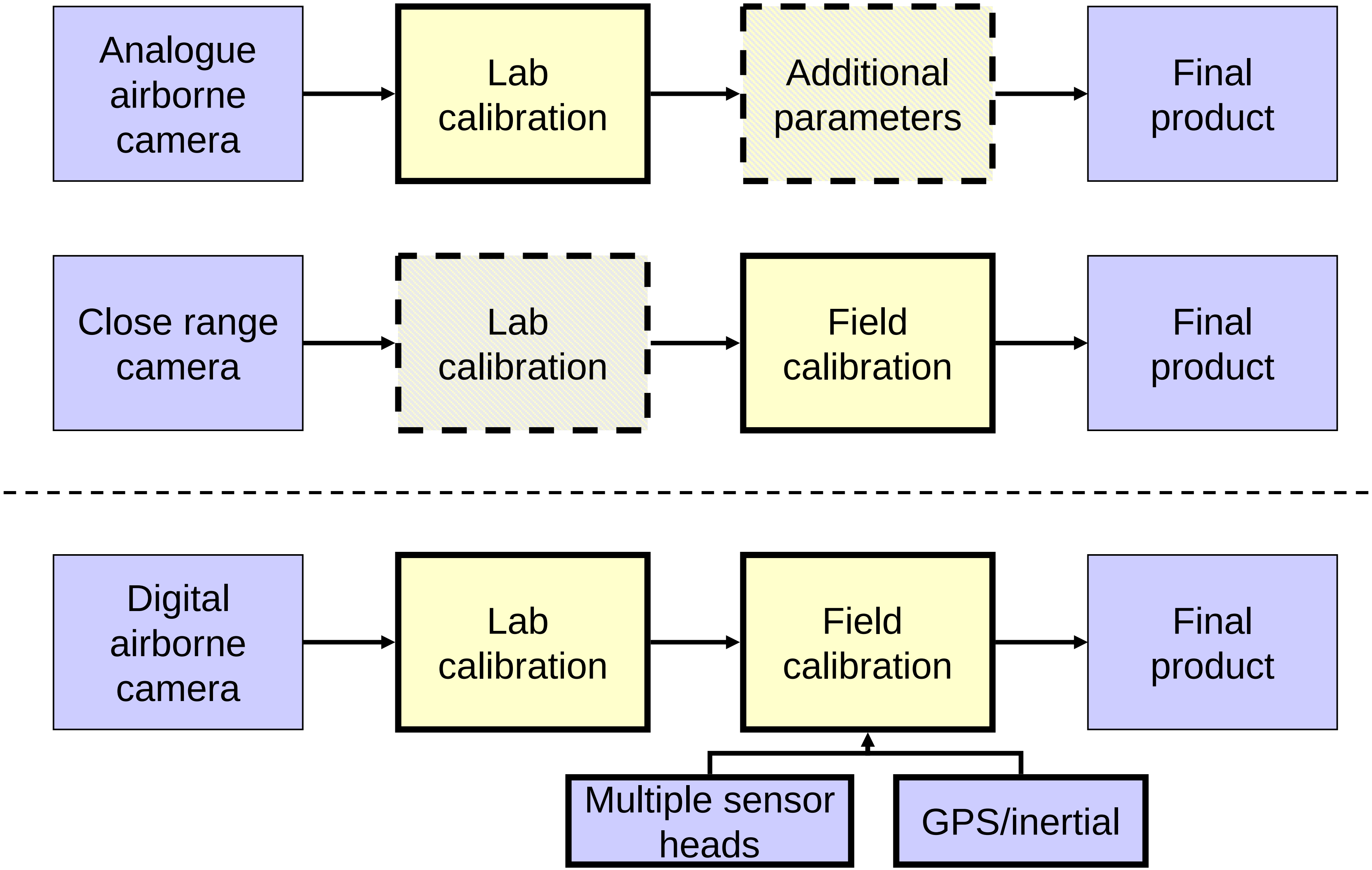


Calibration & Validation of digital airborne cameras

Some remarks on system calibration

“Shifting from traditional to future calibration strategies?”

Calibration steps



Traditional camera lab-calibration

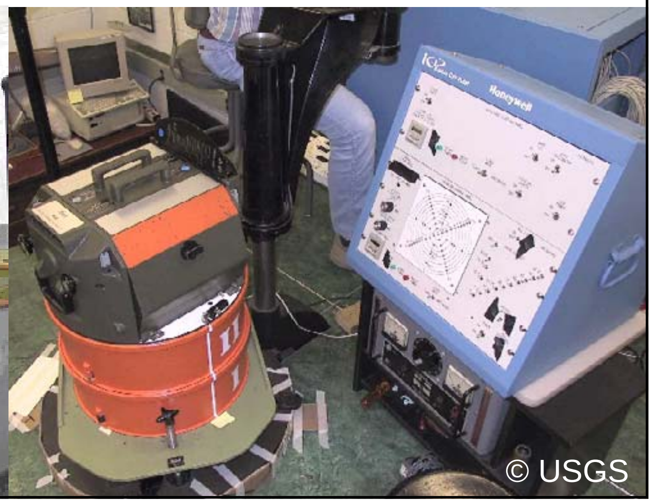

© Zeiss

Goniometer
Zeiss, Oberkochen


CVG Leica, Heerbrugg
© Leica

Multi-collimator
USGS OSL, Reston

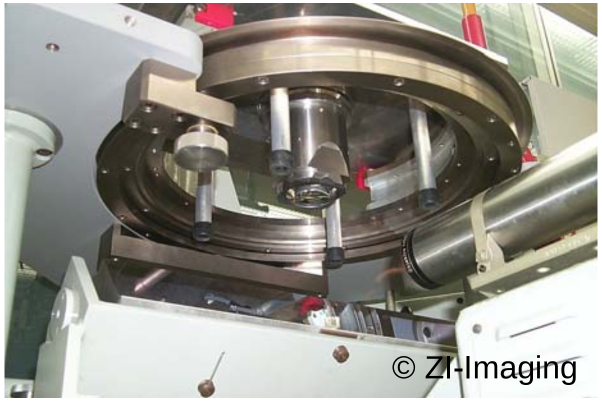

© USGS

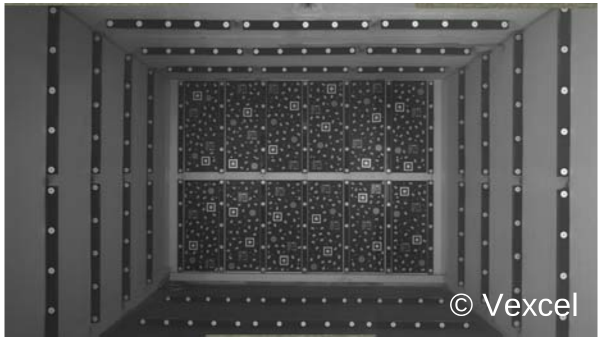

© USGS

Digital airborne sensor calibration

Today's situation

- ADS40
  - Coded vertical goniometer (lab)
  - Calibration flights for self calibration (SC)
    - in future potentially based on SC only
- DMC
  - Goniometer (lab)
    - Calibration for each camera head individually
  - In flight platform calibration via tie point matching
- UltracamD
  - Terrestrial test site calibration (lab) for each camera head
  - In flight relative orientation of cones from tie points

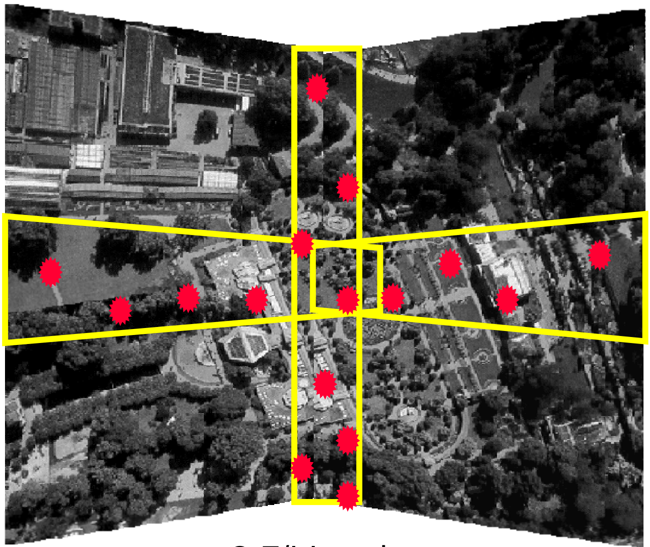




Digital airborne sensor calibration
Virtual image formation

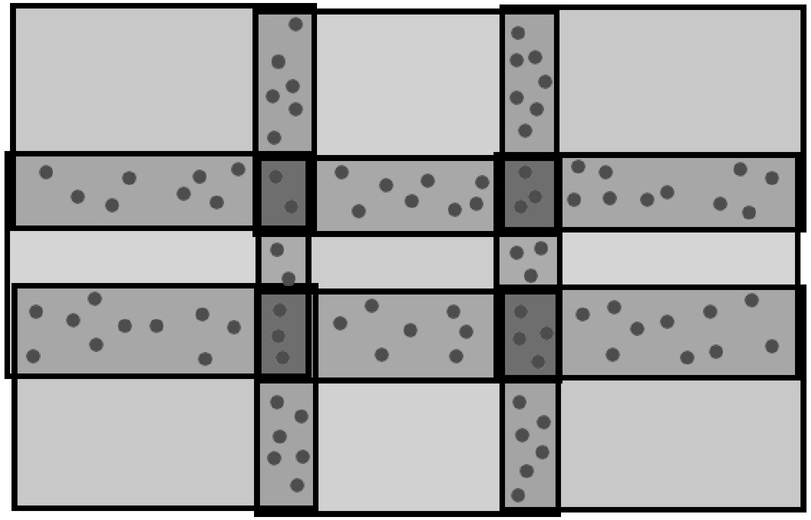
- Virtual large format images formed from individual smaller format images, via tie point matching

Platform calibration (DMC)



© Z/I-Imaging

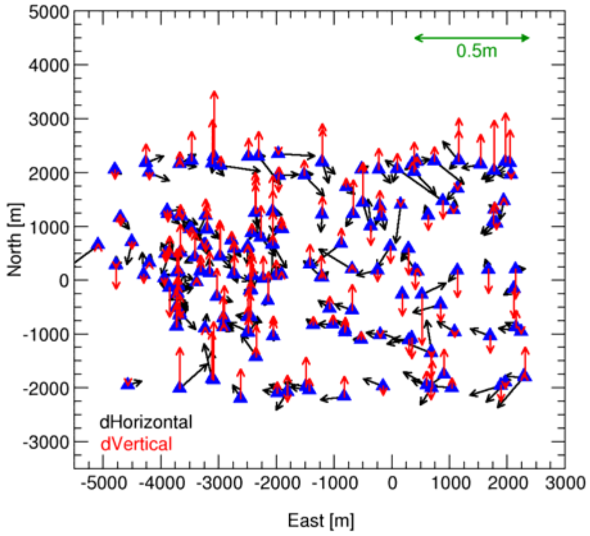
Image stitching (UltracamD)



© Vexcel

- Since calibration parameters are applied, virtual large format images are distortion free (theoretically)

Part II



Calibration & Validation of digital airborne cameras

Empirical performance tests and system validation

"From systems development to operational practice"

ifp
Universität Stuttgart

ifp – Test site Vaihingen/Enz

Universität Stuttgart

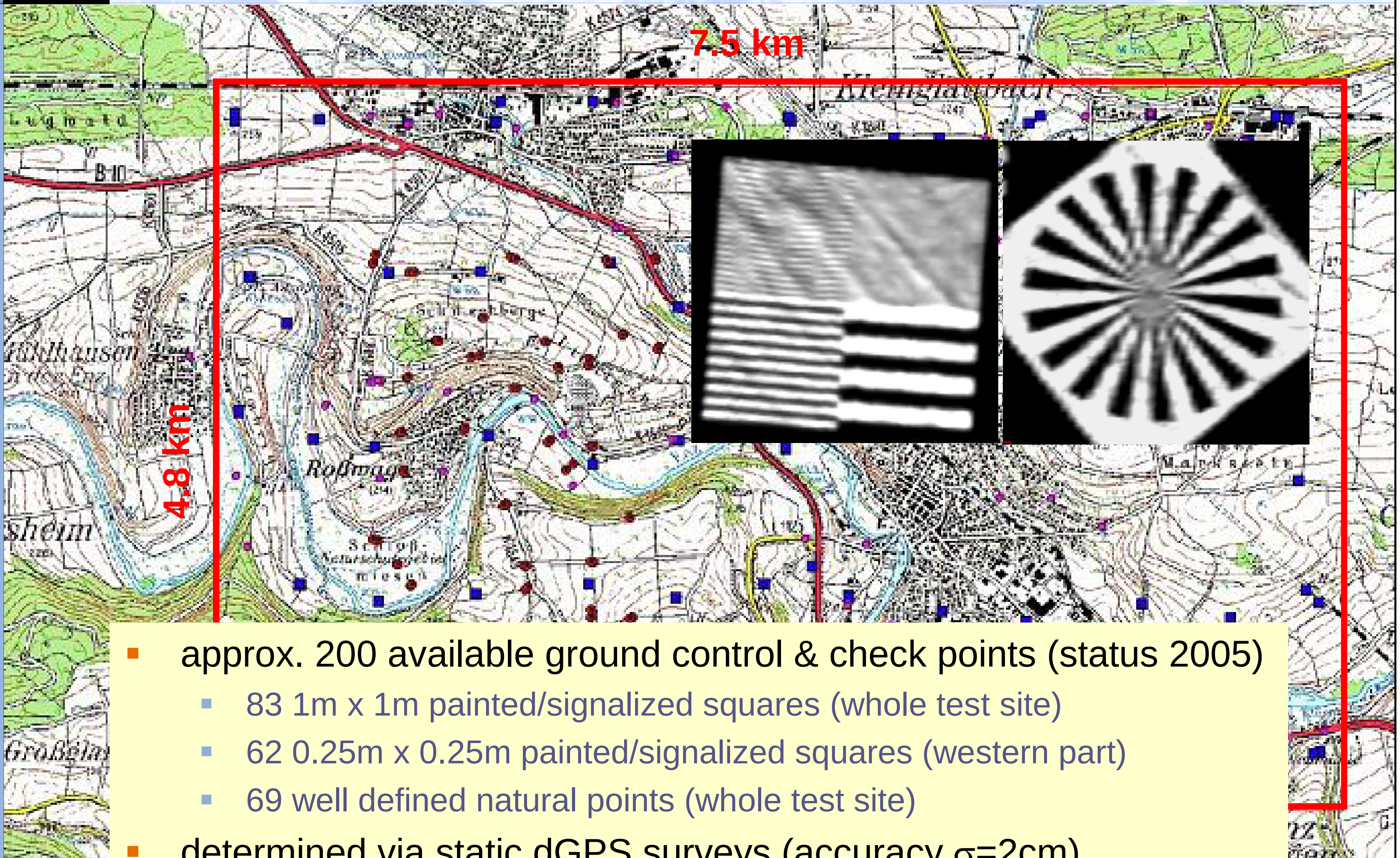
ifp – Test site Vaihingen/Enz

Test site	Date	**Sensor**	GPS/inertial components
Vaihingen/Enz	07/95, 08/96 10/96, 11/98	**DPA**	DPA – system specific
Vaihingen/Enz	11/97	**WAAC**	WAAC – system specific
Vaihingen/Enz	02/98	**HRSC-A**	POS/AV-510 DG, LR86
Vaihingen/Enz	12/98	**RMK-Top15**	POS/AV-510 DG, LR86
Vaihingen/Enz	06/00, 09/02	**RMK-Top15**	AEROcontrol-IId, IMU-IId
Vaihingen/Enz	04/03	**DMC**	POS/AV-510 DG, AIMU
Vaihingen/Enz	06/04	**ADS40**	POS/AV-510 AIMU / LN200, AEROcontrol-IId

ifp

Universität Stuttgart

ifp – Test site Vaihingen/Enz



- approx. 200 available ground control & check points (status 2005)
  - 83 1m x 1m painted/signalized squares (whole test site)
  - 62 0.25m x 0.25m painted/signalized squares (western part)
  - 69 well defined natural points (whole test site)
- determined via static dGPS surveys (accuracy σ=2cm)

ADS40 test set-up

Test June 26, 2004

Aircraft installation

ADS camera head
including different IMUs

POS-AV
AIMU

AEROcontrol
IMU-IId

POS-AV
LN200 (non visible)

ADS40 evaluation

Goals of the test

- Geometric performance test from independent check point analysis using
  - standard Leica AT process flow (orientation fix model (ORIMA/CAP-A))
  - alternative AT processing (direct georeferencing model)
- Influence of different GPS/inertial trajectory performance
  - Post-processed solutions based on standard and alternative IMU input data
  - Integrated GPS/inertial solution based on real-time GPS trajectory
- Effect of trajectory performance on L1 image generation and automatic tie point measurements
- Additional tie point measurements from MS channels
- Influence of self-calibration

📖 results published in ISPRS special issue journal on **Digital Airborne Cameras** (spring 2006)

- Determination and improvement of geometric spatial resolution (📖 Becker et al 2005)
  - Staggered array approach & Pan-sharpening

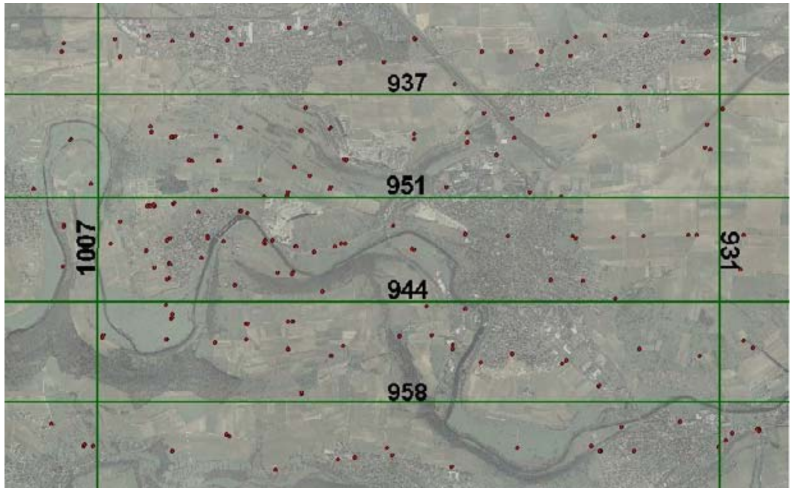
ADS40 performance

The ifp Vaihingen/Enz test campaign

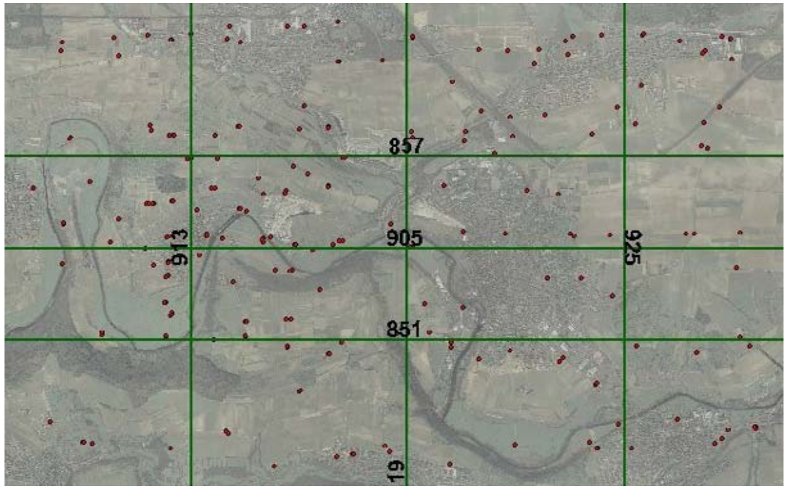
Block configurations (exemplarily, from ADS40 test June 26, 2004)

#	flying height h_g [m]	theor. GSD [m]	# long strips	# cross strips	Side lap % E-W lines	Side lap % N-S lines
1	2500	**0.26**	3	3	70	29
2	1500	**0.18**	4	2	44	-

non-staggered



1500m flight



2500m flight

ifp

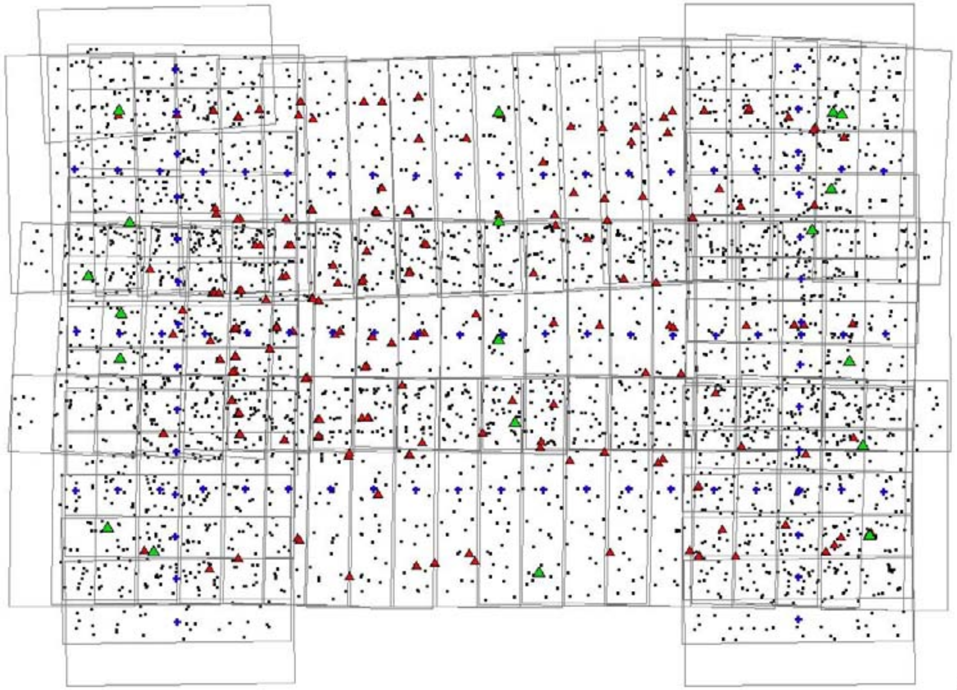
ADS40 performance

The ifp Vaihingen/Enz test campaign

	Configuration	ΔX [m]	ΔY [m]	ΔZ [m]	ΔX Factor	ΔY Factor	ΔZ Factor
RMS 2500m	Theoretical accuracy	0.045	0.046	0.100	-	-	-
	no SC (typical GCP)	0.066	0.065	0.100	1.5	1.4	1.0
	with SC (Brown, typical GCP)	0.064	0.059	0.087	1.4	1.3	0.9
RMS 1500m	Theoretical accuracy	0.035	0.039	0.085	-	-	-
	no SC (typical GCP)	0.052	0.054	0.077	1.5	1.4	0.9
	with SC (Brown, typical GCP)	0.031	0.040	0.057	0.9	1.0	0.7

detailed results/analysis from Vaihingen/Enz ADS40 test published in ISPRS Journal special issue **Digital Airborne Cameras**, Spring 2006

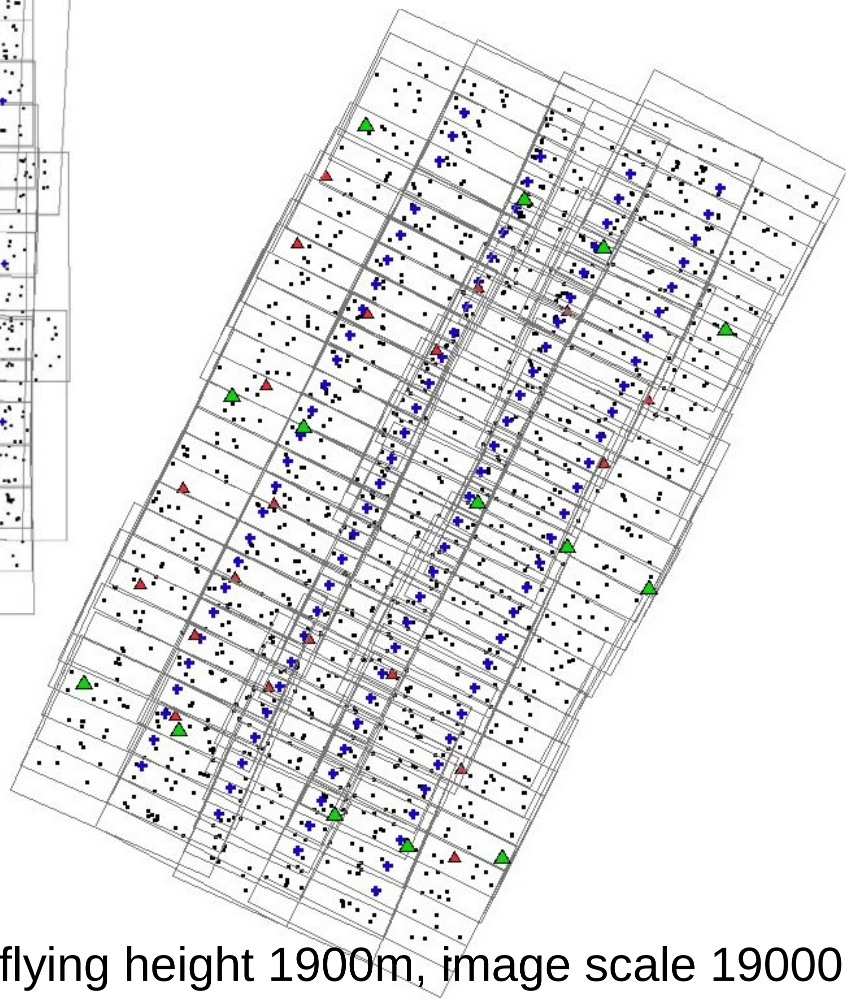
Performance of digital frame sensors
UltracamD & DMC



DMC block

flying height 1500m
image scale 13000
focal length 12cm
GSD **16 x 16 cm²**

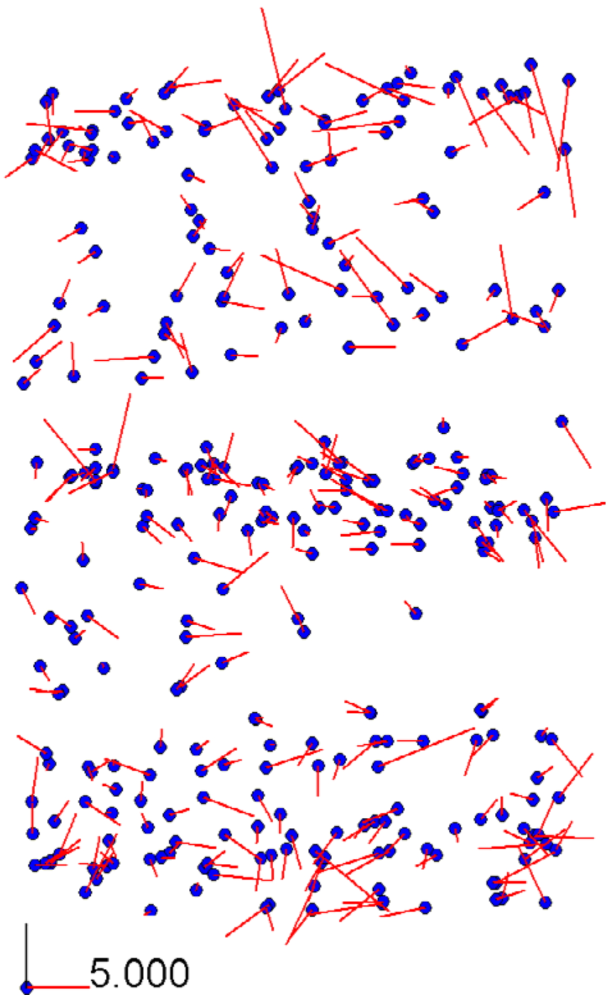
UltracamD block



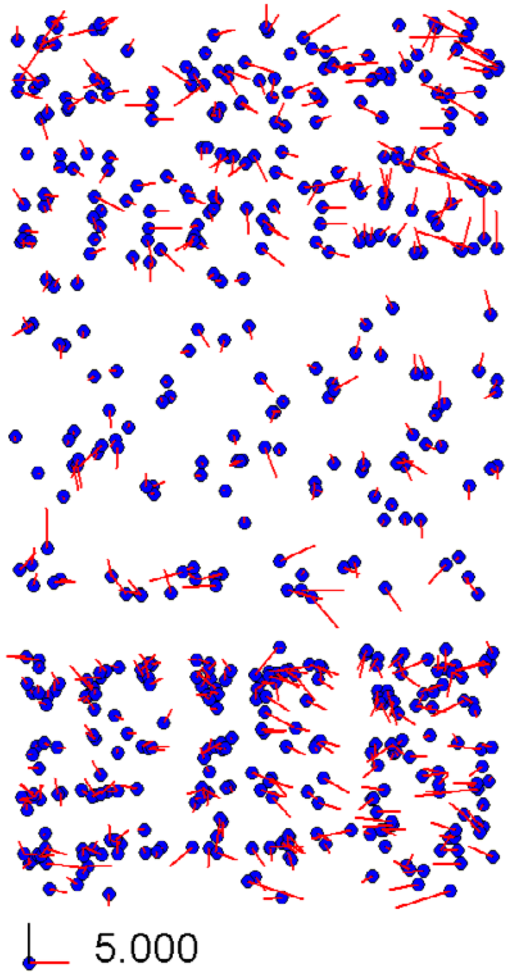
flying height 1900m, image scale 19000
focal length 10cm, GSD **17 x 17 cm²**

Performance of digital frame sensors

UltracamD & DMC



UltracamD residuals

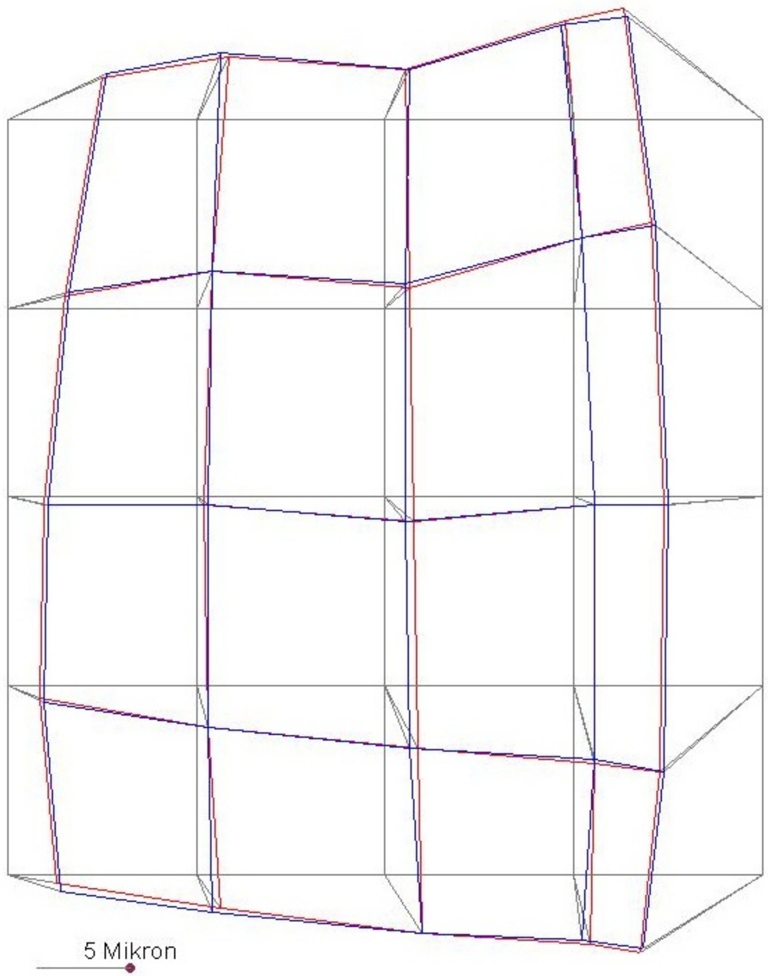


DMC residuals

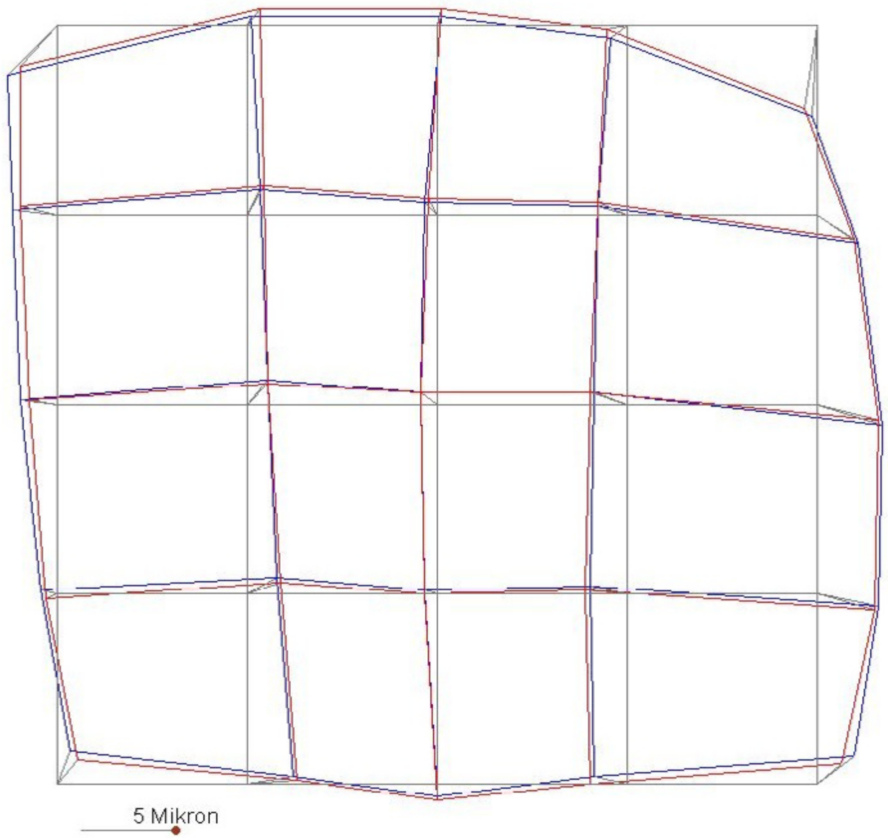
Residuals in image space w/o additional SC

Performance of digital frame sensors
UltracamD & DMC

44 Grün self-calibration parameter
influence in image space



DMC imagery



UltracamD imagery

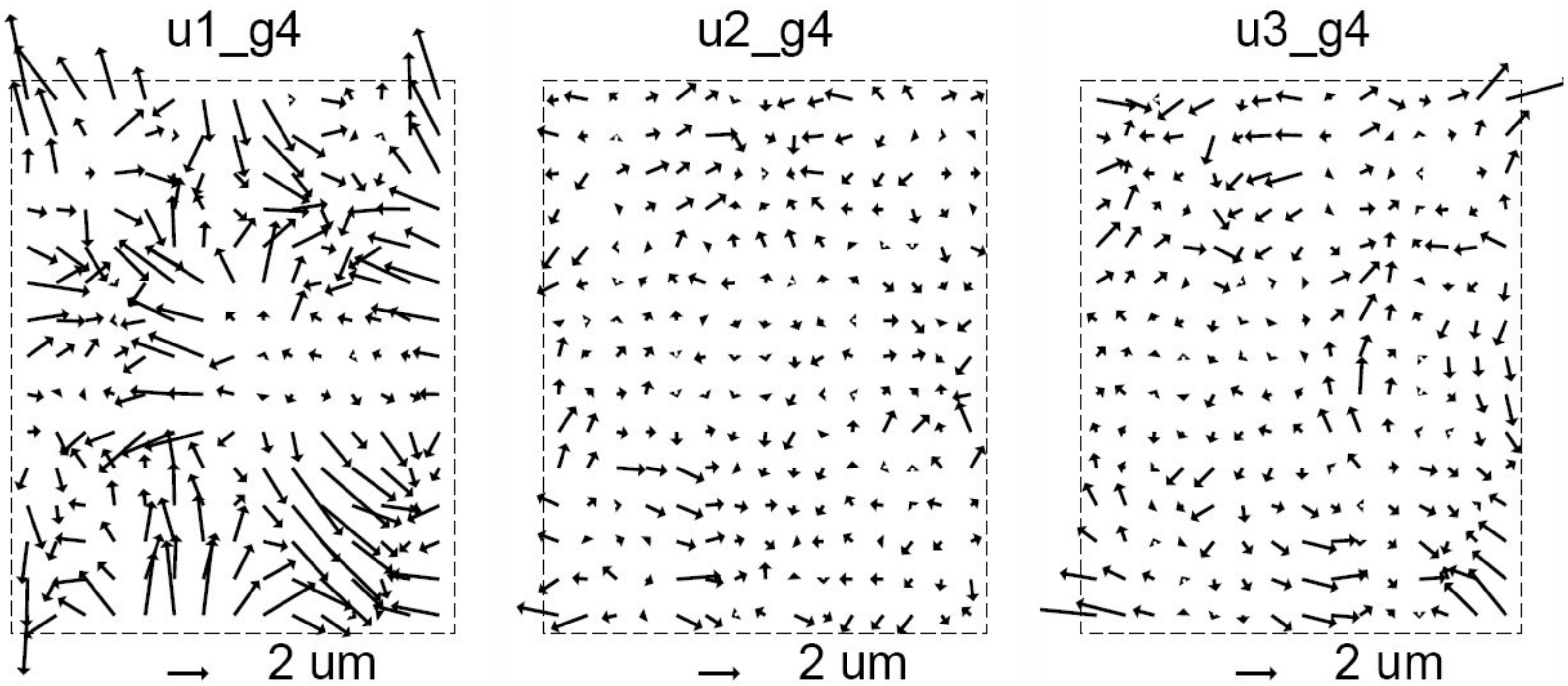
Performance of digital frame sensors

UltracamD & DMC

	Configuration	σ_0	ΔX [m]	ΔY [m]	ΔZ [m]	ΔX Factor	ΔY Factor	ΔZ Factor
DMC RMS	Theoretical accuracy	1.8	0.016	0.019	0.054	-	-	-
	no SC (sparse GCP)	2.3	0.040	0.094	0.136	2.5	5.1	2.5
	with SC (44 params, typical GCP)	1.8	0.023	0.035	0.083	1.5	1.9	1.5
	with SC (44 params, all GCP)	1.8	0.023	0.035	0.078	1.5	1.9	1.4
UltracamD RMS	Theoretical accuracy	1.8	0.028	0.023	0.076	-	-	-
	no SC (sparse GCP)	2.1	0.105	0.043	0.208	3.8	1.8	2.7
	with SC (44 params, typical GCP)	1.8	0.091	0.058	0.193	3.3	2.5	2.5
	with SC (44 params, all GCP)	1.8	0.075	0.051	0.158	2.7	2.2	2.1

UltracamD system validation
Finnish Geodetic Institute

Experiences from empirical tests



Source: Finnish Geodetic Institute FGI
UltracamD performance analysis

ifp

Part III

Calibration & Validation of digital airborne cameras

The EuroSDR network "Digital Camera Calibration"

"Transfer of knowledge and experience"

Project homepage: www.ifp.uni-stuttgart.de/euroSDR

Universität Stuttgart

Road map

Phase 1	Oct ‘03
	Apr ‘04
Phase 2	Jul ‘04
	Jul ‘05

- Official project launch at October 17th, 2003
  - Start collecting publicly available material/experiences with recommendations of camera producers and other experts
- Compilation and distribution of report on currently used practice and methods of digital camera calibration
- Evaluation meeting of core network
- Presentation of results of Phase 1 at 104th EuroSDR meeting Denmark and ISPRS congress Turkey
- Experimental test and investigations
  - Final road map based on results of Phase 1, i.e.
    - testing and development of accepted procedures
    - design for optimal calibration flights
    - geometry, radiometry and image quality
    - stability and repeatability aspects
- Compilation of final report on results of empirical test

EuroSDR camera calibration network

Network members

#	Group	Representatives	#
1	Camera manufacturers	ADS, DIMAC, DMC, DSS, UltracamD, Starimager, 3-DAS-1, DigiCAM, JAS	12
2	Software developers	Bingo, BLUH, ORIMA, inpho	4
3	Other companies	Vito, ISTAR, Geosys, OMC, itacyl	5
4	Science	ETH, OSU, Glasgow, Stuttgart, IdeG, Rostock, DLR, Berlin, Nottingham, DIET	17
5	NMAs	ICC, USGS, OrdSurv, IGN, FGI, NLH, Swedish LandSurvey, Swisstopo, BEV	13
		Σ	51

Objectives

- ***PHASE 1 (finished end of 2004)***

  Collection of publicly available material to compile an extensive report documenting currently used calibration practice and methods

  - All network participants, i.e. camera producers and other experts contribute with their experiences
  - Common knowledge base for the formulation on future strategies
  - Helpful for system users to gain their experience with digital camera calibration
  - Report is open to producers, users and customers

www.ifp.uni-stuttgart.de/EuroSDR/EuroSDR-Phase1-Report.pdf

Objectives

- ***PHASE 2 (starting now)***

  Recommendation/development of commonly accepted procedure(s) for camera systems calibration and experimental testing

  - Focus on some of the technical aspects in a sequential order, i.e. starting with geometrical aspects and verification followed by radiometry
  - Empirical testing should *not* lead to direct comparisons of cameras, but to individual calibration recommendations for each digital camera design

EuroSDR camera calibration network

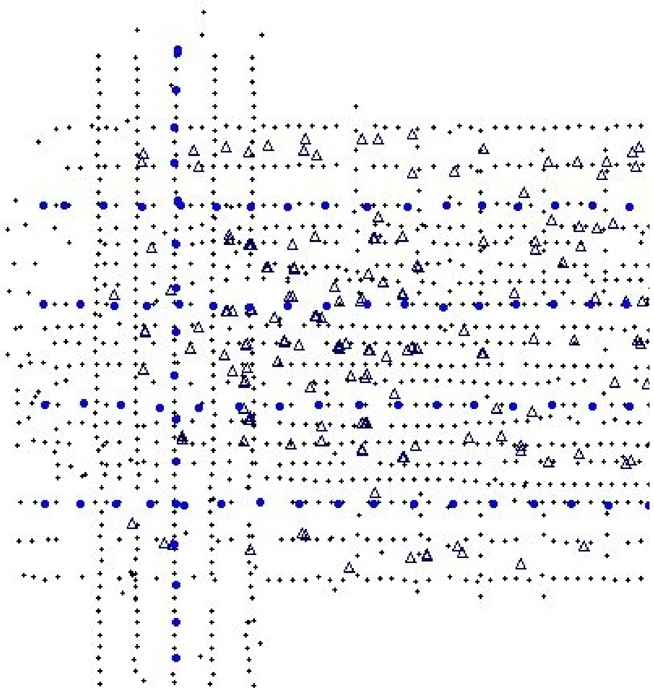
Experimental Phase II data

#	Altitude [m]	GSD [m]	# strips long/cross	% overlap long/side	# Images / Data size [Gb]	Additional data
ADS Testsite: Vaihingen/Enz, June 26, 2004						
1	1500	**0.18**	4 / 2	100 / 44	36 / 16.7	GPS/INS
2	2500	**0.26**	3 / 3	100 / 70	36 / 9.8	GPS/INS
DMC Testsite: Fredrikstad, October 10, 2003						
1	950	**0.08**	5	60 / 30	115 / 10.0	-
2	1800	**0.15**	3	60 / 30	34 / 2.9	-
UltracamD Testsite: Fredrikstad, September 16, 2004						
1	1900	**0.17**	4 / 1	80 / 60	131 / 30.6	GPS/INS
2	3800	**0.34**	2	80 / 60	28 / 6.5	GPS/INS

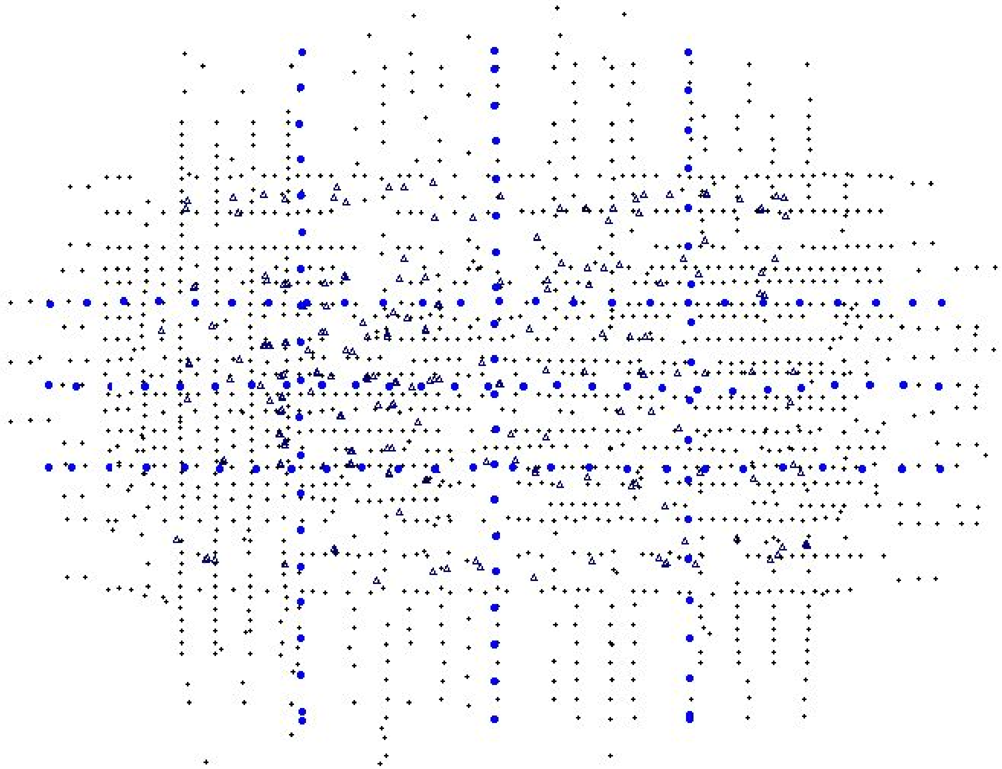
EuroSDR camera calibration network

Phase II data

ADS Testsite: Vaihingen/Enz, June 26, 2004



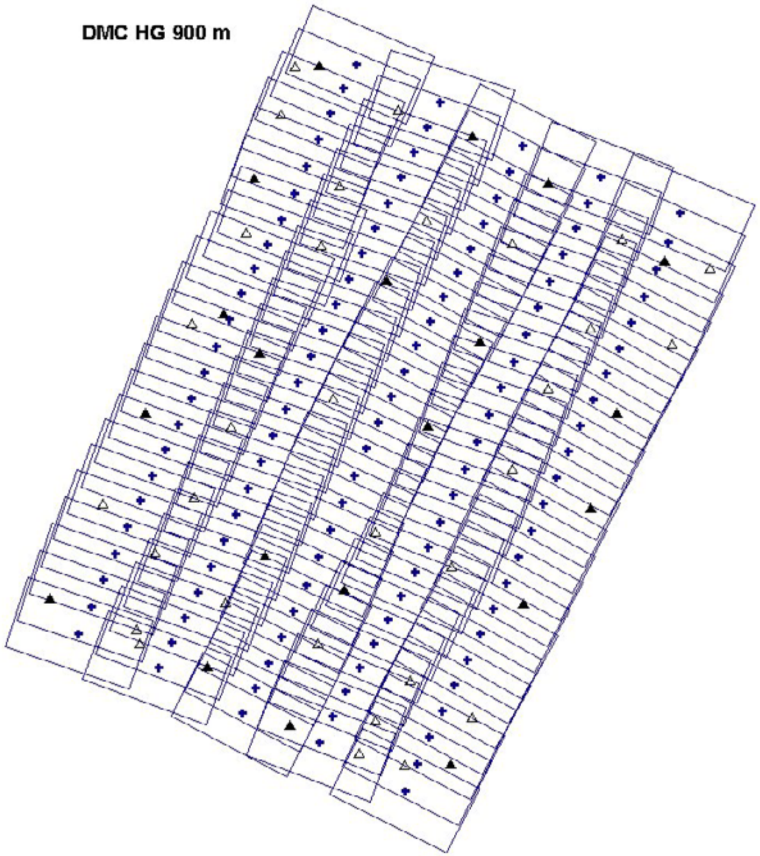
1500m block



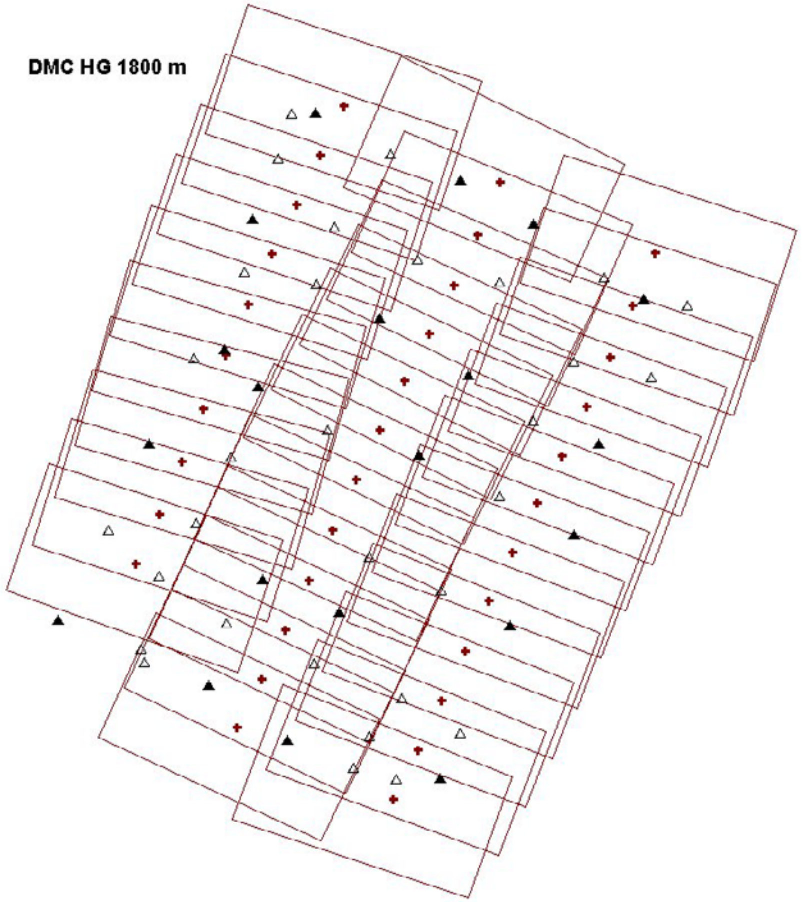
2500m block

EuroSDR camera calibration network
Phase II data

DMC Testsite: Fredrikstad, October 10, 2003

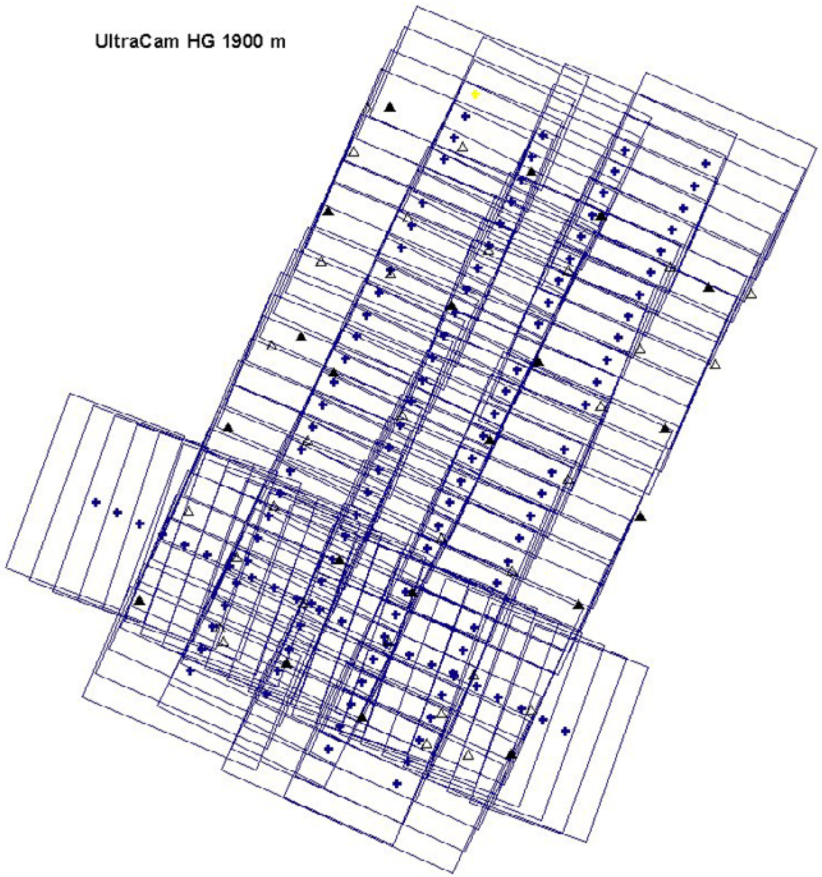


950m block

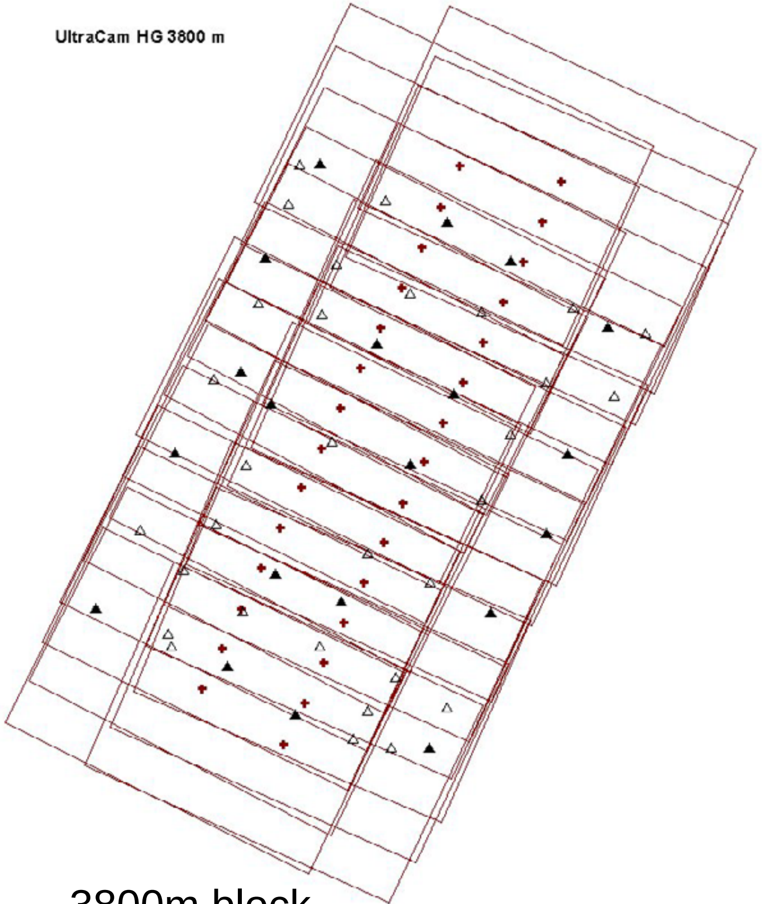


1800m block

UltracamD Testsite: Fredrikstad, September 16, 2004



1900m block



3800m block

EuroSDR camera calibration network
Phase II organization

Universität Stuttgart

ifp

- What does pilot centre **provide** to participants ?
  - Image data (PAN first) – only one data set in first round
  - sufficient number of GCP/ChP coordinates, remaining ChP only with approx. coordinates (to speed up measurement process)
  - EO values (from GPS/inertial or approx. values from a priori adjustment)
  - GCP and ChP sketches

- What does pilot centre **expect** from participants ?
  - results from AT, including list of ChP **object coordinates**, the optimal result has to be marked
  - brief **report** on evaluation strategy, i.e.
    - different flying heights used separately or in combined approach
    - additional parameter sets, used models
  - general experiences / recommendations from **this** and **other data sets** obtained so far

EuroSDR camera calibration network
Phase II organization

- What will pilot centre **derive** from participants input ?
  - compilation of comprehensive report
    - technical part
      - documentation of experimental phase 2 results
      - comparison of camera specific results
      - analogies in evaluation strategies and modeling
    - further experiences based on individual users input
    - derivation of recommendations for „optimal“ camera specific processing work flow
    - How to consider calibration parameters in later processing ?
  - official publication in conference proceedings and / or journal in close cooperation with network participants

- And what is coming next ?
  - Design of potential second experimental round
    - alternative data sets
    - focus on other aspects: radiometry, color, resolution, …

EuroSDR camera calibration network

Phase II schedule

Activity		Relative Time	**Absolute Time**
Pilot Centre	Official announcement of data availability		**Feb. 14**
Participant	Request of **one** data set	+ 1 week	**Feb. 21**
Pilot Centre & Participant	Start of distribution of data discs via land mail chain	+ 1 week	**Feb. 28**
Participant	Receivement of data	+ 2 weeks	**Mar. 15**
Participant	Processing of data	+ 6 weeks	**Apr. 30**
Participant	Individual report	+ 2 weeks	**May 14**
Pilot Centre	Analysis of results, Report (1^{st} version)	+ 4 weeks	**Jun. 14**

Thanks for your attention

Any remarks and comments are welcome !

All interesting people are cordially invited to actively participate within the second phase of this EuroSDR project !

Please let me know:
michael.cramer@ifp.uni-stuttgart.de