

RMK D – A True Metric Medium Format Digital Aerial Camera System

Christoph Dörstel, Manager SW Development

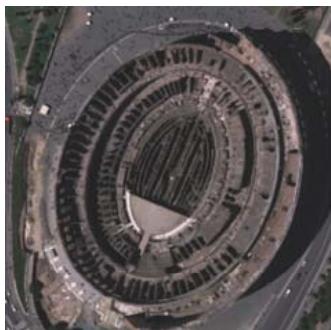


Image courtesy of Rossi Fotogrammetri, Italy.



Image courtesy of AAM Hatch, Australia.

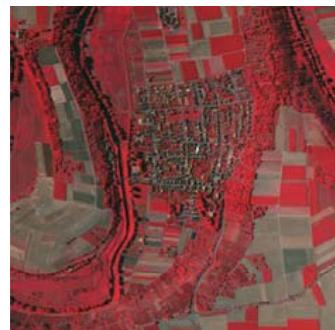


Image courtesy of Z/I Imaging, Germany.

Security, Government & Infrastructure



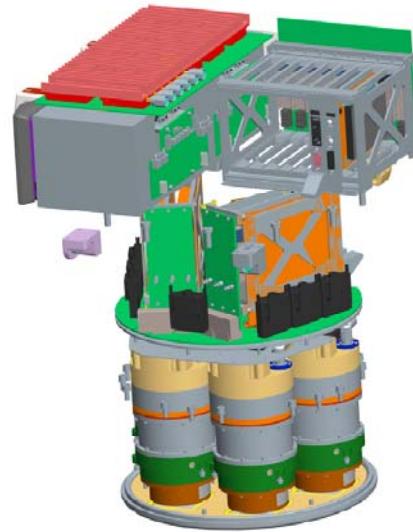
Agenda

- ❑ Camera System Overview
- ❑ Sensor System
- ❑ Radiometric Calibration
- ❑ Test Flight results
- ❑ Conclusions



System Overview

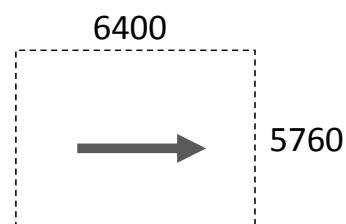
- 4 multi spectral camera heads + “cargo space”
 - Real TDI
 - 1:1 color resolution
- 2 SSDC (Solid State Disc Cartridges) to capture 2000 or 4000 images
 - Sustained data transfer rate of 160 MByte/sec
- 1 sec cycle rate
 - Allows for 0.06 [m] GSD (2.4 [inch]) with **80% end lap at 152 [knots]**
- Real Time histograms and thumbnails
 - Features **quality inspection** during flight
- Operating range
 - Temperature: 0 – 40° C
 - Altitude: 8000m AMSL



✓ Capture best quality imagery possible!

Photogrammetric System Properties

- RMK D footprint
 - 6400 x 5760 [pixel]
 - 46.08 x 41.47 [mm]
- Field of view
 - 54.2° x 49.5° [deg]
- Focal Length
 - 45 [mm]
- Pixel Size
 - 7.2 [μm]
- Height / Base ratio
 - 2.4

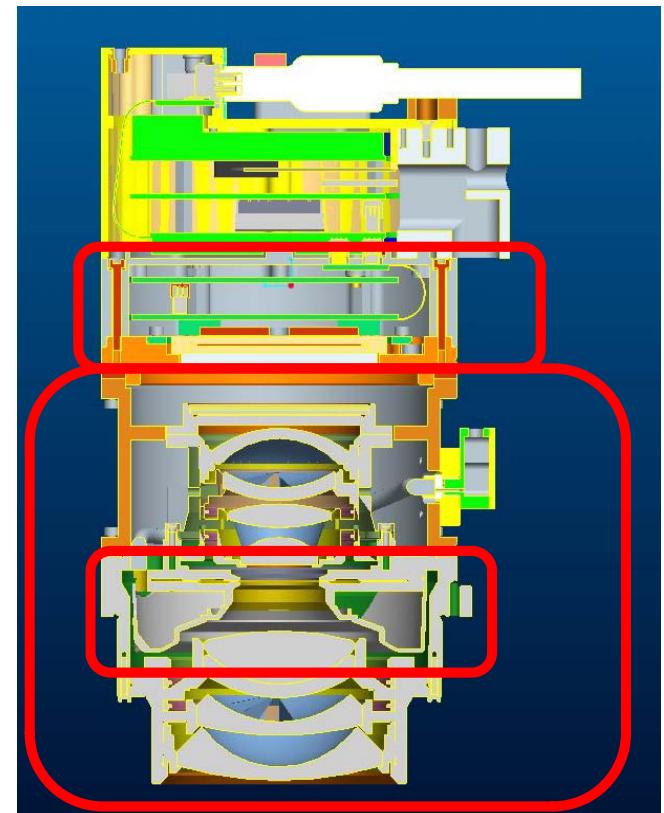


Height AGL [m] / [ft]	Image Scale	GSD [m] / [in]	Footprint [m] / [ft]
500 1640	1:11.111	0.08 3.1	512 x 461 1680 x 1512
1000 3280	1:22.222	0.16 6.3	1024 x 922 3360 x 3024

✓ Excellent Height to Base ratio of intermediate angle camera is unique for mid format cameras!

Sensor System

- Optical System
- Shutter
- Sensor

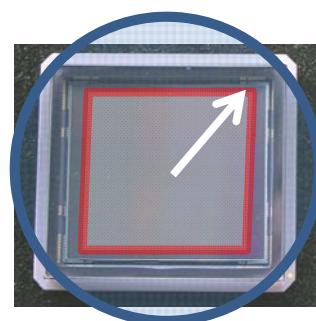


Optics

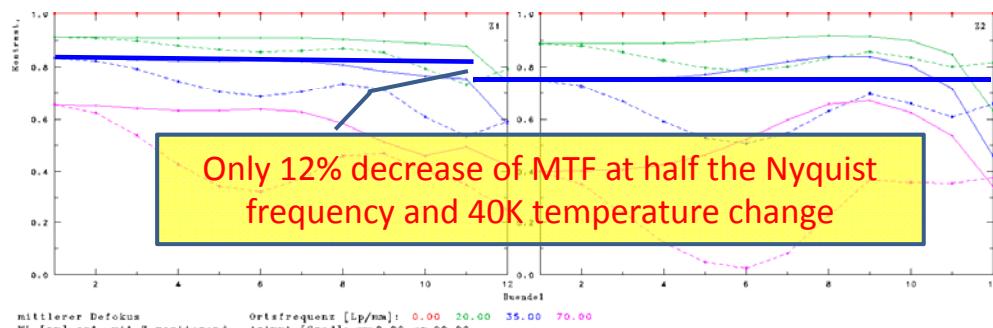
- Compute MTF
final image shall be smaller!

Image Height CCD
33 mm

Image Height **Final Image**
31 mm
(white arrow)



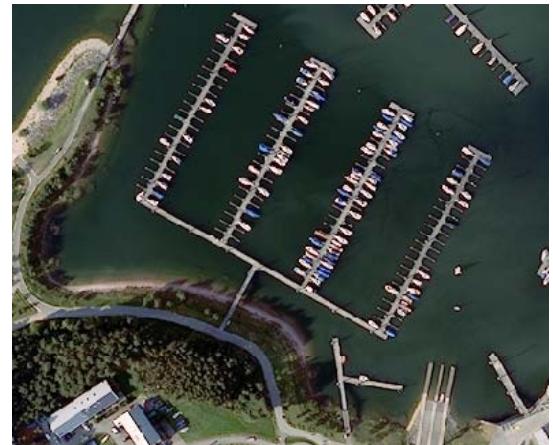
- Low sensitivity to changes in air pressure (10%) and temperature (12%)



(D. Döring (2009) Carl Zeiss AG, Jena)

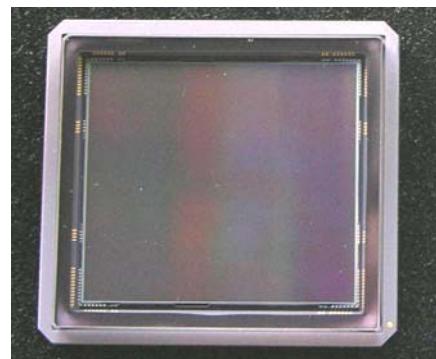
Shutter

- ❑ Mechanical shutter with 7 blades
- ❑ Last “remaining” moving part in a digital sensor
- ❑ Measure position of shutter blades
 - Auto adjust mechanical deviations
 - Increase color stability



Sensor

- DALSA (FT 53) 42 Megapixel
- 7.2 micron pixel size
- 6096 x 6846 pixel
- 14 bit A/D converter
 - 14 bit = 16383 DN
- 70 db dynamic range
 - 3162 DN or \approx 11.6 bit effectively



$$\begin{aligned} n [\text{db}] &= 20 \log \frac{DN}{DN_0} \\ DN &= 10^{\frac{n[\text{db}]}{20}} \end{aligned}$$

$$\begin{aligned} DN &= 2^b \\ b &= \frac{\log DN}{\log 2} \end{aligned}$$

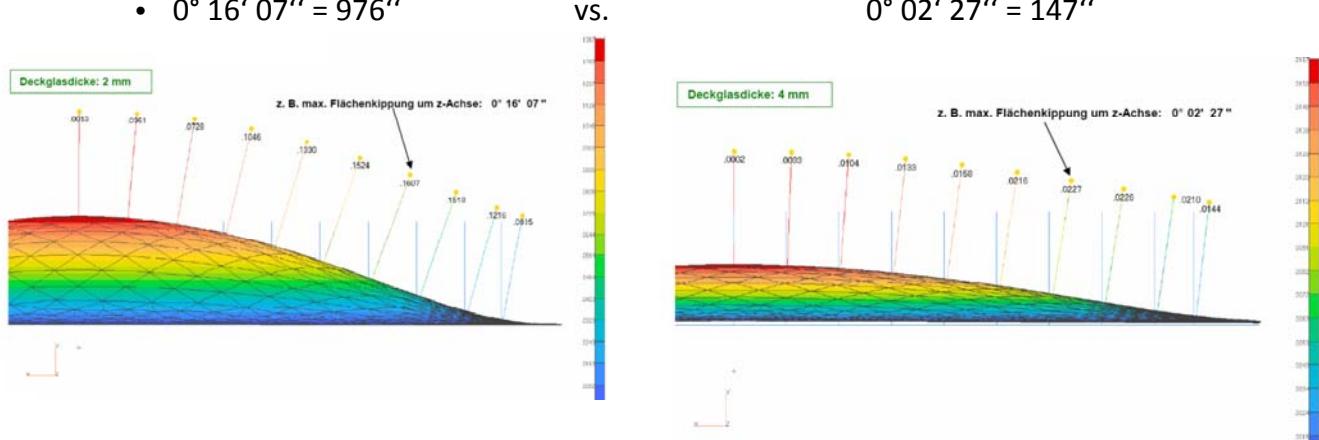
- ✓ 14 bit A/D converter minimizes quantization errors

- Customized CCD - Intergraph proprietary design

Sensor ...



- RMK D CCD is sealed with 4 mm front glass
 - Normal CCD's covered with 1.4 – 2 mm front glass only!
 - Withstand changes in air pressure $\Delta H = 8000\text{m}$
 - Reduce deflection by a factor of 6
 - $0^\circ 16' 07'' = 976''$ vs. $0^\circ 02' 27'' = 147''$



- Capture best quality imagery possible – and maintain highest possible system stability during operation!

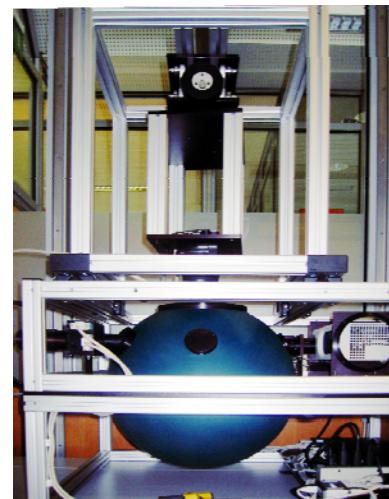


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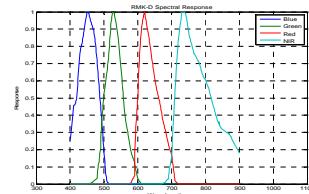
Radiometric Calibration



- Absolute calibration
 - Combine xenon arc and tungsten light source
 - Produce solar spectrum comparable to 60° deg solar zenith for 50% reflective target (TOA)
 - Adjust light sources with calibrated spectrometer
 - Absolute accuracy: < 1%



Band	Peak (nm)	50% Points (nm)	10% Points (nm)
Blue	450	419-488	390-503
Green	525	499-557	482-592
Red	620	600-662	530-704
NIR	733	709-816	695-921



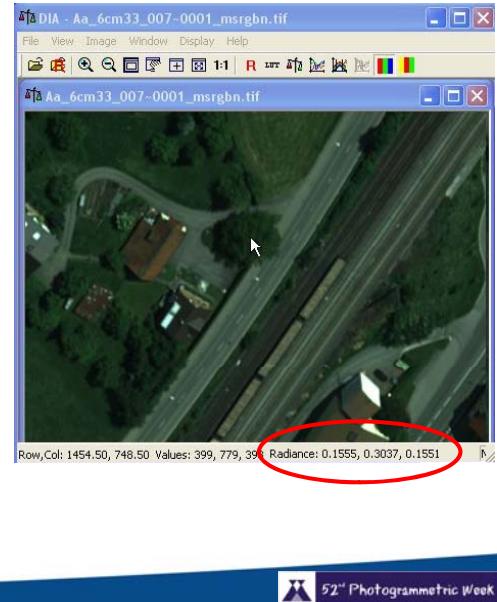
(R. Ryan (2009) I2R Corp., USA)

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Absolute Calibration & Radiometry



- ❑ Increase color stability across different cameras
 - Replace sensors in the field
 - Combine multiple sensors in one project
- ❑ Deliver images for classification purpose
 - Supplement remotely sensed data (cloudy satellite images)
 - Compute vegetation indices (NDVI)
 - Use for various monitoring tasks
- ❑ Write calibration coefficients into image header during post processing
- ❑ Measure radiance values from images
 - Radiance unit $\left[\frac{\mu W}{cm^2 sr nm} \right]$



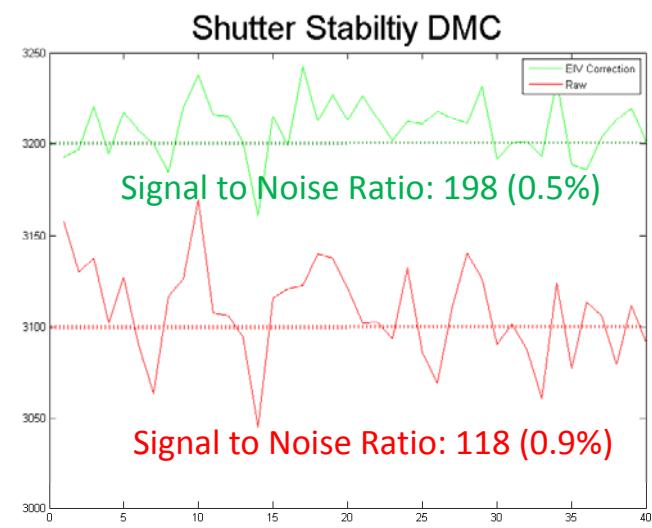
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Color Stability



- ❑ Efficiency proof for calibration - apply shutter measurements
 - Reprocess 40 bright images
 - Large opening F-stop 4.0
 - Short exposure time 4 ms
 - Apply flat fielding
 - Check signal to noise
 - before (RED)
 - after (GREEN)
- ❑ Expectation
 - Accuracy of relative radiometry <1%

✓ Maintain best color stability possible for frame sensors!



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Test Flight

- Test flight Aalen
 - 60% / 60% overlap
 - 5 strips / 11 images
 - NE & SW
 - 42 control points
 - 8 cm GSD
 - GPS /IMU

- Test flight Cologne
 - 8 cm GSD



Geometric accuracy – 8 cm block

- Compare different triangulation results
 - Control only
 - Control and GPS/IMU

- Different control configurations

DMC Block Geometry	Control/Check	Control Points Only			Control + GPS/INS		
		RMS Check Points					
		X	Y	Z	X	Y	Z
176 - Cross Strips EW,NS	4 / 36	0,026	0,034	0,046	0,025	0,035	0,040
	5 / 35	0,027	0,031	0,034	0,025	0,032	0,031
	4 / 36	0,030	0,043	0,060	0,029	0,040	0,045
44 – Photos – EW (60/30%)	5 / 35	0,030	0,041	0,056	0,029	0,039	0,042

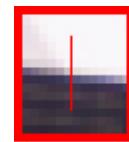
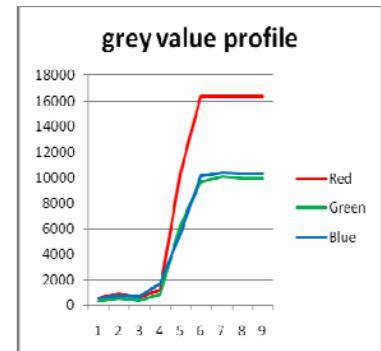
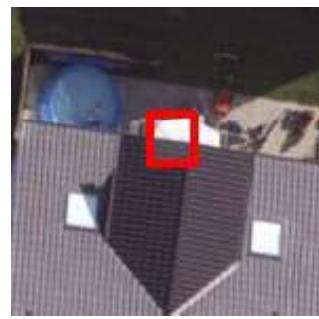
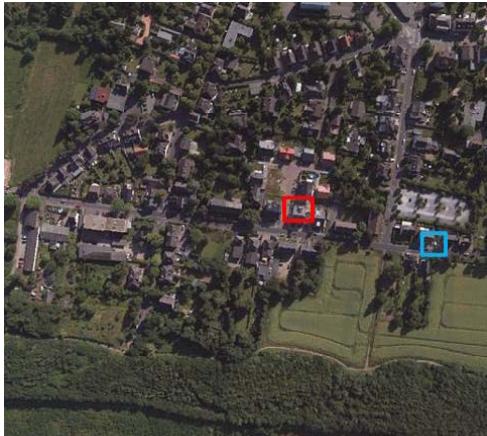
RMK D Block Geometry	Control/Check	Control Points Only			Control + GPS/INS		
		RMS Check Points					
		X	Y	Z	X	Y	Z
220 - Cross Strips EW,NS	4 / 35	0,047	0,032	0,041	0,043	0,027	0,028
	5 / 34	0,039	0,033	0,043	0,035	0,027	0,030
	4 / 36	0,038	0,047	0,063	0,033	0,044	0,036
55 Photos - EW (60/30%)	5 / 35	0,037	0,044	0,058	0,033	0,041	0,036

Different operators for DMC and RMK D!

Image Quality

- Edge analysis

- Select edge close to image center cross flight direction
- High contrast - app. 10000 DN
- Edge slightly tilted – 8.3° [deg]
- 9 pixel profile measurement



- Dynamic range in the scene is ≈ 9600 DN

Conclusions

- RMK D is a new platform and allows to mount 1 additional sensor



- System is designed to deliver stable quality results within the operating range
- RMK D delivers metric imagery for geometry and radiometry
- Results from a manually assembled system do match the accuracy of the DMC ...

... more to come

Thank you for your attention!



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