DMC – (R)evolution on geometric accuracy

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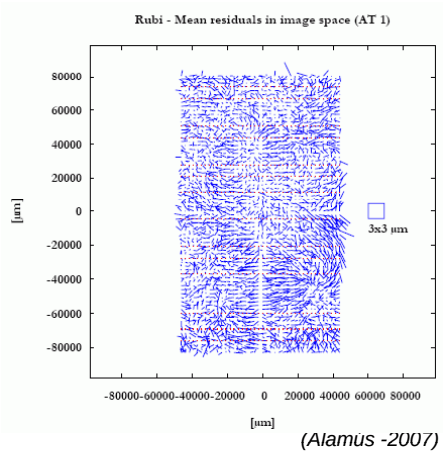
Images Courtesy of Stereocarto, Spain; PhotoScience, USA; AAM Hatch PTY Ltd., Australia

INTERGRAPH

Motivation – outstanding results but …

ZI IMAGING

- Investigations discover pattern of systematic corrections with
- Low frequency errors



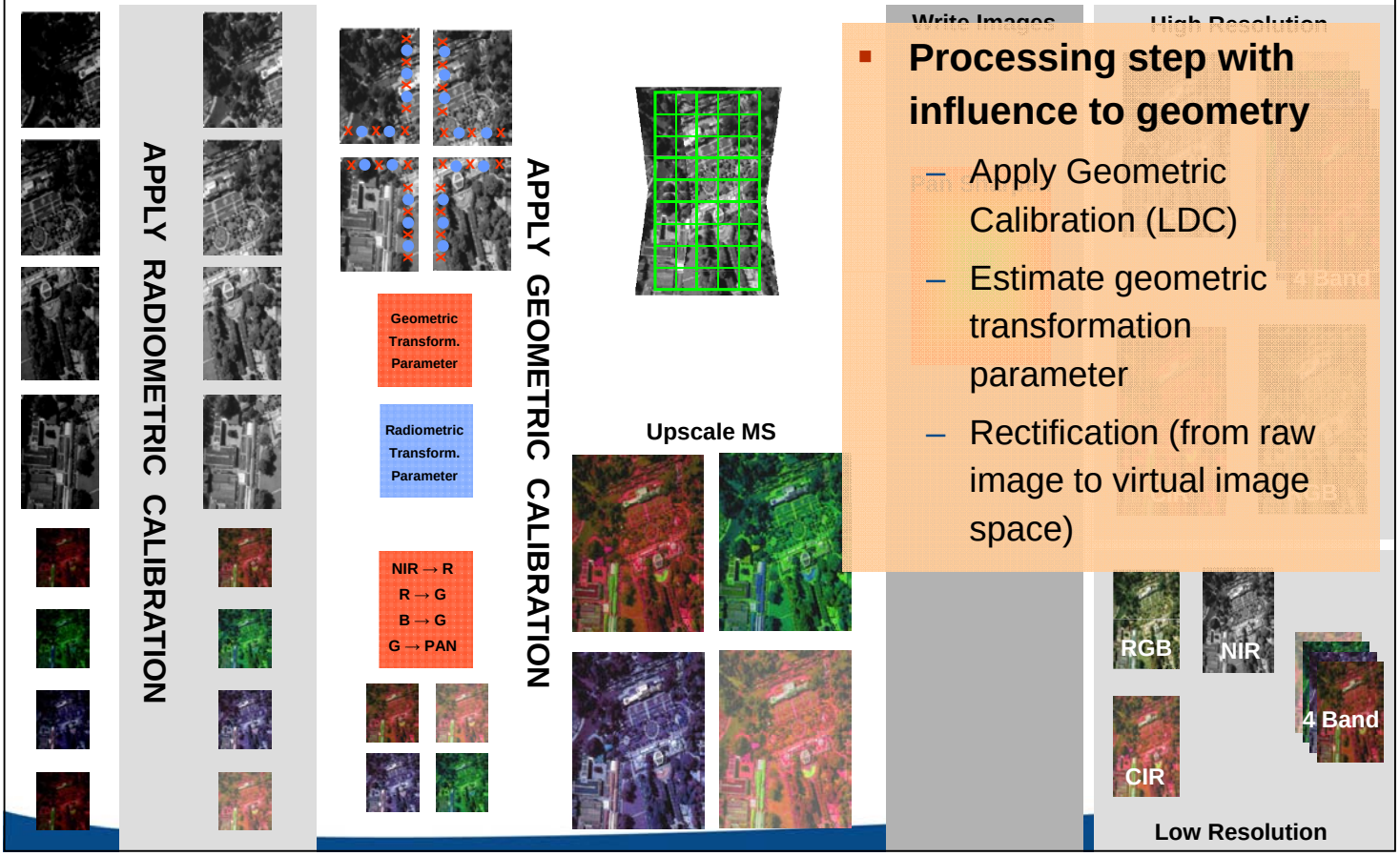
(Alamús -2007)

- Studies show that results can be improved

(Jakobsen, Kruck, Alamús)

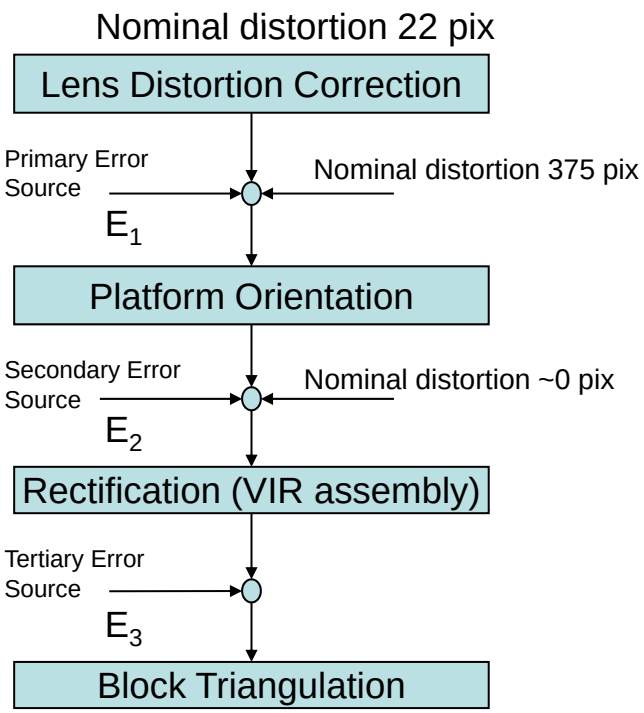
DMC Post Processing – some steps dismissed, some not

RAW | INTERMEDIATE | CO - REGISTER | RECTIFICATION | OUTPUT | PRODUCTS



- **Processing step with influence to geometry**
  - Apply Geometric Calibration (LDC)
  - Estimate geometric transformation parameter
  - Rectification (from raw image to virtual image space)

Error Budget – where to attack the problem?



Error sources:

- **E1 remaining non-linear image distortion** ***35%***
  - **12.5% environment (0.25 µm)**
  - **87.5% constant (1.75 µm)**
- **E2 angular and magnification** ***64 %***
- **E3 re-projection and re-sampling** ***1%***

Collocation Technique – better models edges

- **Correction grid estimation technique – collocation technique**
- **Definition (math):** numerical solution of differential and integral equations - choose from finite space of candidate solutions *and* a number of so called collocation points ➔ select that **solution** which **satisfies the given equation at the collocation points**.

  - ***Systematic trend surface*** *in camera frame space – estimated by iterative collocation to BBA* ***with tight GPS/GCP and relaxed image observations weights****.*

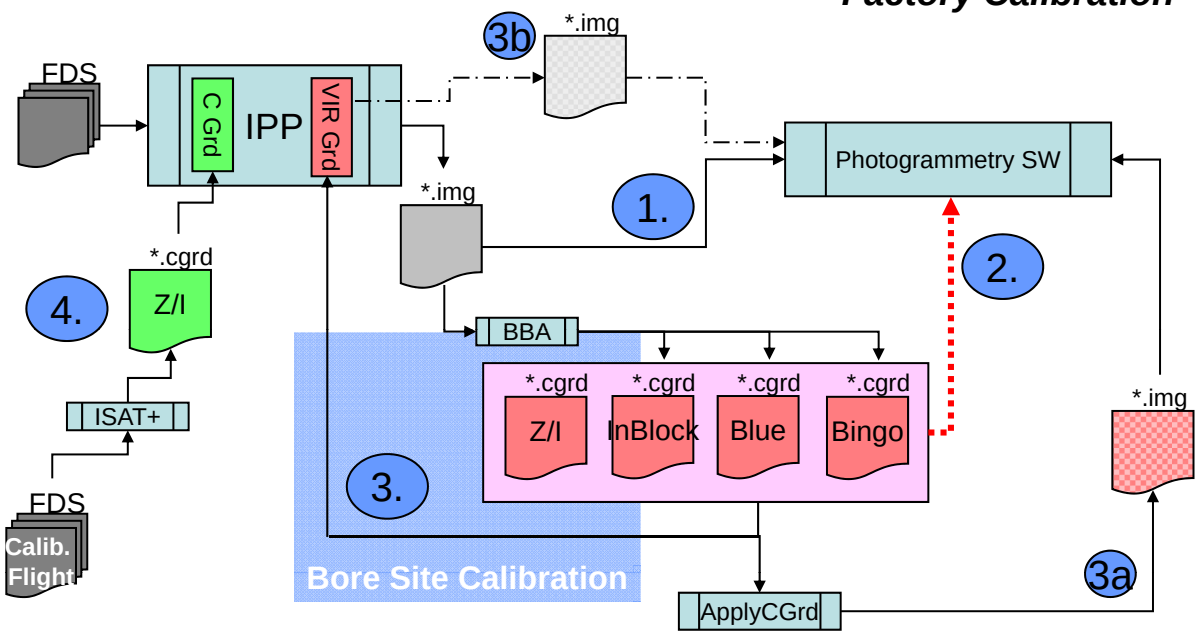
    After every bundle iteration a ***least-squares surface piecewise-spline is fit to absorb average systematic trend*** *and subtract it from image observation on the next iteration*

    Source: C. Reinsch, “moothing by spline functions” Numerische Mathematik 10 177-183 (1967)

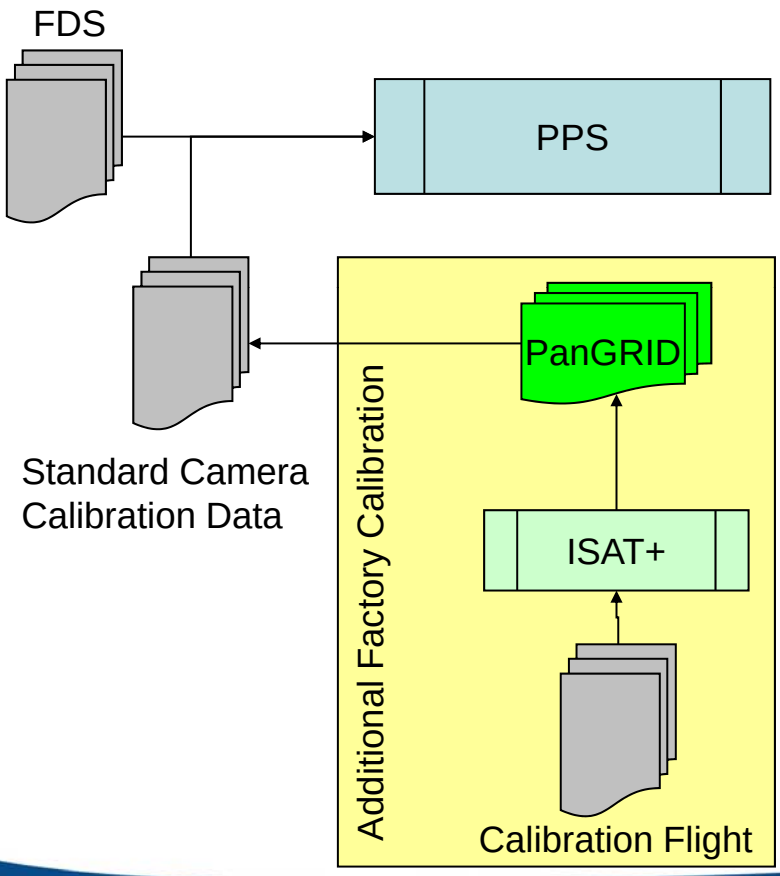
- **Pro: local correction technique - does not overcompensate at the edges**
  (all measures (collocation points) are part of the final solution)
- **Cont: requires a dense population of image observations**

Processing workflows – nothing is impossible

- **Processing Options**
  1. Regular workflow
  2. Correction in Real time Loop
  3. Correction Grid = VIR Grid
     InSitu or ***Type calibration***
  4. Collocation Grid = Pan Grid
     Factory Calibration



Factory Calibration Procedure – attack from source

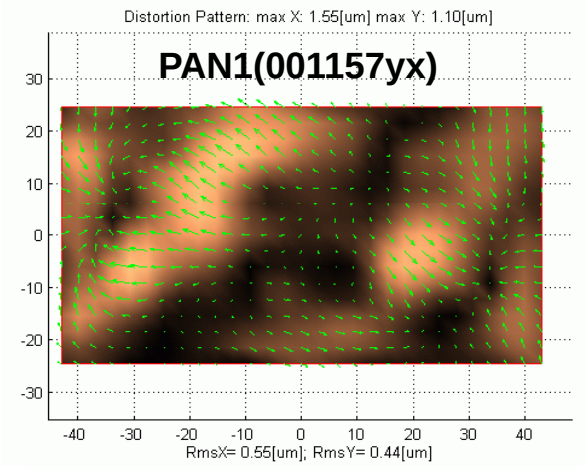


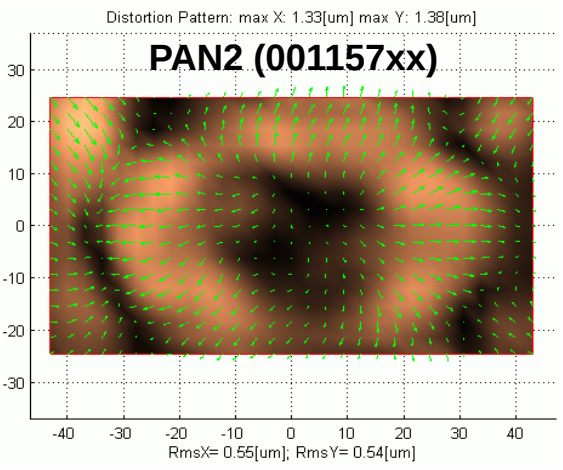
- **Additional Factory Calibration**
  - Calculate correction grid for each pan camera head
  - Deliver with Calibration CD
  - Apply correction grid automatically during DMC Post Processing

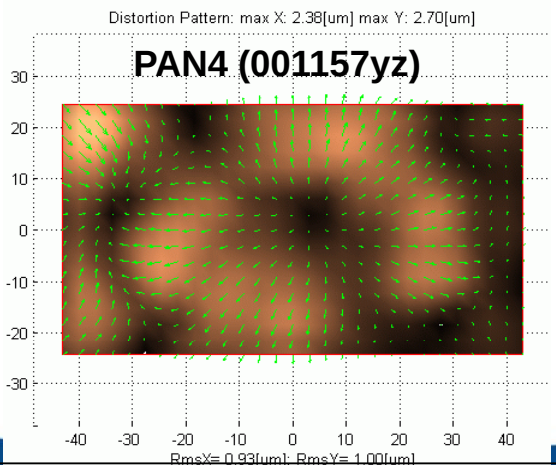
Factory Calibration

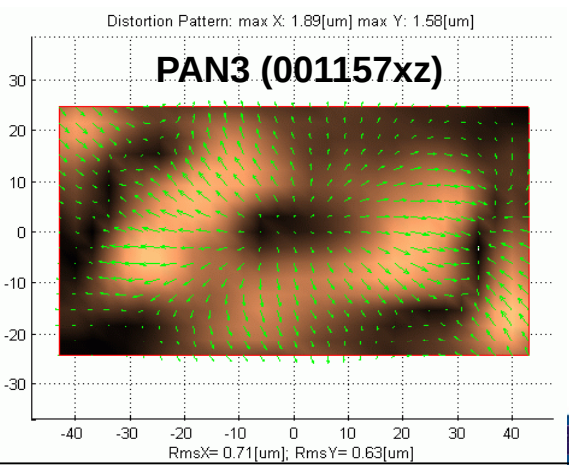
- Addresses E1 only!
- Covers max 35% of the total error **AND** reduces E2 up to 50%

Pan Grid





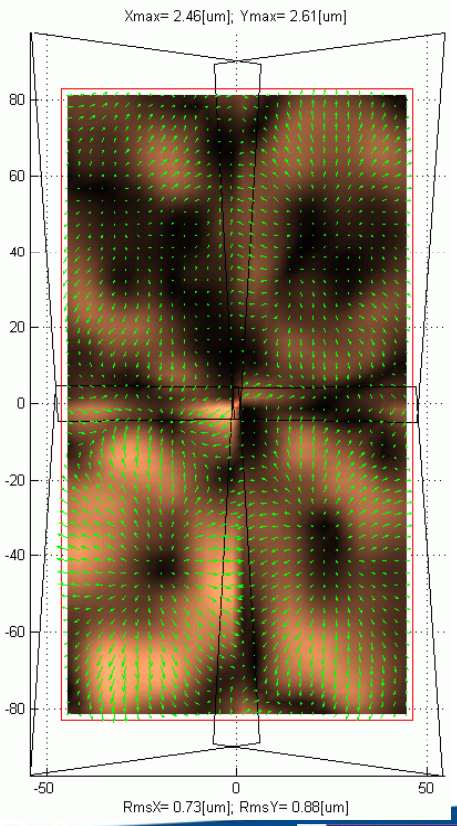




DMC VIR Grid solution - proof of concept

VIR Distortion Component Analysis/Reconstruction: E1 error

Re-projection of individual PAN Grid's into the VIR image space



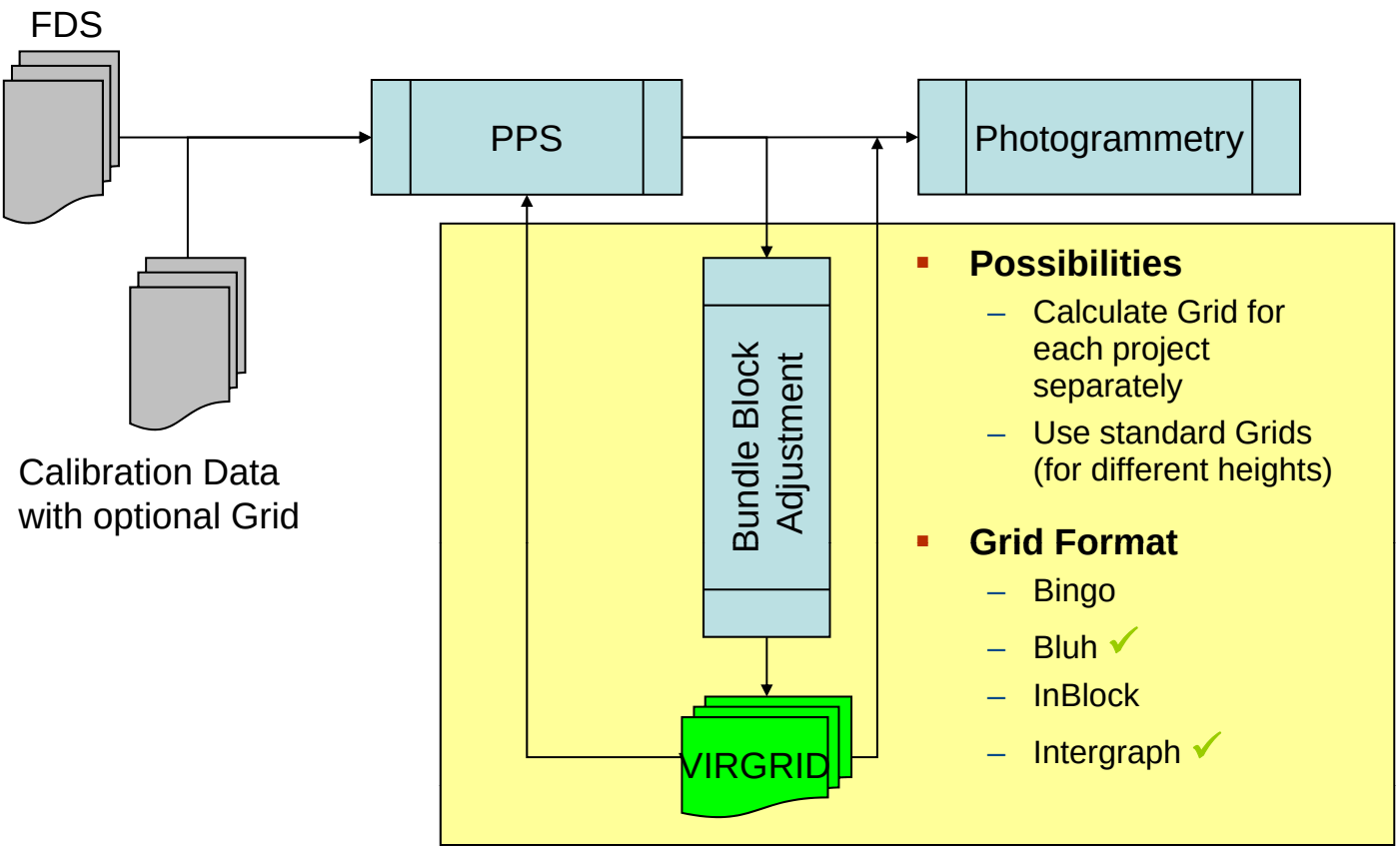
The estimated VIR distortion field due to Uncompensated Lens Distortion only

(modeling error in 10-AP "Australis" distortion model: 35% of total VIR distortion)

Maximum correction: 2.61 µm

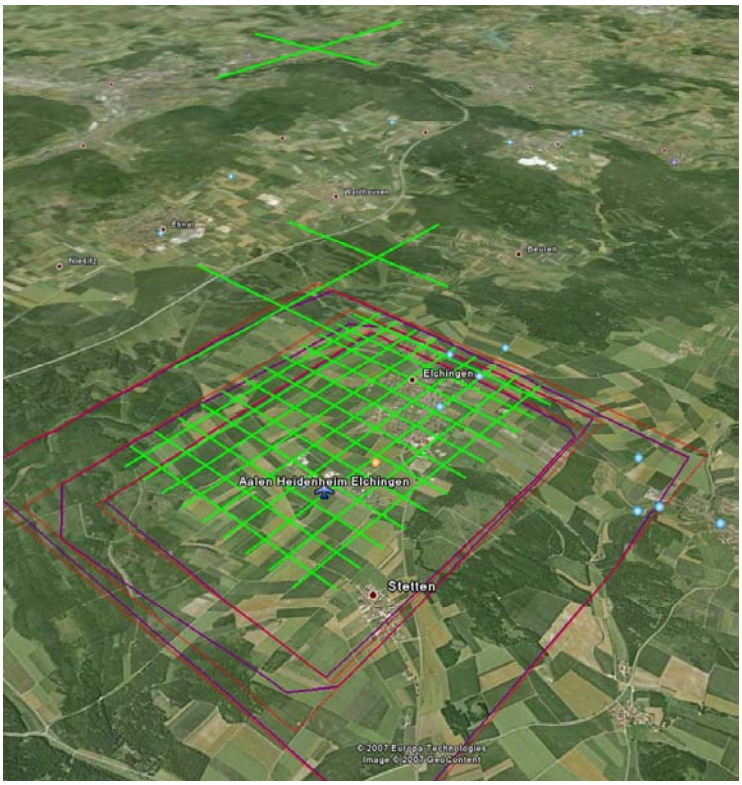
Results showed improvements

VIR Grid correction – models E1 and E2 error



- **Possibilities**
  - Calculate Grid for each project separately
  - Use standard Grids (for different heights)
- **Grid Format**
  - Bingo
  - Bluh ✓
  - InBlock
  - Intergraph ✓

Case 1 - Test Flight



- **Task**
  - Generate VIR Grid for 5cm
    Calibration Flight
  - Validate VIR Grid at 20cm GSD
- **Test flight**
  - Overlap 80/80
  - 5 cm GSD (used for Grid calculation)
  - 20 cm GSD

DMC VIR Grid solution – grid computation

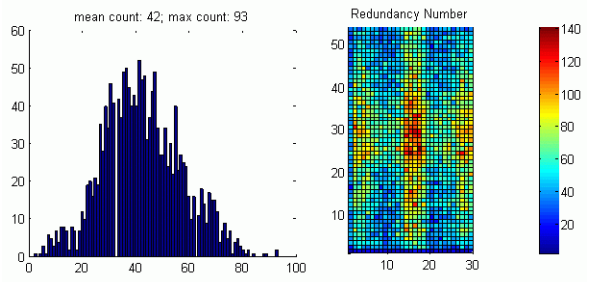
DMC01-00x1 Calibration Flight: GSD: 5[cm]

400 photos, ~35,000 multi-ray image points

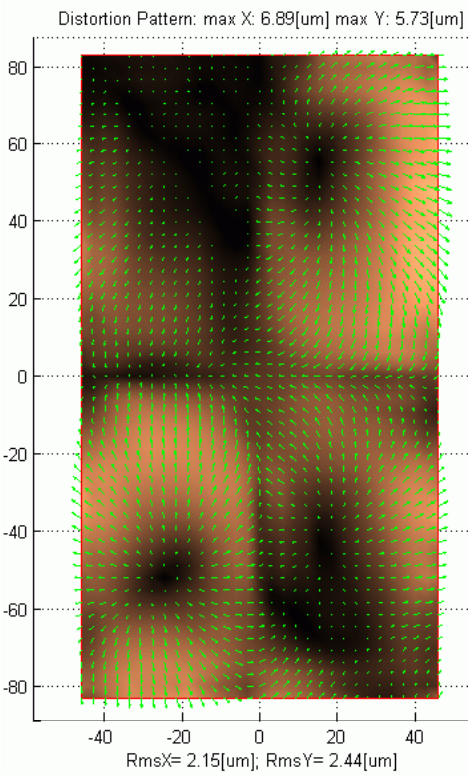
Iterative collocation adjustment
of the residual trend surface

30x52 cell-grid (256x256 pix)

Distribution of points-per-cell



The estimated VIR distortion field



DMC VIR Grid solution – independent validation

Test Flight: GSD: 20[cm] correction grid computed from 5cm

24 photos, 414 multi-ray image points (all signalized GCP)

Bundle adjustment with 11 control and 29 check points

Std Dev for Control points: 0.03, 0.03 0.04m

Before
Parameters

Parameter	X	Y	**Z**	XY
RMS Control	0.031	0.021	0.036	0.027
RMS Check	0.042	0.074	**0.212**	0.061
Max Ground Residual	0.050	0.037	0.053	
Sigma	2.3	um		

After CGRID_VIR01_00x1
Parameters

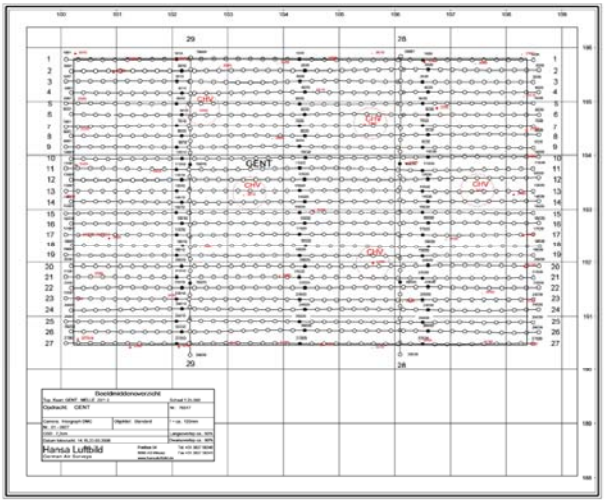
Parameter	X	Y	**Z**	XY
RMS Control	0.020	0.017	0.021	0.019
RMS Check	0.049	0.067	**0.137**	0.059
Max Ground Residual	0.040	0.034	0.033	
Sigma	1.5	um		

Block unbend by **45%**

Case 2 - Test Block Gent (ongoing) – another proof

DMC flight spring 2006

- **Block size 5,5 km * 8,5 km**
  29 strips, 1.105 images, GSD = 7,2 cm
- **Flying height Hg = 800 m**
- **DGPS/INS**
- **End lap: 60 %**
- **Side lap: 80 %**
- **53 GCP**



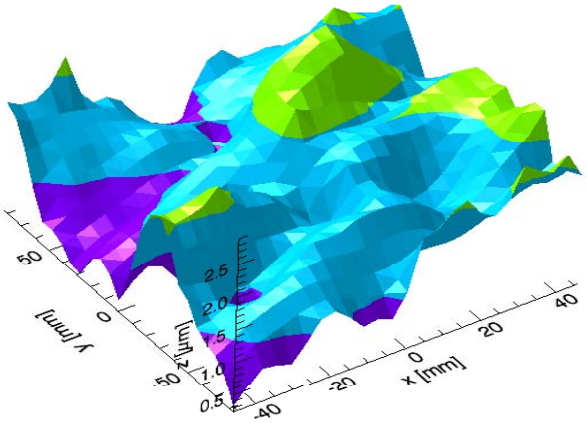
For statistical analysis 14 check points in the block center were used.

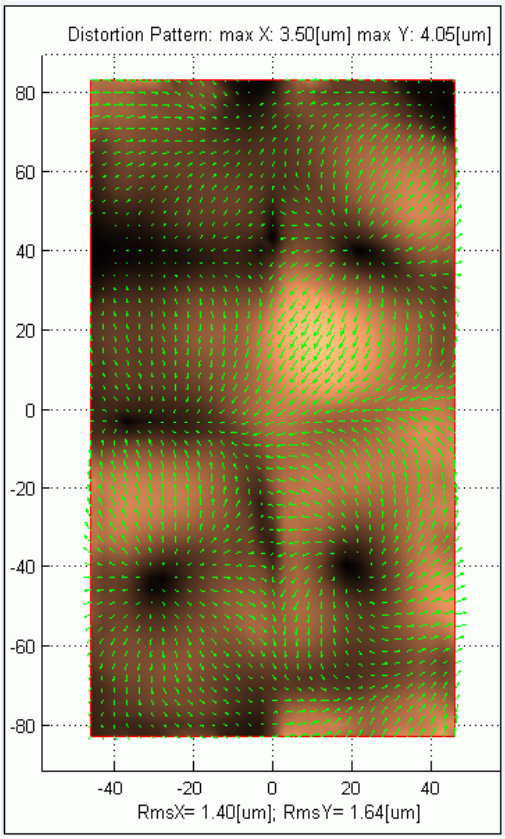
A priori standard dev.	x	y	Z
Ground control points	0,030 [m]	0,030 [m]	0,030 [m]
Projection centers	0,050 [m]	0,050 [m]	0,050 [m]
Image points	0,002 [mm]	0,002 [mm]	

Hansa Luftbild
German Air Surveys
+ AGIV

VIR Grid

Visualization of VIR Grid computed for Gent test Block





AT Result – demonstrate effectiveness of VIR Grid

XYZ GPS StdDev = 5cm
xy photo StdDev = **6µm vs. 2µm**
no image space refinements;
39 GCP StdDev=(3cm,3cm,5cm), 14 CP
➔ error shows up in image space

Parameter	*X/Omega*	*Y/Phi*	*Z/Kappa*	*XY*
RMS Control	0.072	0.073	0.191	0.072
RMS Check	0.043	0.038	**0.262**	0.041
Max Ground Residual	0.173	0.209	**0.441**	
RMS Photo Position	0.068	0.142	0.143	

Correction grid applied
XYZ GPS StdDev = 20cm;
xy photo StdDev = 2µm

Block bending reduced 4 times !!

Parameter	*X/Omega*	*Y/Phi*	*Z/Kappa*	*XY*
RMS Control	0.056	0.049	0.074	0.053
RMS Check	0.043	0.033	**0.059**	0.038
Max Ground Residual	0.136	0.183	**0.144**	
RMS Photo Position	0.015	0.017	0.014	

XYZ GPS StdDev = 20cm **relaxed GPS!!**
xy photo StdDev = 2µm
➔error shows up in check points

Parameter	*X/Omega*	*Y/Phi*	*Z/Kappa*	*XY*
RMS Control	0.060	0.052	0.045	0.056
RMS Check	0.038	0.026	**0.033**	0.033
Max Ground Residual	0.136	0.137	**0.101**	
RMS Photo Position	0.062	0.097	0.050	

Assessment of techniques

- **VIR Grid**

  Generate with: (self calibration) Blue, Bingo, InBlock PhotoT (add collocation)

  Input: any Photogrammetric block (preferred 80% side lap)

  Pro: compensates systematic error in VIR production process

  includes lab calibration errors

  includes relative orientation error

  models environmental conditions (negligible)

  Con: is very sensitive to tie point distribution

- **PAN Grid**

  Generate with: "CGRID.exe" (non-public)

  Input: Photogrammetric block with 60% end lap / 80% side lap

  Pro: improves camera calibration, basic correction, independent from flying height

  Con: models only parts of the total error (E1 = non-linear image distortion)

Experience

- **VIR Grid**
  - Expected improvement of vertical accuracy ~2 times (RMS on check points in Z reduced by ~40%) *21 cm ➔ 13 cm*
  - Block bending in Z reduced by half !
  - Successfully corrected projects at higher altitudes with grids computed from low altitudes!
  - Interpolation between grids is implemented
  - Apply VIR Grid during post processing or during Bundle Adjustment
- **Pan Grid (CGrid)**
  - Stable - captures only static parts of lens calibration
  - No dependency to flying height

  ➔ Further test implementation under work

Conclusions - adapt adopt improve

- **Correction Grids improve DMC Geometry and unbend blocks**
  - Vertical ~40%
- **Image corrections**

	Pan Grid [µm]	VIR Grid [µm]
Average	**0.5**	**1.8**
Maximum	**2.8**	**6.9**

- **Integration concept**
  - Does not require second resampling
  - Grid interpolation technique eliminates recursive processing
- **Geometric correction grid may be used during PPS for future projects**
- **Geometric correction grid is similar to updating the camera calibration**
- **Continue our work in other areas of geometric correction of the PPS software**

Thank you for your attention.

Questions and Comments?

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