The EuroSDR network on Digital Camera Calibration and Validation

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EuroSDR Network on Digital Camera Calibration and Validation

#	Group	Institutions / Systems	#
1	Camera manufacturers	ADS, DIMAC, DMC, DSS, UltracamD, Starimager, 3-DAS-1, DigiCAM	12
2	AT software developers	BLUH, ORIMA, inpho, dgap	5
3	Other companies	Vito, ISTAR, Geosys, OMC	4
4	Science	ETH, OSU, Glasgow, Stuttgart (2x), IdeG, Rostock, DLR (2x), Berlin, Nottingham, Aas, Pavia	28
5	NMCAs	ICC, USGS, OrdSurv, IGN, FGI, Lantmäteriet, Swisstopo, BEV, ICV, itacyl	13
		Σ representatives	62

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Objectives

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

  Collection of publicly available material to compile an extensi…
  documenting currently used calibration practi…
  - All network participants … …ute
    with th…
  - …ormulation on future strategies
  - …ystem 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

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

  Empirical phase 2 recently extended to **Phase 2b**

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Phase 2
Active Participants

#	Code	Institutions
1	**ICC**	**Institute Cartographic Catalunya, Spain**
2	ICV	Institute Cartographic Valenciano, Valencia, Spain
3	**LM**	**Lantmatäriet, Gävle, Sweden**
4	itacyl	ITACYL, Valladolid, Spain
5	**inpho**	**inpho, Stuttgart, Germany**
6	CSIRO	CSIRO Information Sciences, Wembley, Australia
7	DLR-O	DLR, Oberpfaffenhofen, Germany
8	DLR-B	DLR, Berlin, Germany
9	Anhalt	University of Applied Science, Anhalt, Germany
10	**HfT**	**University of Applied Science, Stuttgart, Germany**

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Phase 2
Active Participants

#	Code	Institutions
11	UoL	University of Leon, Spain
12	**IPI**	**IPI, University of Hannover, Germany**
13	ETH	ETH Zürich, Switzerland
14	UoP	University of Pavia, Italy
15	UoN	University of Nottingham, England
16	**Ingr.ZI**	**Intergraph ZI, Aalen, Germany**
17	Vexcel	Vexcel, Graz, Austria
18	Leica	Leica Geosystems, Heerbrugg, Switzerland

participants focussing on DMC data printed in bold letters

Experimental Phase 2 data

#	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						
low	**950**	**0.10**	**5**	**60 / 30**	**115**	**(GPS(/INS))**
high	**1800**	**0.18**	**3**	**60 / 30**	**34**	**(GPS(/INS))**
UltracamD Fredrikstad, September 16, 2004						
low	1900	0.17	4 / 1	80 / 60	131	GPS(/INS)
high	3800	0.34	2	80 / 60	28	GPS(/INS)

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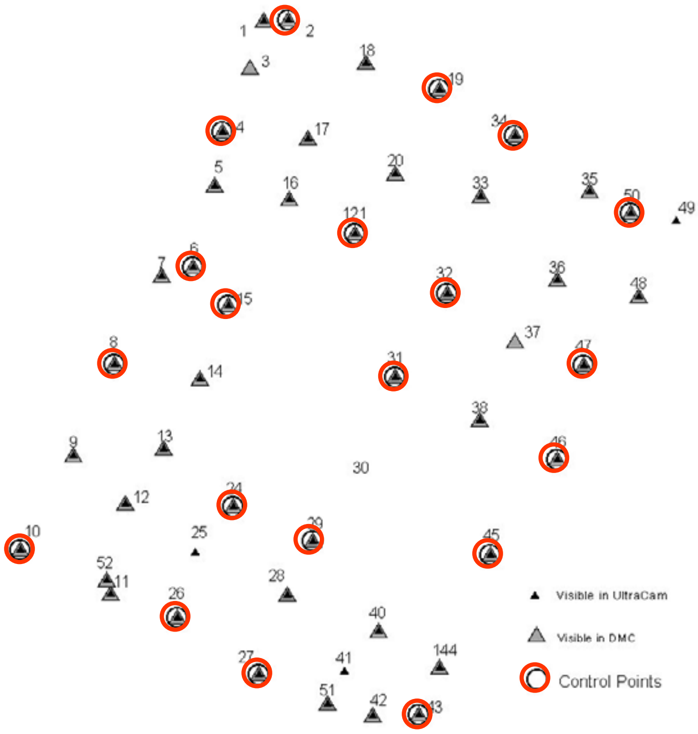
The Fredrikstad test range

DMC and UCD flights



object points

~ 20 control points

~ 25 check points

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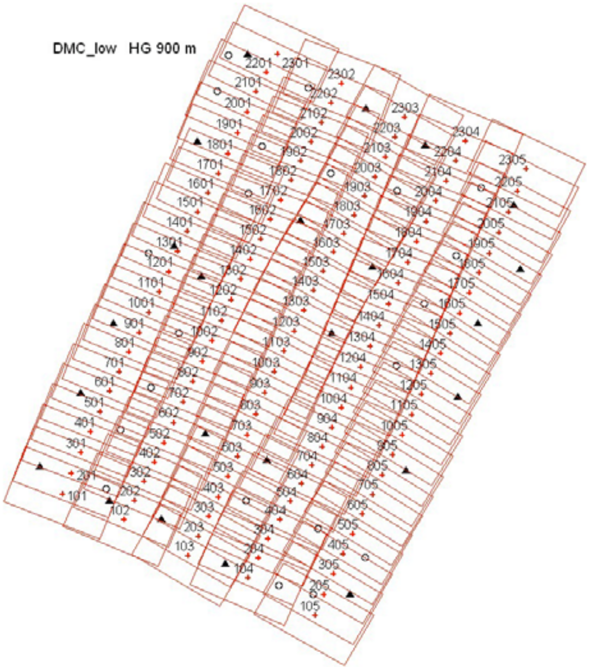
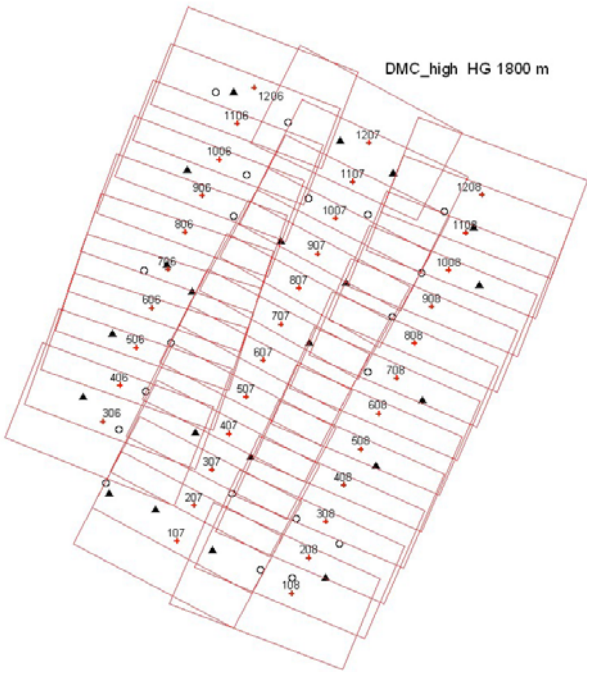
DMC image block geometry



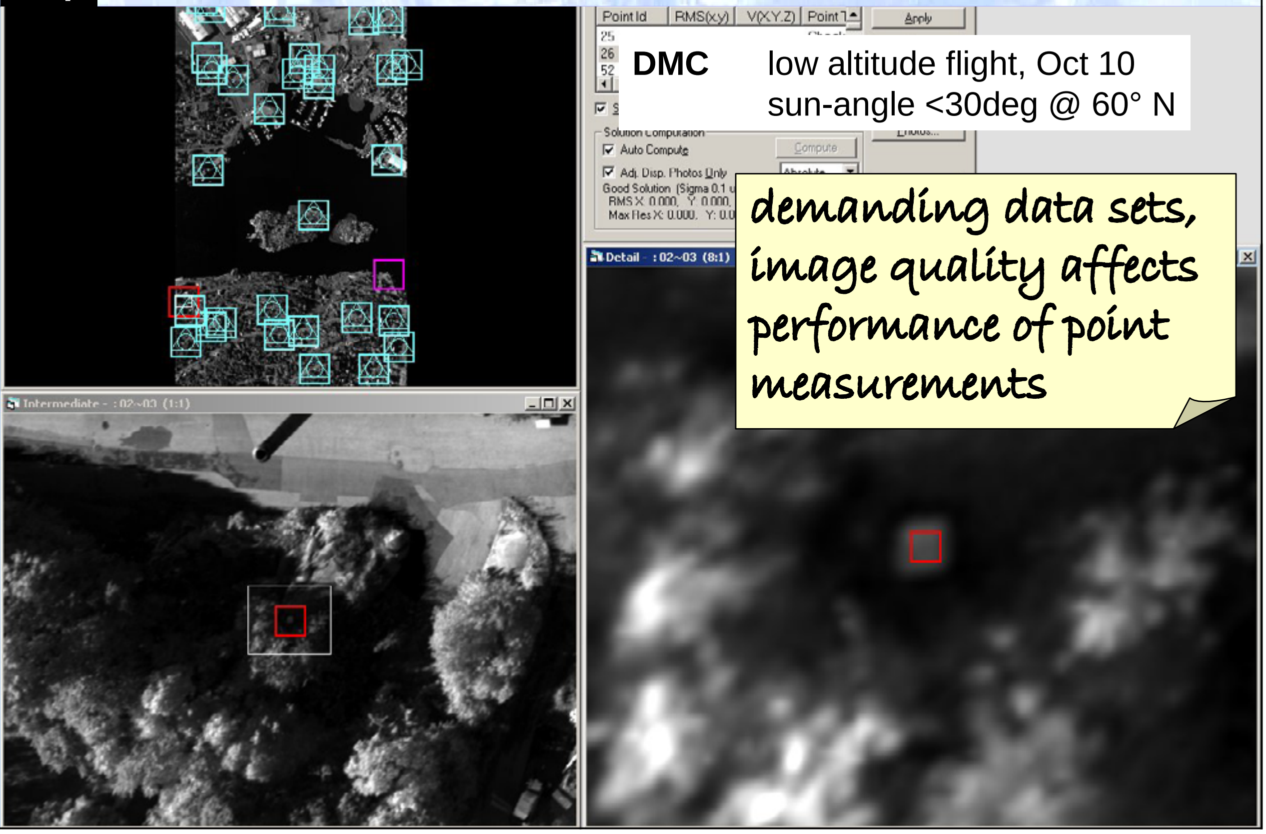


DMC low (GSD 8cm)

DMC high (GSD 15cm)

DMC and UCD flights

Image quality and point measurements



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„Reference“ processing at ifp

1. estimation of additional parameters using all coordinated object points (GCP + ChP)
2. adjustment using GCP only, add. parameter used as fixed values as determined in step 1.

DMC high (22 significant parameters)

```
(  +4.2,  -6.5) (  +2.9,  -1.2) (  +1.2,  -0.5) (  +5.5,  -1.2) (  +1.8,  -6.5)
(  -4.0,  -4.2) (  +1.3,  -1.1) (  +3.1,  -0.1) (  +2.8,  -1.1) (  +8.5,  -4.2)
(  -0.2,  +0.6) (  -1.1,  +1.2) (  -1.8,  +1.5) (  -2.2,  +1.2) (  -1.9,  +0.6)
(  -1.3,  -0.6) (  +3.7,  -2.4) (  +1.8,  -3.0) (  +1.1,  -2.4) (  +3.0,  -0.6)
(  +8.3, -17.9) (  +0.9, -20.0) (  +3.1, -19.6) (  +5.1, -20.0) (  +8.9, -17.9)
```

DMC low (11 significant parameters)

```
(  +1.2,  +9.0) (  -9.9,  +8.6) (  -9.2,  +8.9) (  -8.4,  +8.6) ( -19.6,  +9.0)
(  -2.9,  -1.4) (  +0.9,  +0.8) (  -0.1,  +1.2) (  -1.2,  +0.2) (  +2.6,  +0.5)
(  -0.6,  +1.3) (  +0.1,  -0.3) (  -0.1,  +0.1) (  -0.2,  +0.1) (  +0.5,  -0.1)
(  -3.2,  +0.7) (  +0.7,  -0.4) (  -0.1,  -1.0) (  -1.0,  -1.0) (  +2.9,  +2.6)
(  -5.1,  -7.8) ( -13.1,  -8.8) (  -9.2,  -8.7) (  -5.2,  -8.8) ( -13.2,  -7.8)
```

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„Reference“ processin

Rule of thumb
$s_Z = 0.05‰ \cdot h_g$
$= 9cm (hi), 5cm (lo)$
$s_{XY} = 2\mu m \cdot m_b$
$= 3cm (hi), 2cm (lo)$

	DMC high	DMC low
Precision [m]		(from error propagation)
Sigma0 [µm]	1.4	1.8 (1.4)
SEast	0.032	0.029 (0.023)
SNorth	0.027	0.025 (0.019)
SVertical	0.107	0.095 (0.074)
Accuracy [m]		(from check point differences)
# ChPs	20	21
ΔEast	0.048	0.040
ΔNorth	0.048	0.048
ΔVertical	0.116	0.132

General remarks on data processing (1/2)

- typically the two different flight heights processed independently
- only three participants used both heights for common adjustment of the two UCD and DMC flight heights
- standard and proprietary software packages used

Process step	Software
Matching and point measurement	Manual, MATCH-AT, LPS, ISAT, Gpro, PhotoMod, others
Bundle adjustment	Match-AT, ORIMA, InBlock, BLUH, PhotoMod, ACX-Geotex, IS-PhotoT, others

- participants typically provided more than one solution, altogether 77 different solutions (all sensors) evaluated and results reported back to participants
- **6 participants provided DMC data evaluations**

General remarks on data processing (2/2)

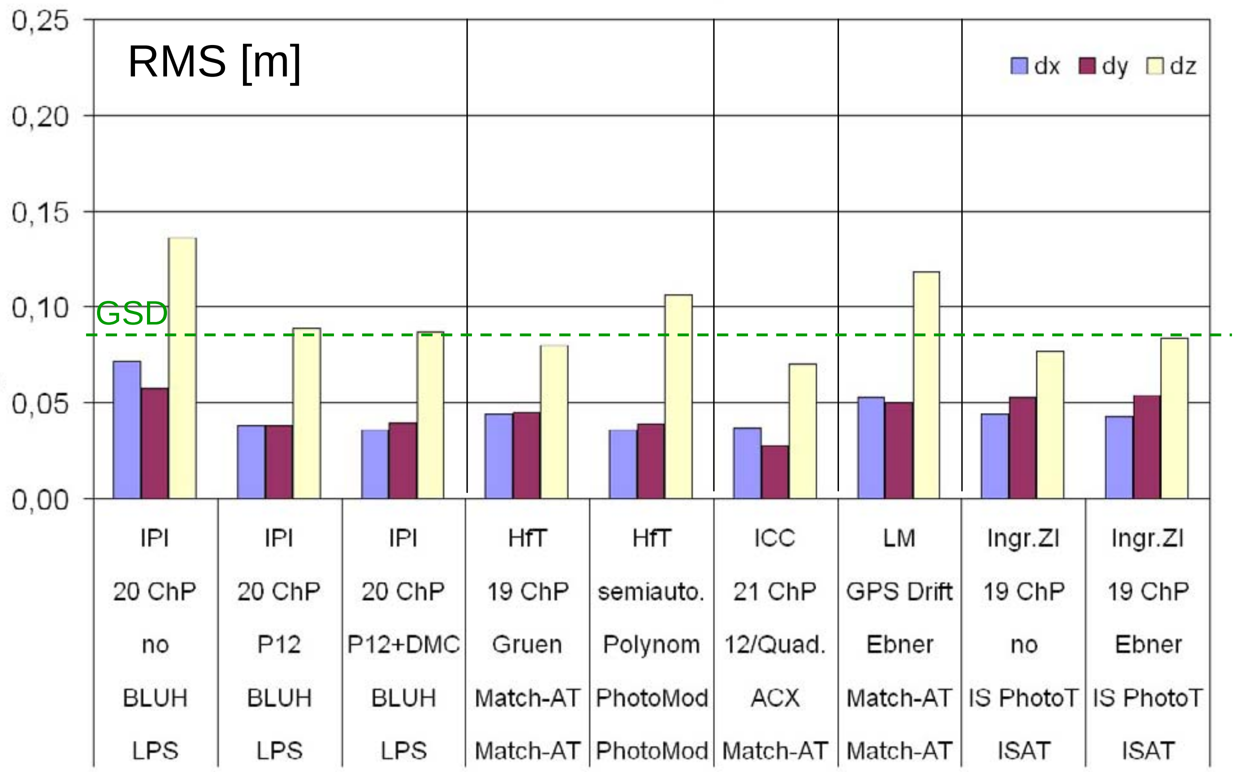
- Self-calibration was mostly applied for whole image
- but, almost each participant also provided solution w/o use of additional SC
- 2 participants used modified SC approaches taking the specific image geometry of large format DMC imagery into account

Data set	Self-calibration parameter set (if applied)
DMC	**12 Ebner per quadrant, BLUH DMC specific Ebner, Grün, Polynom, BLUH parameters**
UCD	Brown, Grün
ADS	Brown

DMC low

h_g 950m, GSD 0.10m

Rule of thumb
s_Z = 5cm
s_{XY} = 2cm



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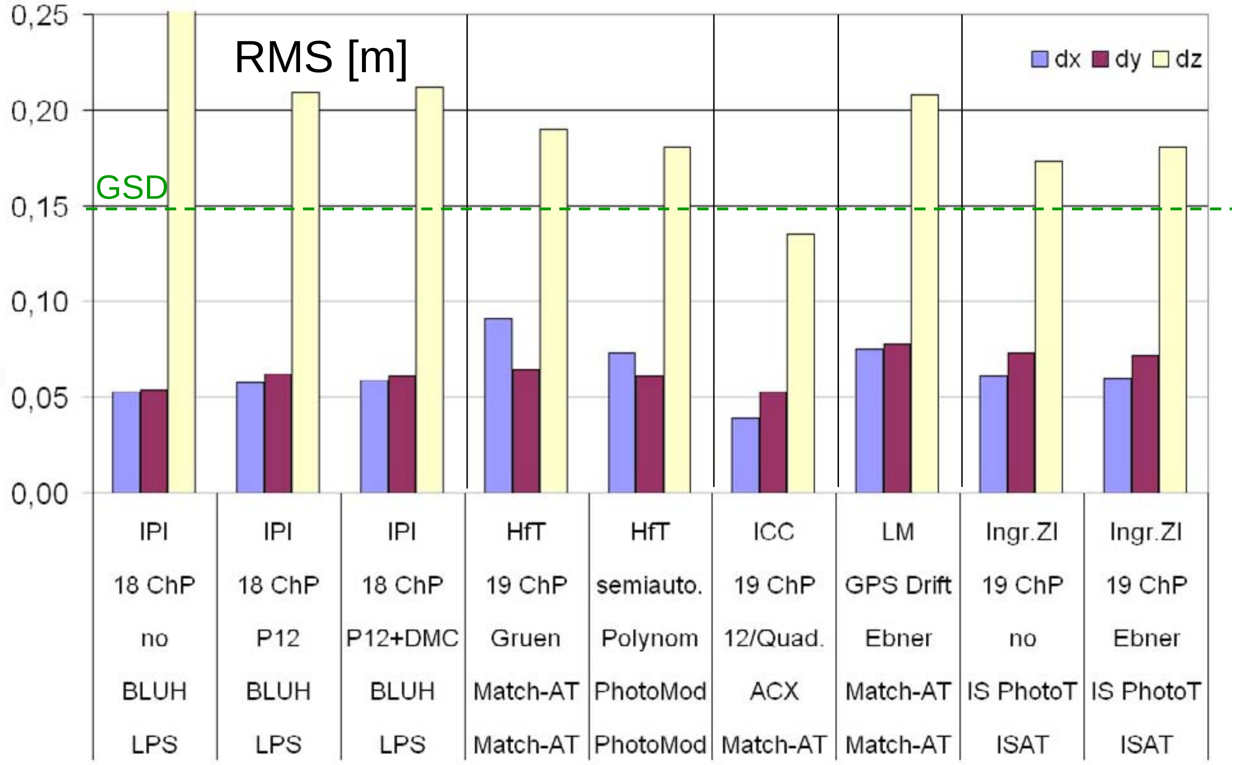
DMC high

h_g 1800m, GSD 0.18m

Rule of thumb
$s_Z = 9cm$
$s_{XY} = 3cm$



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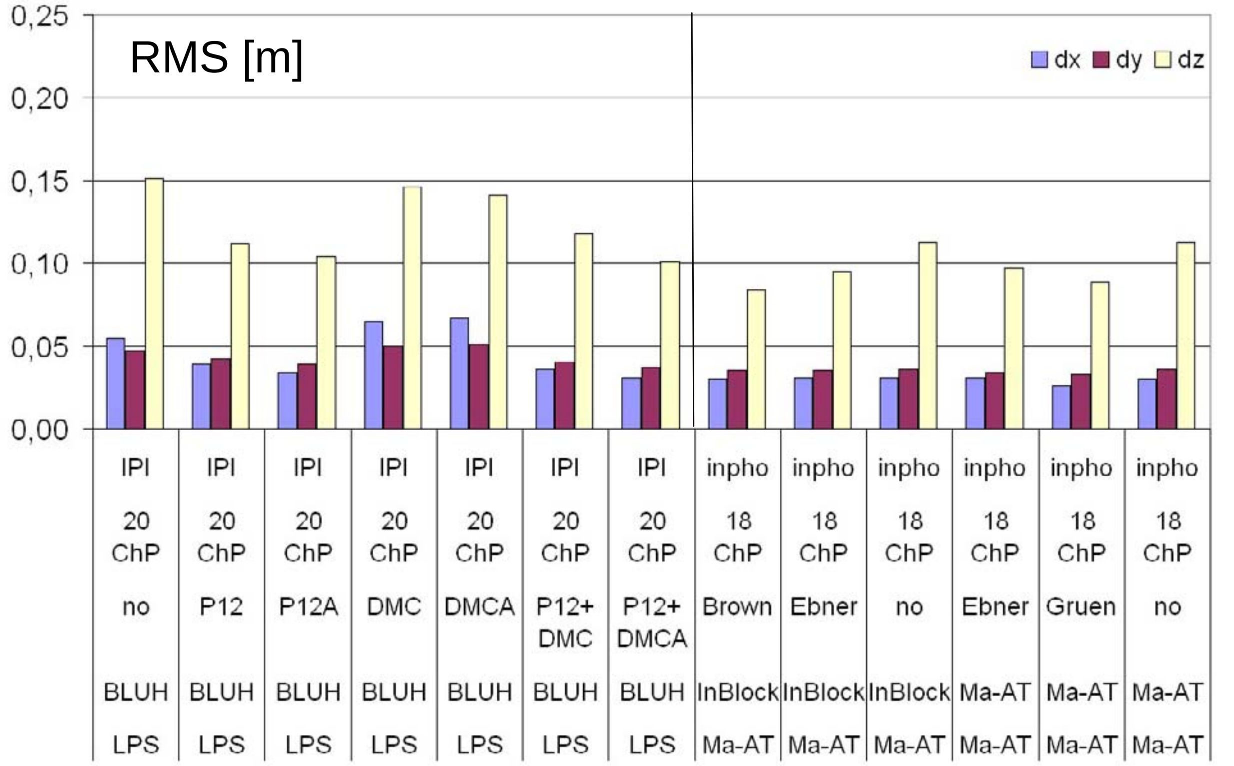
DMC combined

h_g 1800m + 950m, GSD 0.18m + 0.10m



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Conclusions

- self calibration seems to be necessary to improve object space accuracy in all cases for all three tested cameras
- self calibration mainly refines the vertical component
- for DMC data standard parameters seem to be sufficient to compensate for the dominating error sources, although the quadrant specific approach followed by ICC shows very reasonable results

- DMC and UCD data evaluation are influenced on image point identification errors in measurement (in some cases dominating error source), influences the comparison between different processing runs (i.e. applied model of SC)
- non sufficient number of samples per data set to recommend most-optimal sensor related processing approach

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Open topics

- influence of errors in image measurement could not be separated from influence of different SC approaches
  - pilot centre provided set of measured image coordinates for DMC and UCD image blocks, this new
  - **Phase 2b recently started**

- other data sets from different sensors (i.e. medium format) ?

- new project / proposal ?
  - new project covering new aspects like radiometry, resolution, pan-sharpening, colour? Who has already expertise in that?
  - new data sets required for that (already distributed data still should be accessible for future requests)

Open topics

- future role of self-calibration ?
  - significant determination of additional parameters non trivial and complex task, requires certain block configuration (i.e. overlaps, GCP distribution, GPS and/or GPS/IMU)
  - does AT really have to compensate for „weaknesses“ in geometric digital camera design?
  - are the SC parameters also considered in the further processing chain?
  - does the individual user pay for this additional effort?