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The EuroSDR Performance Test for Digital Aerial Camera Systems

EuroSDR network on Digital Camera Calibration and Validation

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The EuroSDR Calibration network

EuroSDR Network on Digital Camera Calibration and Validation

#	Group	Institutions / Systems	#
1	Camera manufacturers	ADS, DIMAC, DMC, DSS, Ultracam, Starimager, 3-DAS-1, DigiCAM	12
2	AT software developers	BLUH, ORIMA, inpho, dgap, CSIRO	5
3	Other companies	Vito, ISTAR, Geosys, OMC, stereocarto	5
4	Science	ETH, OSU, Glasgow, Stuttgart (2x), IdeG, Rostock, DLR (2x), Berlin, Nottingham, Aas, Pavia, Leon	29
5	NMCAs	ICC, USGS, OrdSurv, IGN, FGI, Lantmäteriet, Swisstopo, BEV, ICV, itacyl	13
		$\sum$ representatives	64

Objectives

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

  Collection of publicly available material to compile an extensive report documenting currently used calibration practices

  - All network participants [illegible] with their [illegible]
  - [illegible] formulation on future strategies
  - [illegible] system users to gain their knowledge in digital camera calibration
  - Report is open to system suppliers, users and customers

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

- *empirical **PHASE 2** (finished end of 2006)*

  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
  - **Empirical testing should not lead to direct comparisons of cameras, but to individual calibration recommendations for each digital camera design**

  Empirical phase 2 extended to **Phase 2b** (finished May 2007)

The EuroSDR Calibration network

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Network Digital Camera Calibration

The empirical test flight data

Experimental Phase 2 data

The empirical test flight data

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#	Altitude [m]	GSD [m]	# strips long/cross	% overlap long/cross	# Images	Additional data
ADS Vaihingen/Enz, June 26, 2004						
low	1500	0.18	4 / 2	100 / 44	36	GPS/INS
high	2500	0.26	3 / 3	100 / 70	36	GPS/INS
DMC Fredrikstad, October 10, 2003						**Phase 2b**
low	950	0.10	5	60 / 30	115	n.a.
high	1800	0.18	3	60 / 30	34	n.a.
UltracamD Fredrikstad, September 16, 2004						
low	1900	0.17	4 / 1	80 / 60	131	GPS
high	3800	0.34	2	80 / 60	28	GPS

DMC and UCD flights

Frederikstad image block geometry

The empirical test flight data

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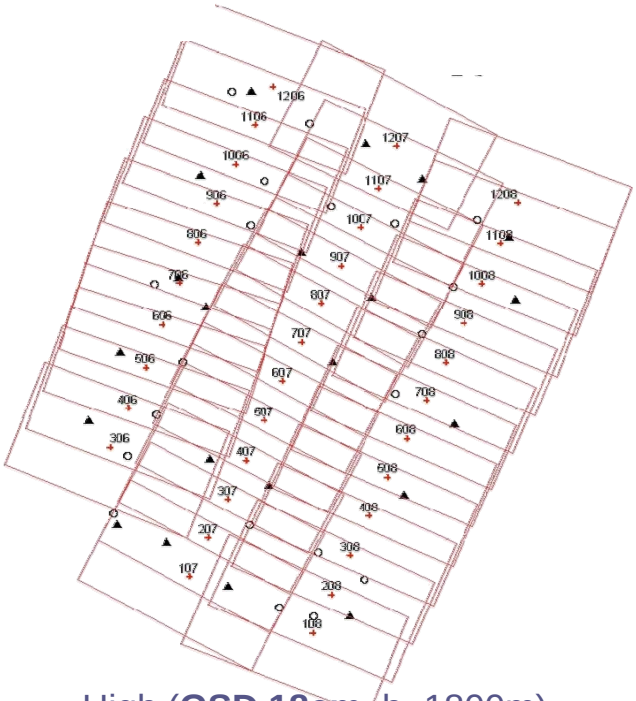
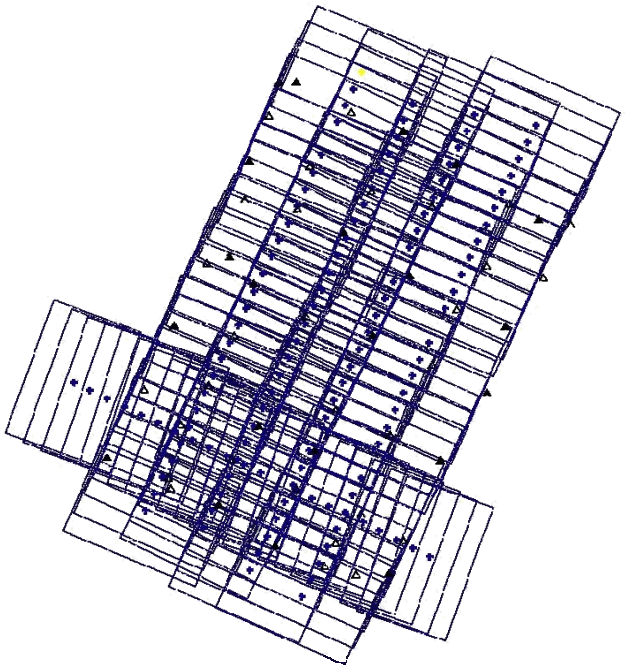
DMC October 10, 2003



High (**GSD 18cm**, h=1800m)

UCD September 16, 2004



Low (**GSD 17cm**, h=1900m)

DMC and UCD flights

Image quality and point measurements

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The empirical test flight data

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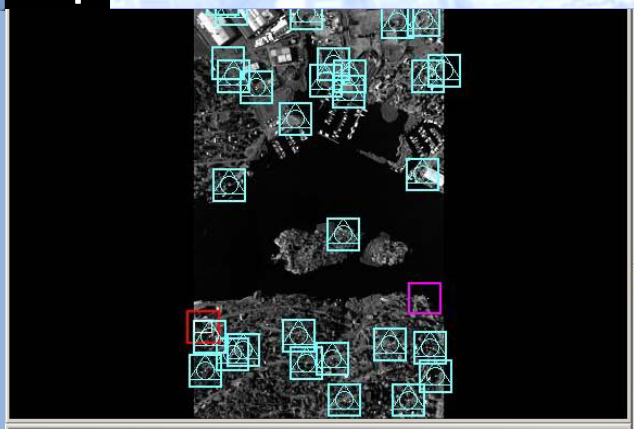
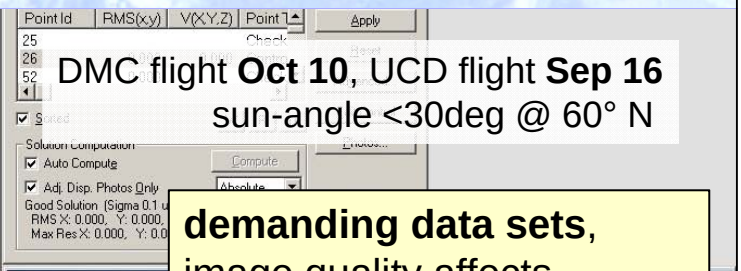
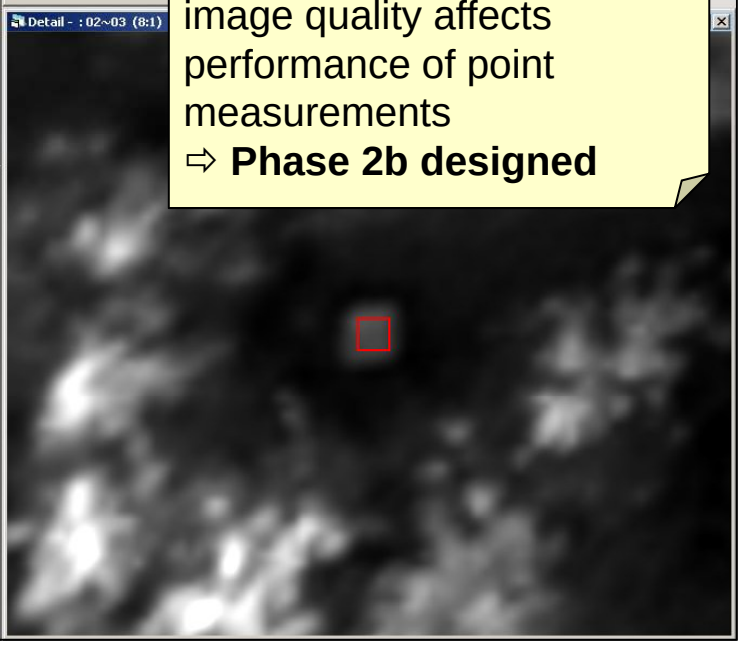




DMC flight **Oct 10**, UCD flight **Sep 16**
sun-angle <30deg @ 60° N



demanding data sets, image quality affects performance of point measurements
⇨ **Phase 2b designed**

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Network Digital Camera Calibration

The results

Phase 2 / 2b
Evaluated data sets

Phase 2 Data Set	# Results	Participants
ADS	3	UoP, DLR-B, ETH
DMC	6	ICC, IPI, inpho, HfT, LM, Ingr.ZI
UltracamD	5	UoN, IPI, itacyl, inpho, CSIRO

77 different versions (Phase 2) evaluated

Phase 2b Data Set	# Results	Participants
DMC	5	ICC, IPI, CSIRO, ETH, Ingr.ZI
UltracamD	4	IPI, CSIRO, ETH, Vexcel

80 different versions (Phase 2b) evaluated

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The test flight results
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General remarks on data processing (1/2)

- typically the two different flight heights processed independently, only few participants used both heights for common adjustment
- standard and proprietary software packages used

Process step	Software
Matching and point measurement (only for Phase 2)	Manual, MATCH-AT, LPS, ISAT, GPro, PhotoMod, others
Bundle adjustment	Match-AT, ORIMA, InBlock, BLUH, Bingo, PhotoMod, ACX-Geotex, IS-PhotoT, others

General remarks on data processing (2/2)

- Self-calibration was applied in general,
- but additionally almost each participant also provided solution w/o use of additional SC
- some participants used modified SC approaches taking the specific image geometry of large format DMC / UCD imagery into account

Data set	Self-calibration parameter set (if applied)
DMC	Ebner, Grün, Polynom, BLUH parameters Ebner / Grün per quadrant, BLUH DMC specific
UCD	Brown, Grün, BLUH parameters Ebner / Grün per image patch, BLUH UCD specific
ADS	Brown (with some extensions)

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The ADS results

Phase 2 – ADS
ifp solution

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The test flight results

Flight	GSD [m] *non-stag.*	Self calibration	RMS		
			X [m]	Y [m]	Z [m]
ADS low	0.18	**not applied**	0.052	0.054	0.077
ADS low	0.18	**applied**	0.031	0.040	0.057

- RMS values from 190 check point differences
- Results obtained from standard Leica processing software
  - ORIMA bundle adjustment, 12 GCPs used
  - self calibration (if applied) based on Brown parameters

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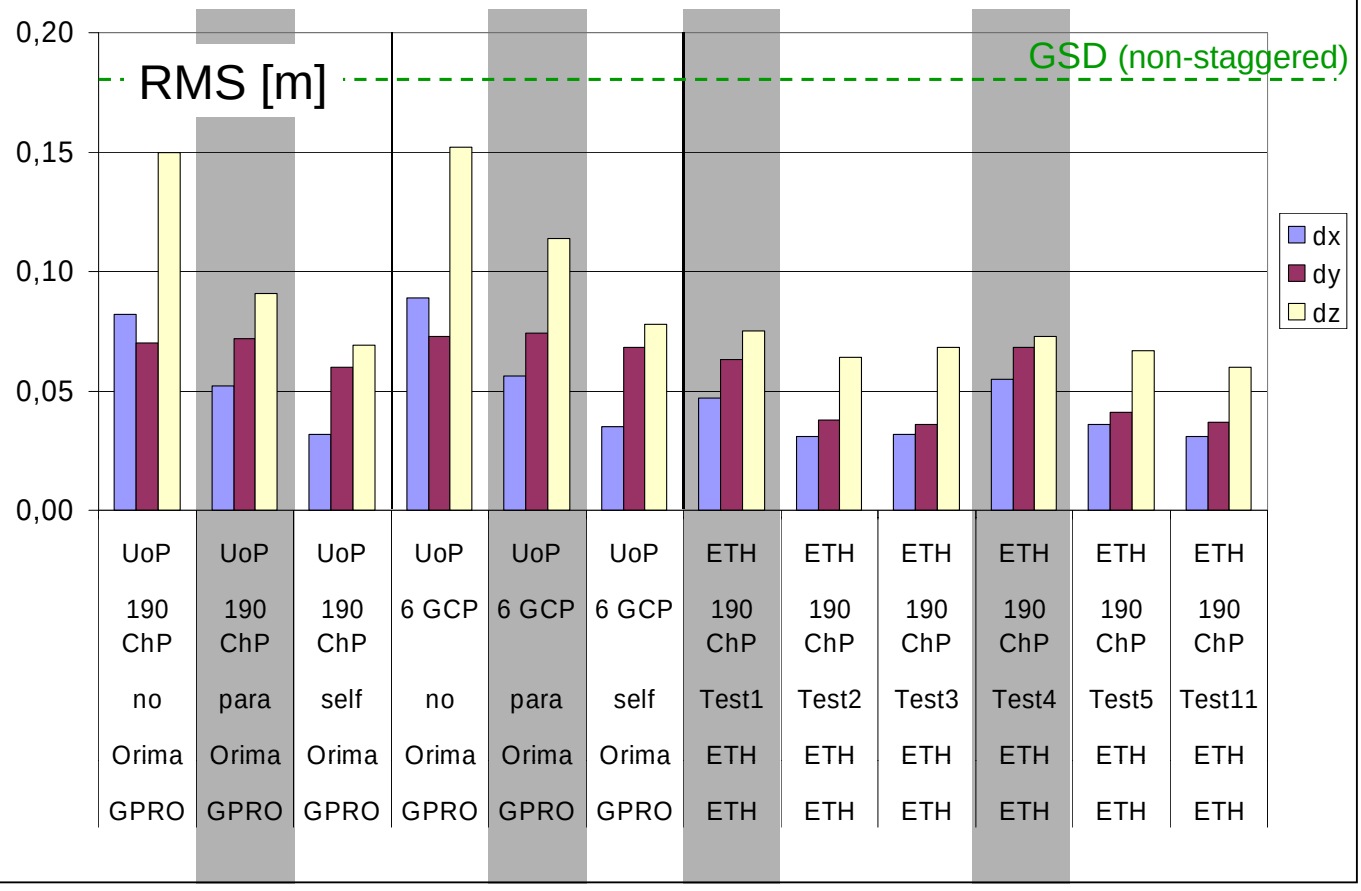
The test flight results

ADS low
h_g 1500m, GSD 0.18m *non-staggered*

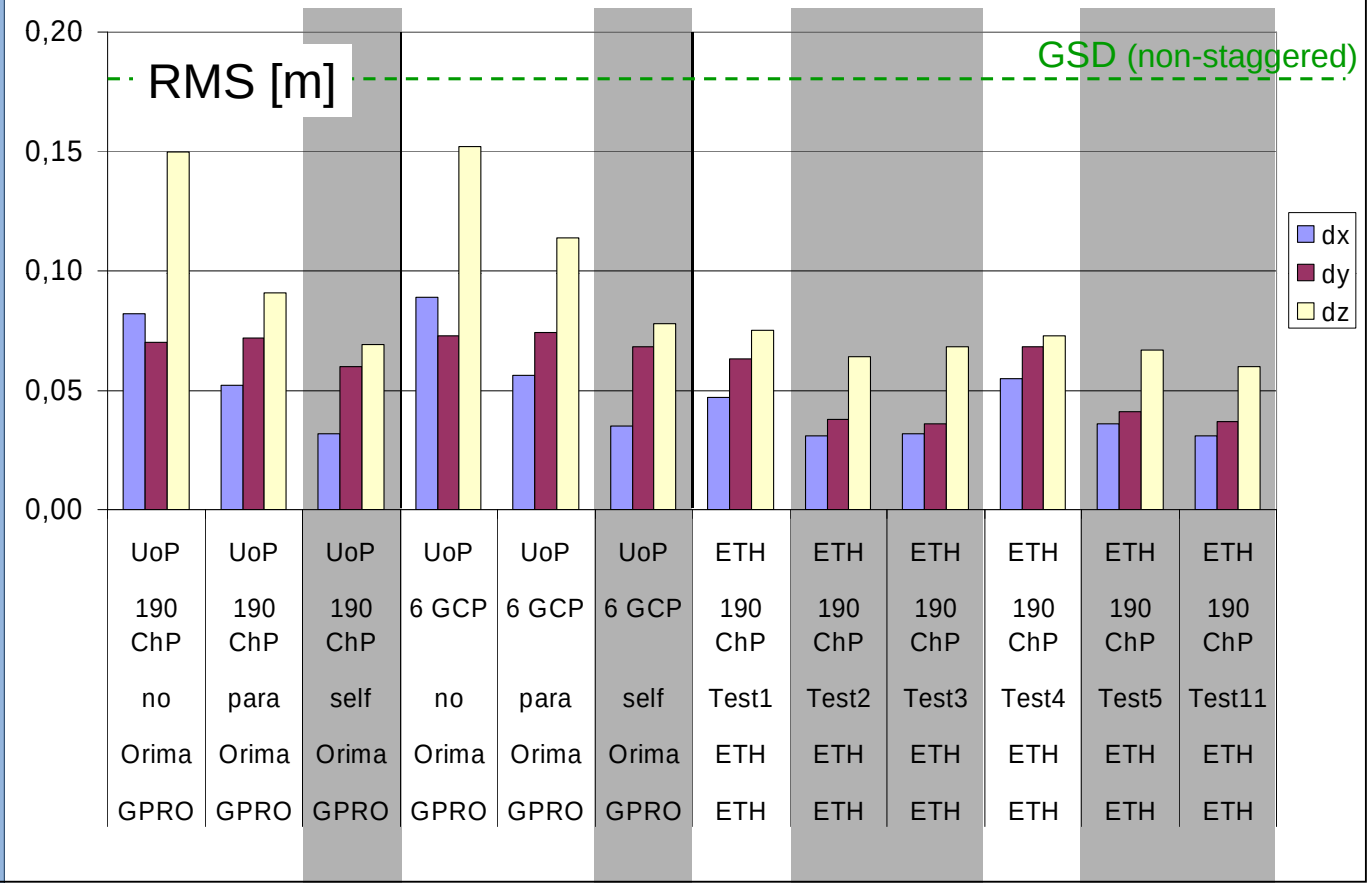
No SC



ADS low

h_g 1500m, GSD 0.18m non-staggered

with SC



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The test flight results

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The DMC & UCD results

(Phase 2b only)

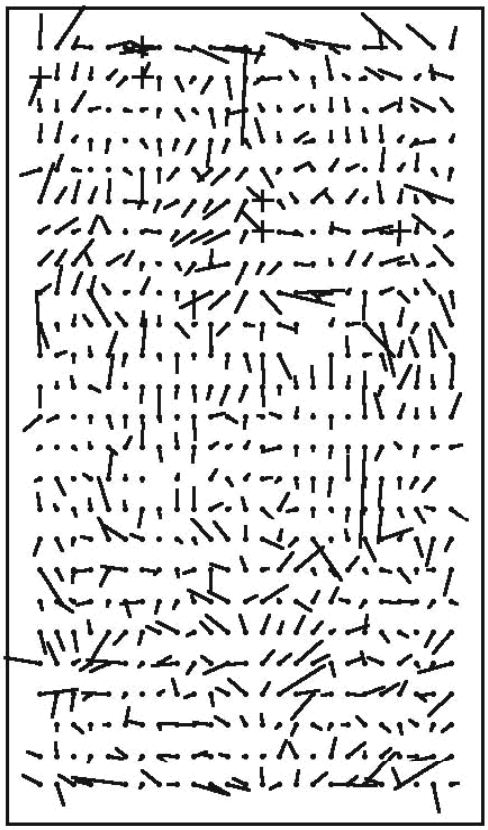
Phase 2b – DMC & UCD
ifp solutions

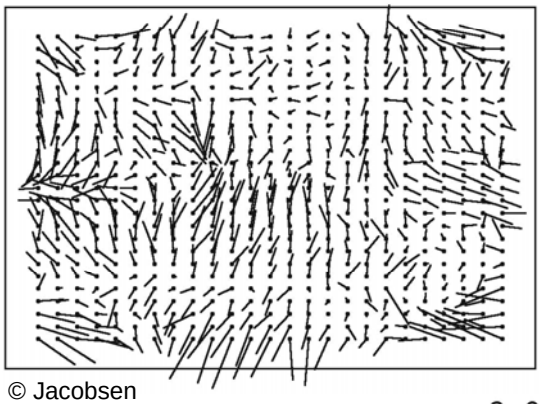
Flight	H [m]	GSD [m]	RMS		
			X [m]	Y [m]	Z [m]
DMC	1800	0.18	0.048	0.047	0.116
UCD	1900	0.17	0.076	0.060	0.059

- RMS values from check point differences
- in all cases **44 significant Gruen parameters** introduced, from all available ground points (GCPs and ChPs)
- Input std.dev. used for weighting:
  - image points 3um
  - GCPs 2cm

Image coordinate residuals AT without add. params

DMC





UCD 3.0

Overlay of residuals from both flying heights (low & high)

Phase 2b – DMC high

GSD 0.18m, h_g 1800m

No SC

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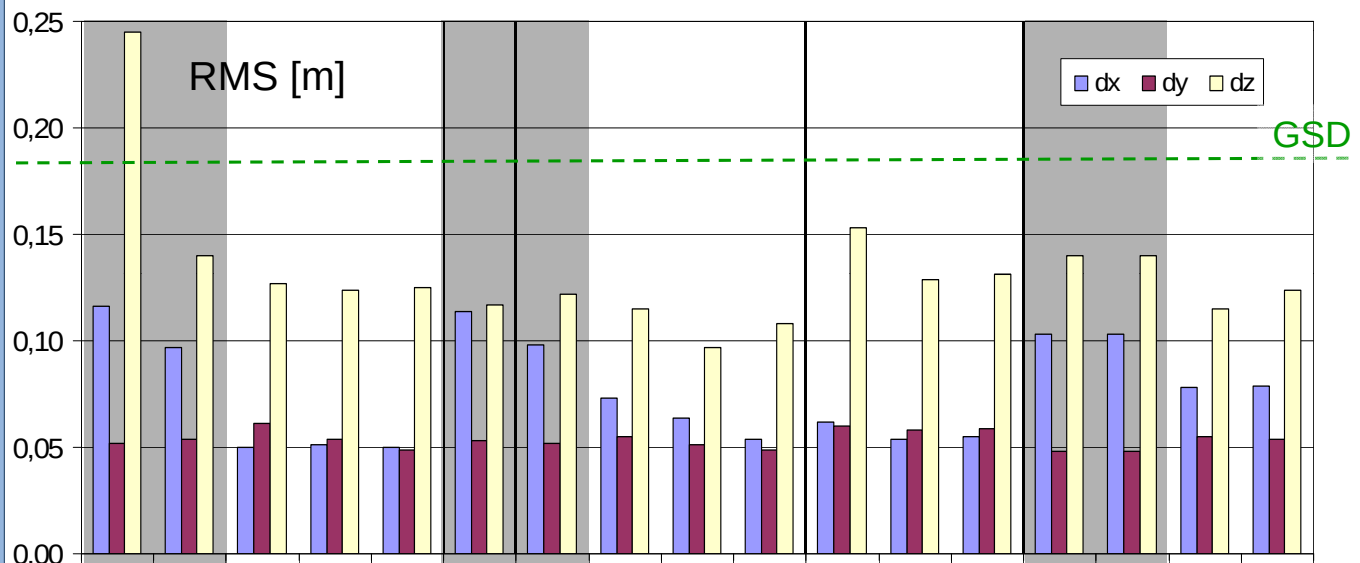

	ETH	ETH	ETH	ETH	ETH	CSIRO	IPI	IPI	IPI	IPI	ICC	ICC	ICC	IngrZI	IngrZI	IngrZI	IngrZI
	no	no	Ebner V0	Ebner V4	Gruen V0	no	no	par1-12	par1-12, 79-80	par1-12,30-	12 per quad.	12 per quad.	12 per quad.	no	no	Ebner	Ebner
	ETH	ETH	ETH	ETH	ETH	CSIRO	BLUH	BLUH	BLUH	BLUH	ACX	ACX	ACX	IngrZI	IngrZI	IngrZI	IngrZI
STD [m] GCPs.	0.01	0.02	0.02	0.02	0.02		0.04	0.04	0.04	0.04	0.05	0.025	0.025	0.1	0.08	0.1	0.08
	0.01	0.02	0.02	0.02	0.02		0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.1	0.06	0.1	0.06
STD [um] Image pts.	3,6	3	3	3	3		3	3	3	3	6	2,5	5	5	3	5	3
	1,2	3	3	3	3		3	3	3	3	2	2	5	5	3	5	3

Phase 2b – DMC high

GSD 0.18m, h_g 1800m

Standard params

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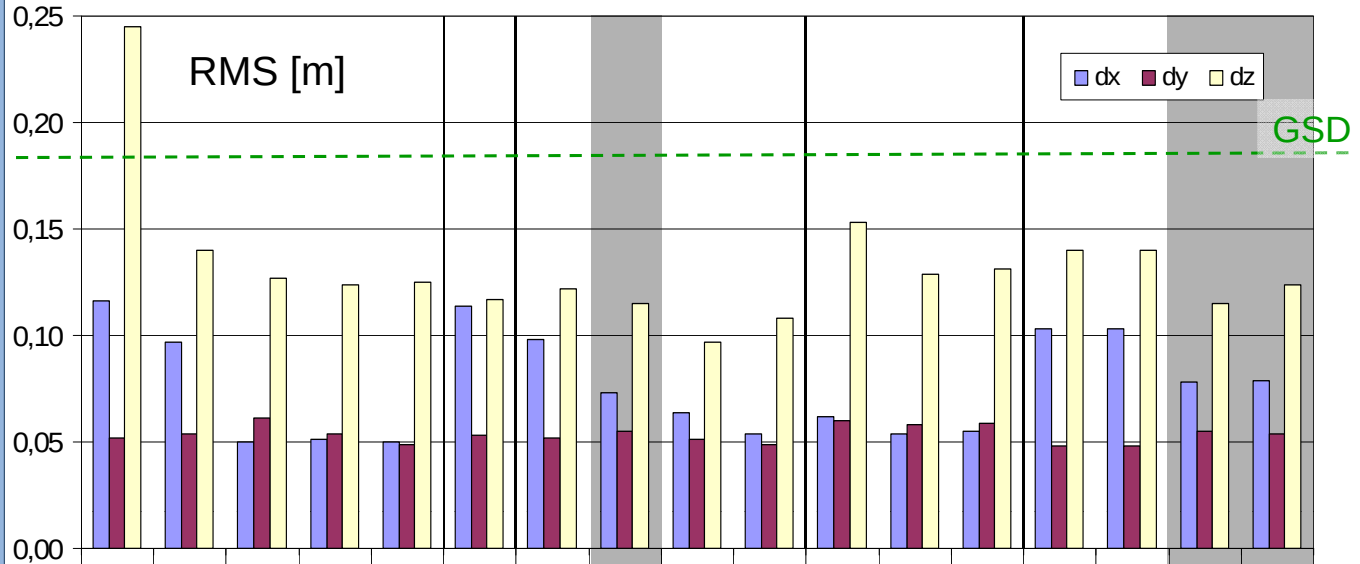

	ETH	ETH	ETH	ETH	ETH	CSIRO	IPI	IPI	IPI	IPI	ICC	ICC	ICC	IngrZI	IngrZI	IngrZI	IngrZI
	no	no	Ebner V0	Ebner V4	Gruen V0	no	no	par1-12	par1-12, 79-80	par1-12,30-	12 per quad.	12 per quad.	12 per quad.	no	no	Ebner	Ebner
	ETH	ETH	ETH	ETH	ETH	CSIRO	BLUH	BLUH	BLUH	BLUH	ACX	ACX	ACX	IngrZI	IngrZI	IngrZI	IngrZI
STD [m] GCPs.	0.01	0.02	0.02	0.02	0.02		0.04	0.04	0.04	0.04	0.05	0.025	0.025	0.1	0.08	0.1	0.08
	0.01	0.02	0.02	0.02	0.02		0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.1	0.06	0.1	0.06
STD [um] Image pts.	3,6	3	3	3	3		3	3	3	3	6	2,5	5	5	3	5	3
	1,2	3	3	3	3		3	3	3	3	2	2	5	5	3	5	3

Phase 2b – DMC high

GSD 0.18m, h_g 1800m

DMC params

The test flight results

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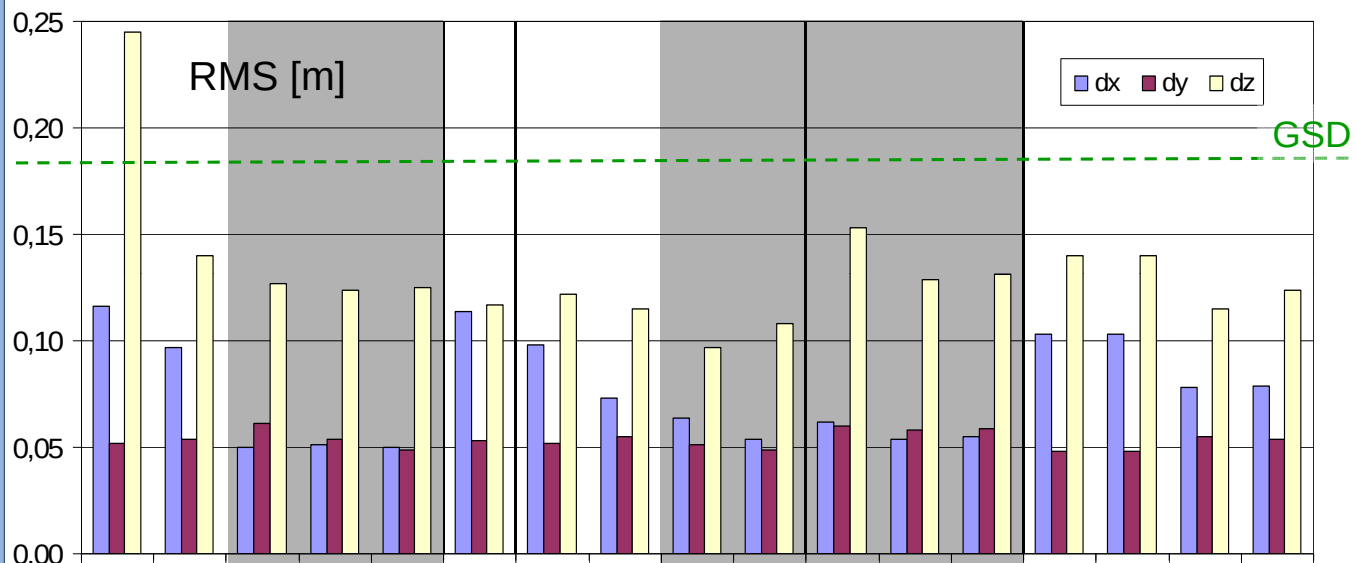

	ETH	ETH	ETH	ETH	ETH	CSIRO	IPI	IPI	IPI	IPI	ICC	ICC	ICC	IngrZI	IngrZI	IngrZI	IngrZI
	no	no	Ebner V0	Ebner V4	Gruen V0	no	no	par1-12	par1-12, 79-80	par1-12,30-	12 per quad.	12 per quad.	12 per quad.	no	no	Ebner	Ebner
	ETH	ETH	ETH	ETH	ETH	CSIRO	BLUH	BLUH	BLUH	BLUH	ACX	ACX	ACX	IngrZI	IngrZI	IngrZI	IngrZI
STD [m] GCPs.	0.01	0.02	0.02	0.02	0.02		0.04	0.04	0.04	0.04	0.05	0.025	0.025	0.1	0.08	0.1	0.08
	0.01	0.02	0.02	0.02	0.02		0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.1	0.06	0.1	0.06
STD [um] Image pts.	3,6	3	3	3	3		3	3	3	3	6	2,5	5	5	3	5	3
	1,2	3	3	3	3		3	3	3	3	2	2	5	5	3	5	3

Phase 2b – UCD low

GSD 0.17m, h_g 1900m

No SC

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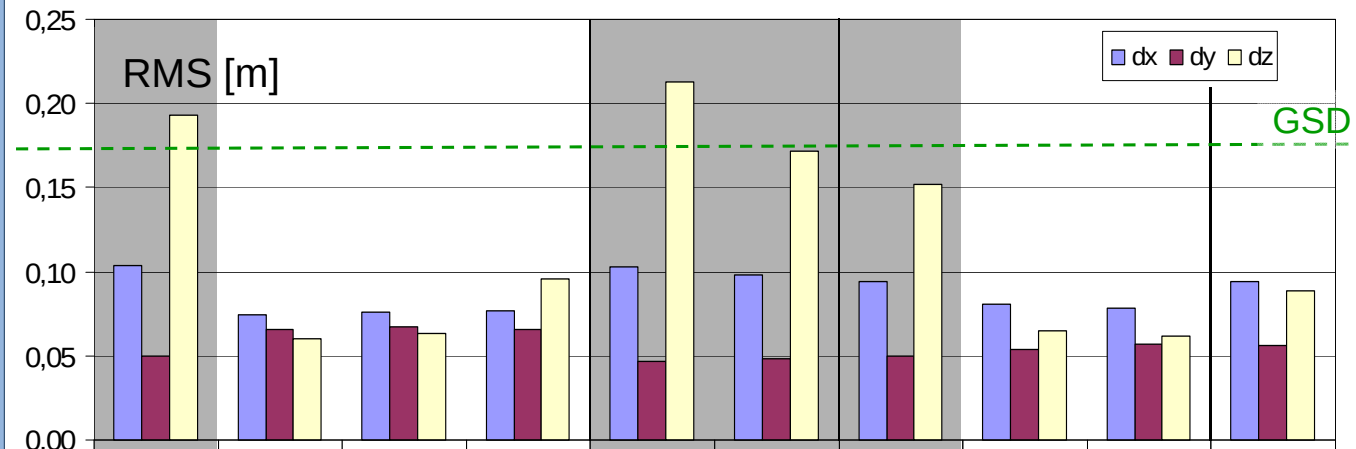
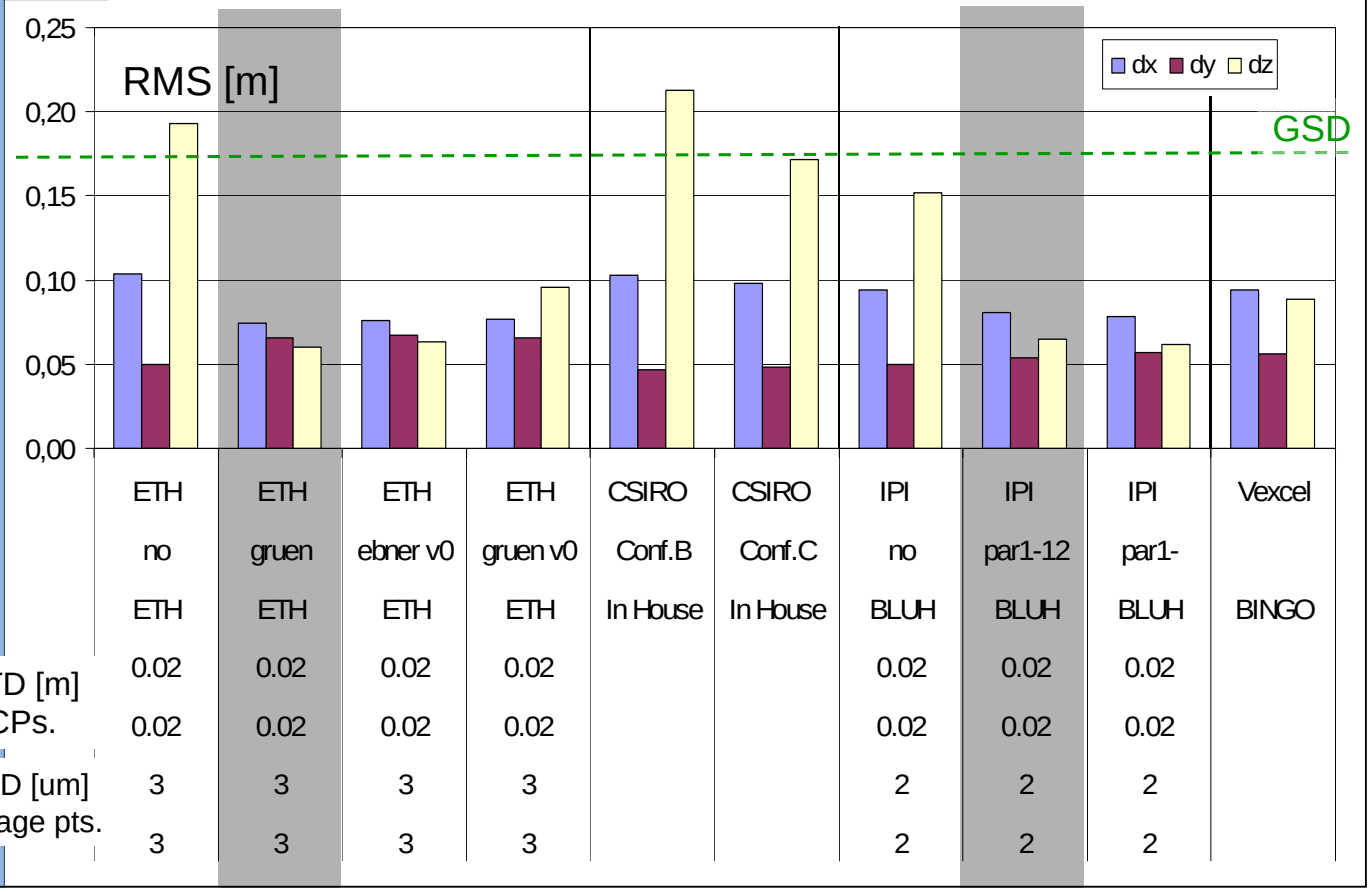


	ETH	ETH	ETH	ETH	CSIRO	CSIRO	IPI	IPI	IPI	Vexcel
	no	gruen	ebner v0	gruen v0	Conf.B	Conf.C	no	par1-12	par1-	
	ETH	ETH	ETH	ETH	In House	In House	BLUH	BLUH	BLUH	BINGO
STD [m] GCPs.	0.02	0.02	0.02	0.02			0.02	0.02	0.02	
	0.02	0.02	0.02	0.02			0.02	0.02	0.02	
STD [um] Image pts.	3	3	3	3			2	2	2	
	3	3	3	3			2	2	2	

Phase 2b – UCD low

GSD 0.17m, h_g 1900m

Standard params



	ETH no ETH	ETH gruen ETH	ETH ebner v0 ETH	ETH gruen v0 ETH	CSIRO Conf.B In House	CSIRO Conf.C In House	IPI no BLUH	IPI par1-12 BLUH	IPI par1- BLUH	Vexcel BINGO
STD [m] GCPs.	0.02	0.02	0.02	0.02			0.02	0.02	0.02	
	0.02	0.02	0.02	0.02			0.02	0.02	0.02	
STD [um] Image pts.	3	3	3	3			2	2	2	
	3	3	3	3			2	2	2	

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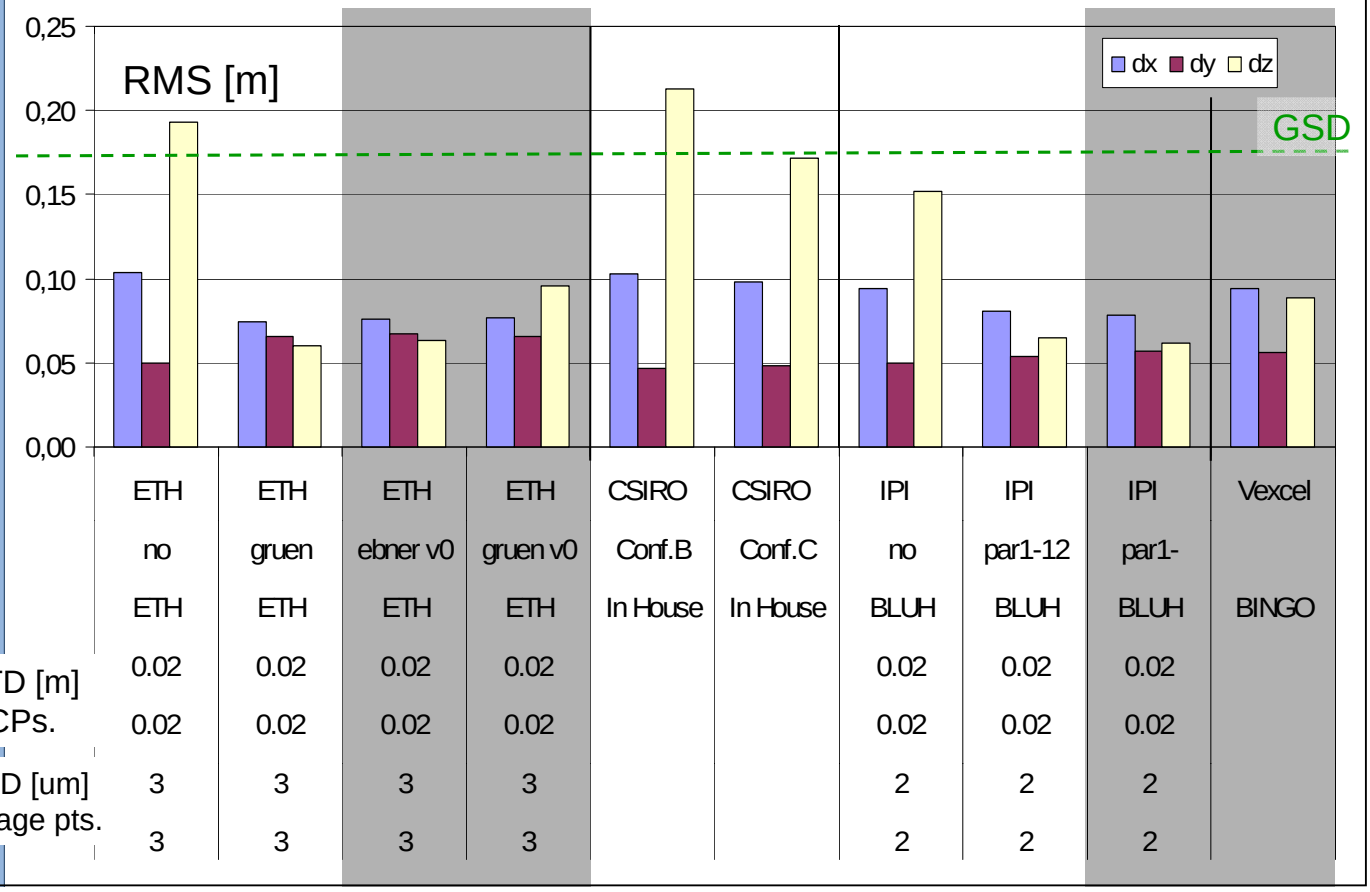
Phase 2b – UCD low

GSD 0.17m, h_g 1900m

UCD params



	ETH no ETH	ETH gruen ETH	ETH ebner v0 ETH	ETH gruen v0 ETH	CSIRO Conf.B In House	CSIRO Conf.C In House	IPI no BLUH	IPI par1-12 BLUH	IPI par1- BLUH	Vexcel BINGO
STD [m] GCPs.	0.02	0.02	0.02	0.02			0.02	0.02	0.02	
	0.02	0.02	0.02	0.02			0.02	0.02	0.02	
STD [um] Image pts.	3	3	3	3			2	2	2	
	3	3	3	3			2	2	2	

The test flight results

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Network Digital Camera Calibration

Conclusions and outlook

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Conclusions

- **self calibration seems to be necessary to improve object space accuracy for all three tested camera systems**
  - Self-calibration is of larger influence for DMC and UCD compared to ADS
  - systematic corrections for UCD are more significant compared to DMC
- absolute accuracy (after self-calibration)

Camera	horizontal	vertical
ADS	1/5 pix	1/3 pix 0.04 ‰ h_g
DMC	1/3 – 1/4 pix	1/2 – 1 pix 0.05 – 0.1 ‰ h_g
UltracamD	1/2 – 1/4 pix	1/3 pix 0.03 ‰ h_g

Note: Different flight configurations (i.e. overlaps, GPS/inertial EO availability), different image data quality, values only from 3 data sets

Conclusions

- **a priori weightings** are also of influence (phase 2b), in some cases choice of weighting factors exceeds effect of additional parameter set
- in some cases **special parameter sets** adopted to sensor geometry seem to be necessary; **standard parameters** like Ebner or Gruen in some cases are not able to fully compensate the systematic errors
- **a priori recommendation of optimal additional parameter set is difficult or even not possible**

- System suppliers are **re-thinking/modifying their present ways of camera calibration**
  - Leica Geosystems – Presentation P. Fricker (today)
  - Intergraph / ZI-Imaging – Presentation C. Dörstel (today)
  - Microsoft Photogrammetry – Presentation M. Gruber (today)

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Conclusions and outlook

Outlook
New EuroSDR initiatives

- **Project now finalized,** final report pending, expected in fall this year

- Two **new EuroSDR projects** currently in their design phase, follow-ups of Camera Calibration Network
  - **Performance of Medium Format Digital Airborne Cameras**
    Project leader: Dr. G. Grenzdörffer, Universität Rostock
  - **Radiometric Aspects of Digital Airborne Imagery**
    Project leader: tbd

EuroSDR

www.ifp.uni-stuttgart.de/eurosdr

⇨ **Invitation to actively participate !**

Outlook
The EuroDAC² initiative

EuroSDR Activities in European Digital Airborne Camera Certification

EuroDAC² - a concept for future certification of digital airborne cameras in Europe

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The EuroDAC² initiative
Why European camera certification ?

EuroSDR in general agrees and underlines the high relevance and impact of the USGS quality assurance plan **but**

- **different requirements** in flight project parameters and accuracy
  - projects are of smaller extension, more regional sized, more stringent requirements in resolution and accuracy
  - different accuracy classes are required for European users
  - Type certification vs. individual sensor (serial number) certification
- new technology of digital airborne imaging mainly **originated in Europe**, i.e.
  - ADS40 (CH), DMC (D), UC-D/X (A), DiMAC (L), JAS-150 (D), HRSC (D), AIC-Rolleimetric (D), DigiCAM (D), IGN-Camera (F)
  - **accepted use of those systems throughout Europe** should be based on their European wide certification
- Europe has already defined its own solutions for other projects of larger impact (i.e. Galileo GNSS). Not only as competition but also **to support / complement each other**. Same might be possible for different certification approaches.

The EuroDAC² initiative

Process steps

#	Process steps
1	Evaluation of users needs / expectations *Action*: (mainly) **NMCAs** and others
2	Input from camera manufacturers *Action*: (mainly) **system suppliers** and others
3	Definition of EuroDAC² process *Action*: (mainly) **EuroDAC² core competence group**
4	Acceptance of EuroDAC² process *Action*: (mainly) **NMCAs, system suppliers** and others
5	Implementation (in Europe) of EuroDAC² process

⇨ **Invitation to actively participate !**

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Conclusions and outlook

Acknowledgments

- system suppliers, mainly **Leica Geosystems**, **Intergraph / ZI-Imaging**, **Microsoft Photogrammetry**
- data providers, namely **TerraTec** & **IFMS-Pasewalk**
- all supporting **network members,** namely

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