

The evolution of Vexcel's Camera Calibration and Image Processing Technology

**JACIE 2011
Boulder, CO**

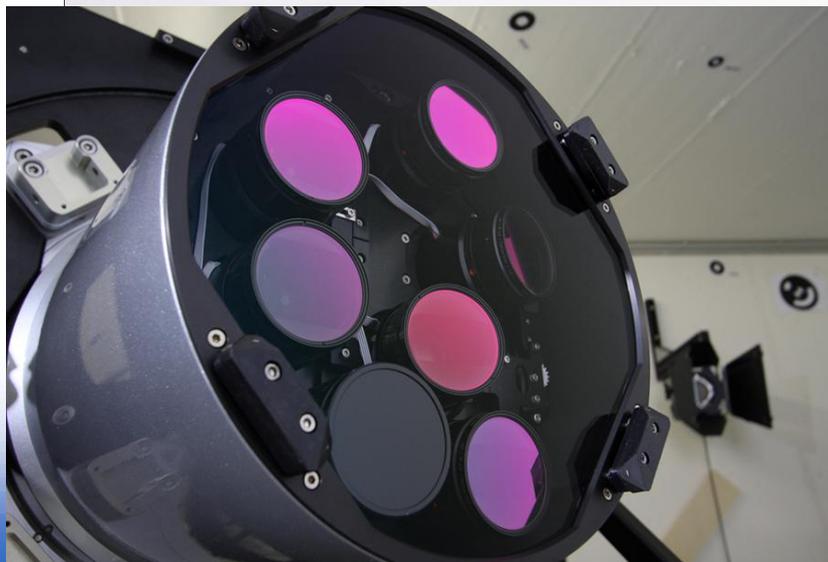
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The UltraCam Family



| | |
|-----------------------|-------------|
| UltraCam D | 2003 |
| UltraCam X | 2006 |
| UltraCamXp | 2008 |
| UltraCam Xp WA | 2009 |
| UltraCam Lp | 2010 |

UltraCam G 2010



Evolution of UltraCam

86 Mpix



UltraCam D
2003

136 MPix



UltraCam X
2006

196 Mpix



UltraCam Xp (Xpwa)
2008/2009

Highest Productivity
Best Image Quality
State of the Art
Components
Software leveraged
Hardware



UltraCam Sensors & Electronics Boards



Workflow

- **Lab Calibration (Graz Calibration Lab)**
- **Flight Mission**
- **Image post-processing including image stitching**
- **Aerial Triangulation and Bundle Adjustment**



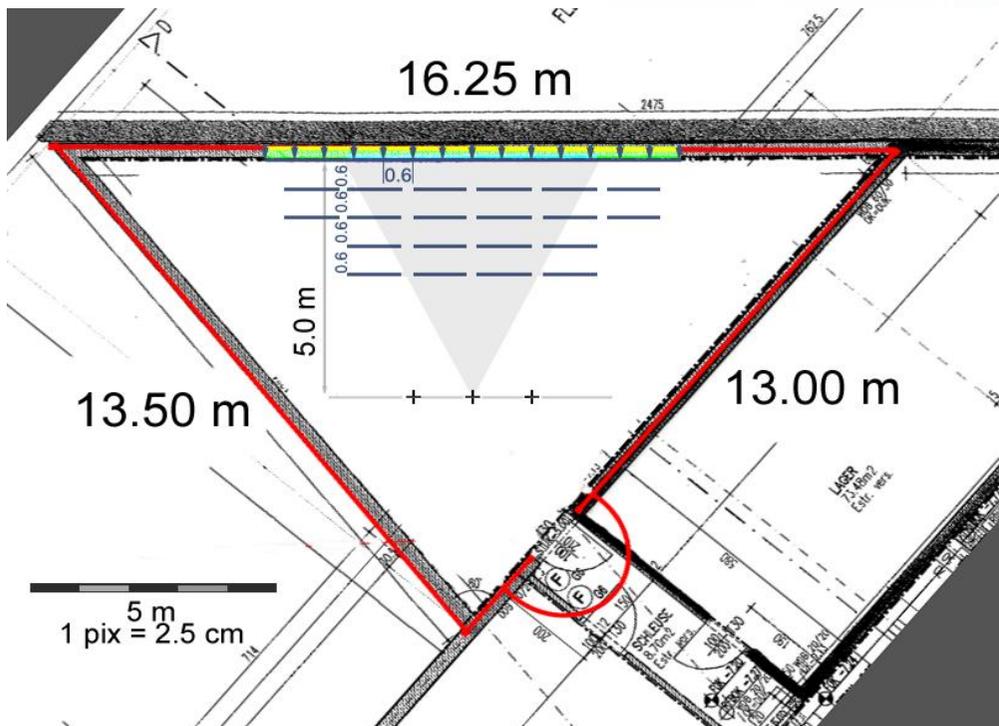
Lab
Calibration

UC flight
mission

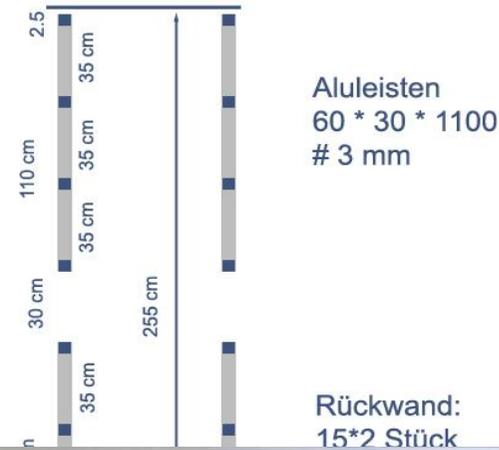
Image post-
processing

AAT

Control and Calibration Laboratory Graz, Anzengruberbergasse 6/ U2



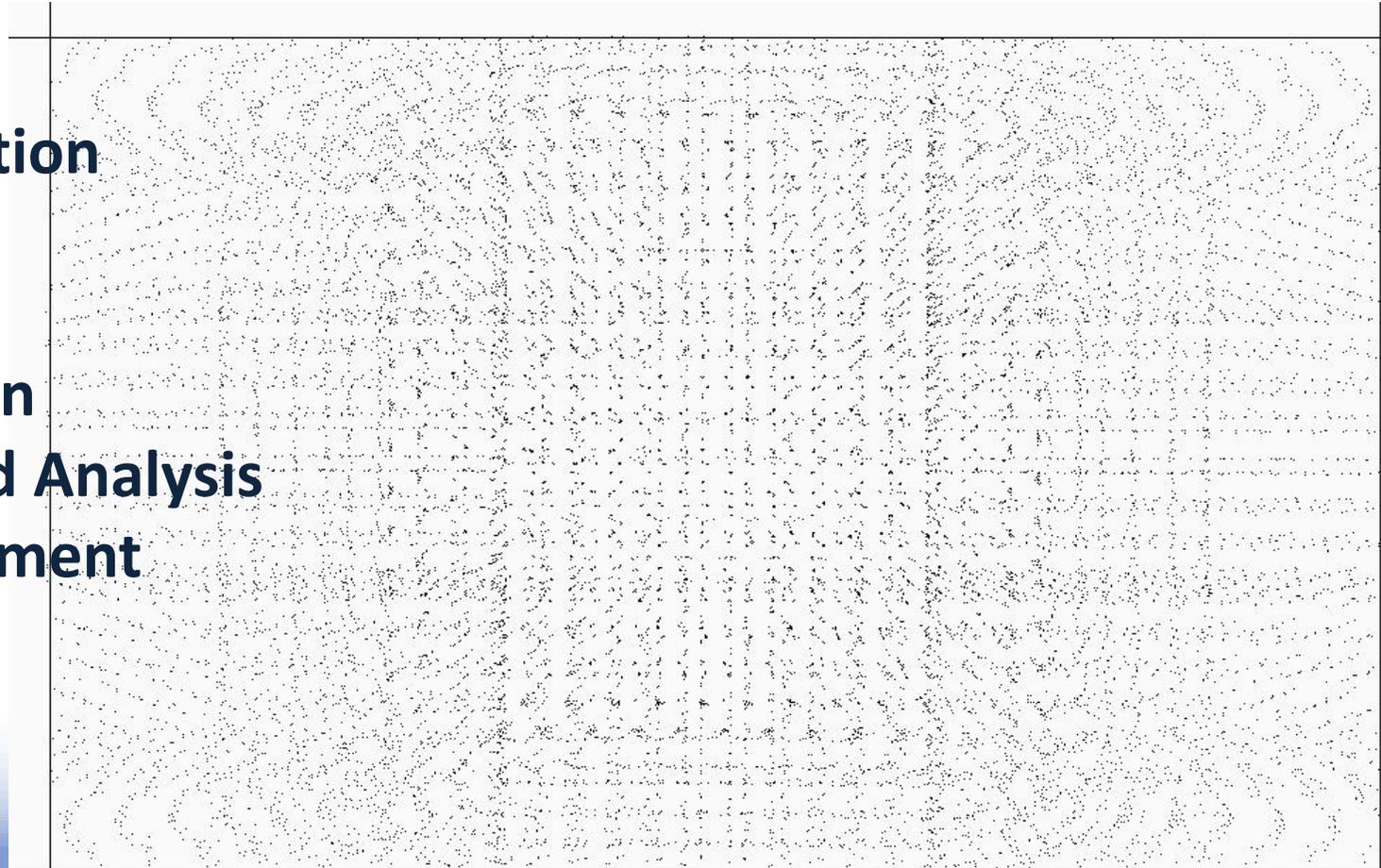
Scale 1:10 1:50 1:37 1:25
103 * 67 380 * 255
515 * 335 257 * 167



Lab Calibration

**Redundant dataset of image measurements
Least Squares Adjustment to estimate specific
Camera Parameters**

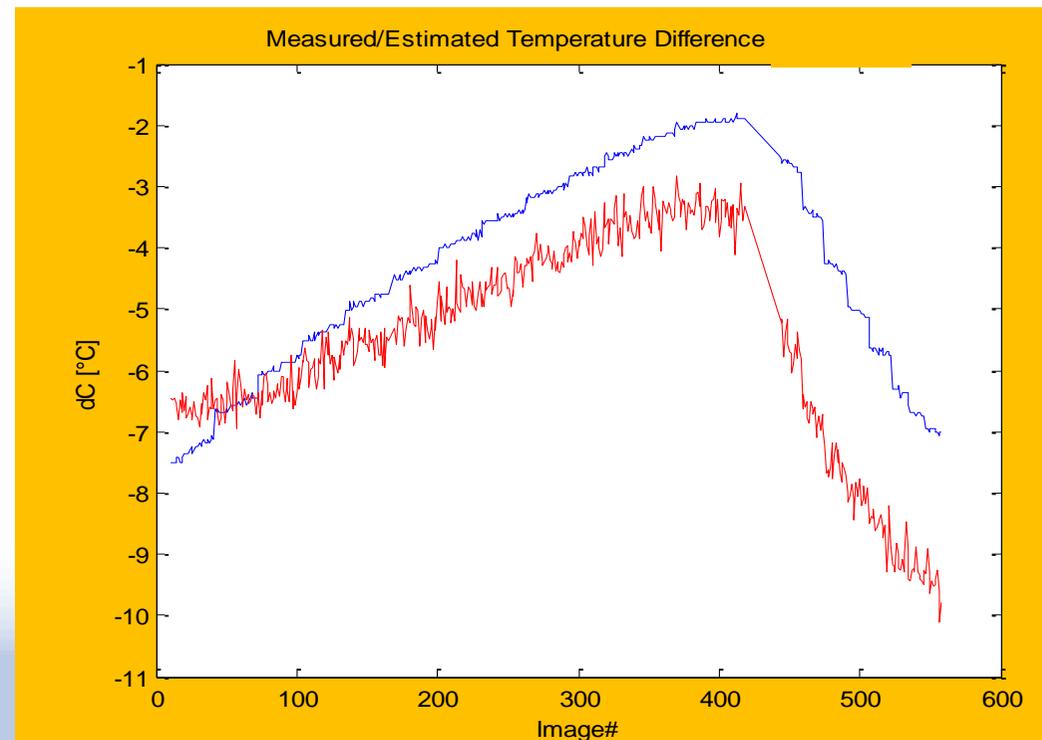
**Radiometric Calibration
Sensor Calibration
Shutter Calibration
Vignetting Correction
Brightfield/Darkfield Analysis
Dark Current Measurement
Color Adjustment**



Lab Calibration

■ Recording of the Camera Temperature

- Mean temperature C_0 at calibration time is recorded and included in the calibration data
- Temperature C_F is recorded during flight mission
- TDM correction uses temperature difference $dC = C_F - C_0$
- dC can now be derived directly from the sensor measurements



Lab Calibration (UCLp, UCG)

- **Calibration of each individual cone**
 - Determination of the position of each sensor within the cone
 - Distortion LUT
- **Platform calibration**
 - The relative orientation of all cones with respect to the master cone is determined
 - Layer images can be transformed using an epipolar transformation prior to stitching
 - Epipolar transformations are stored in the calibration data

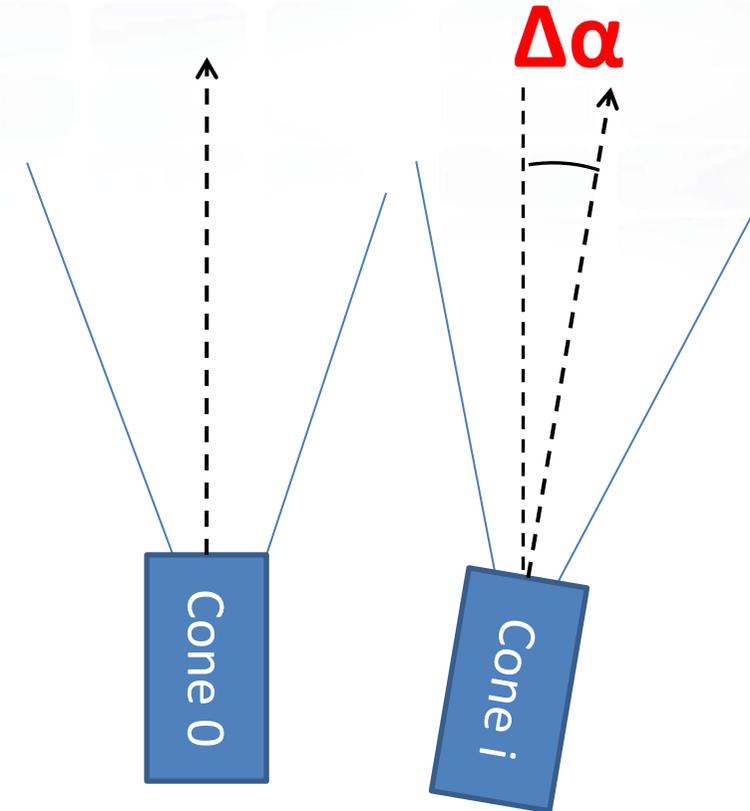
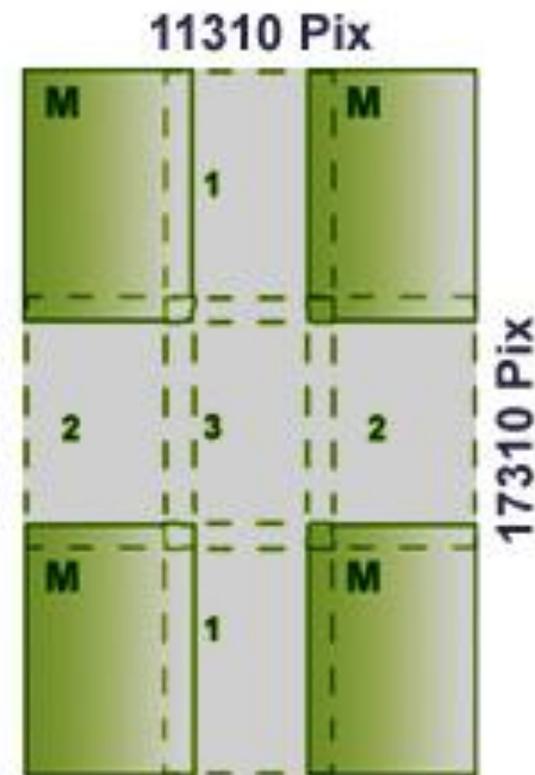


Image Postprocessing (Layer Transformation / Stitching)

Microsoft



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a Microsoft company

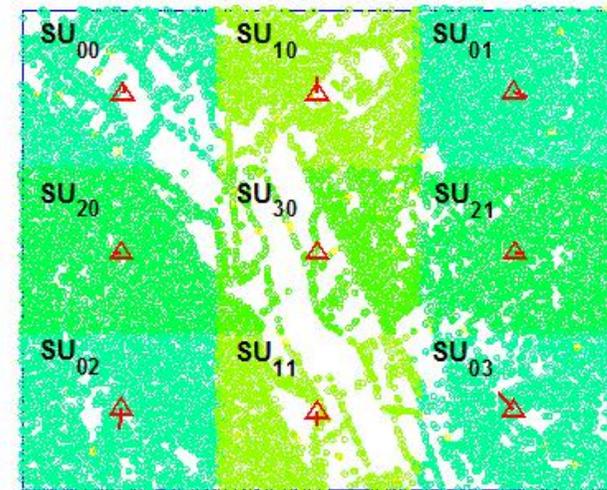
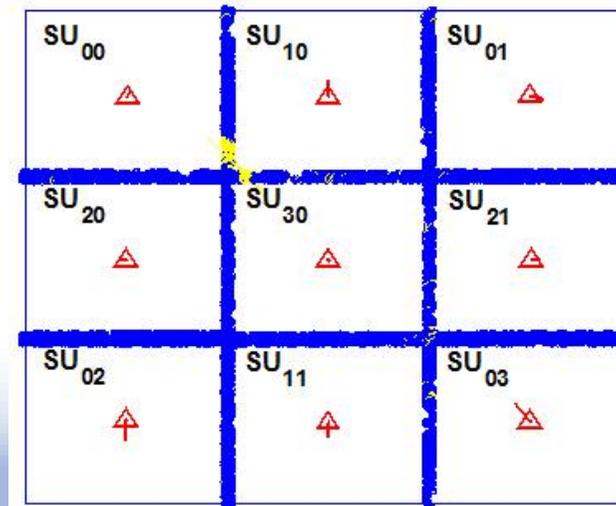
Layer Transformation/ Monolithic Stitching

Microsoft

- **Layer Transformation Concept:**
 - Transform sensor image into layer
 - Transform layer from pan onto master cone layer
- **Monolithic stitching**
 - Geometry Information from color channels is introduced
 - Mosaiking and color referencing is done in a single adjustment procedure

Layer Transformation/ Monolithic Stitching

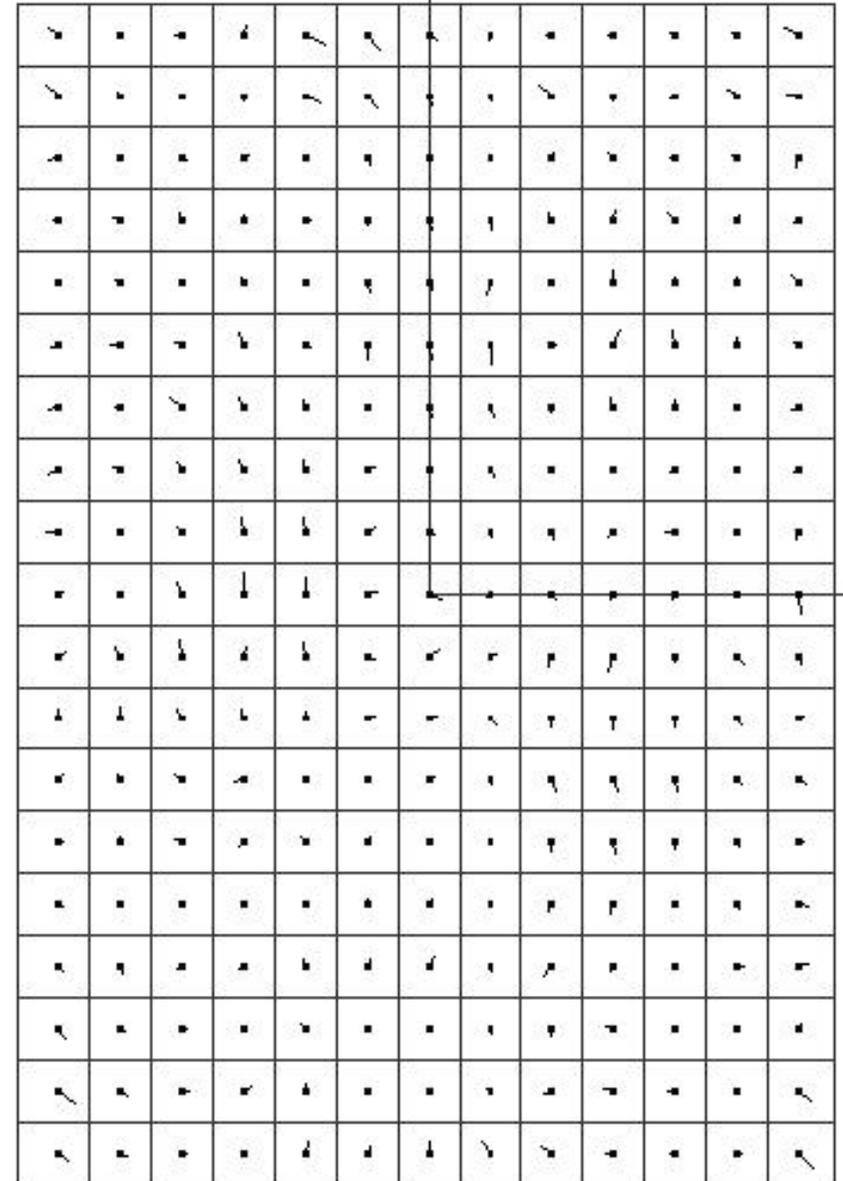
- Tie points are matched between PAN sensors and between PAN and green color channel
 - 10.000 P/P tie points (UCXp)
 - 17.000 P/C tie points (UCXp)
- Tie points are transformed into the VIP
- Residuals between homologous points are minimized (iterative LS adjustment)
- Magnitude of Transformation Parameters is minimized



Results from a Large Scale Mission/AT Results

Microsoft

Camera: UltraCam Xp
Pixel Size: 6.0 μm
GSD: 5 cm
Images: 235
Layout: 60/80, cross strps
Sigma_o: 0.71
CheckPt Res: 2.8 / 1.5 / 2.6 cm
Image Res: 0.6 / 0.6 μm



Monolithic Stitching

A robust concept

Microsoft



- Project flown over desert area
Some areas with very poor image texture
- ~6500 images
- Camera model: UCX
- GSD: 5cm

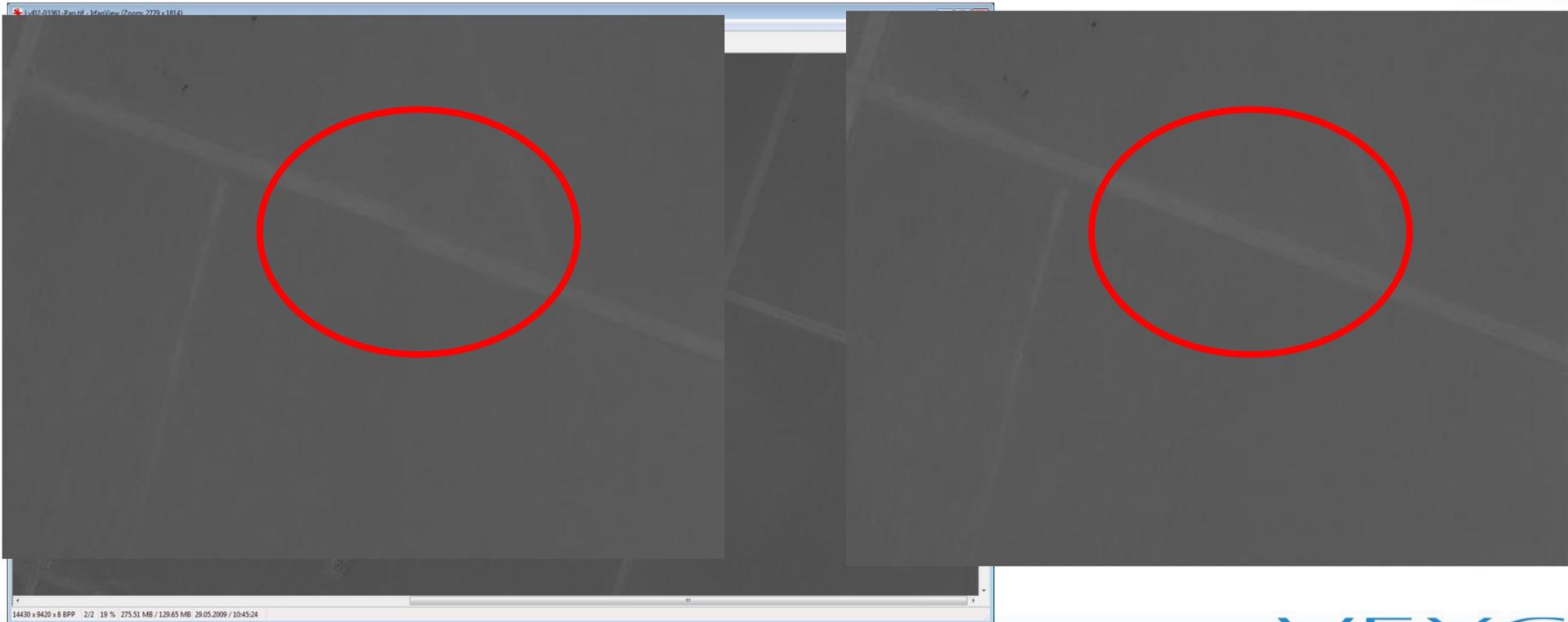
Monolithic Stitching

A robust concept

Microsoft

- **Standard Stitching**
(Example: dessert)

- **Monolithic Stitching**
(=problem solved)



UltraCam Lp

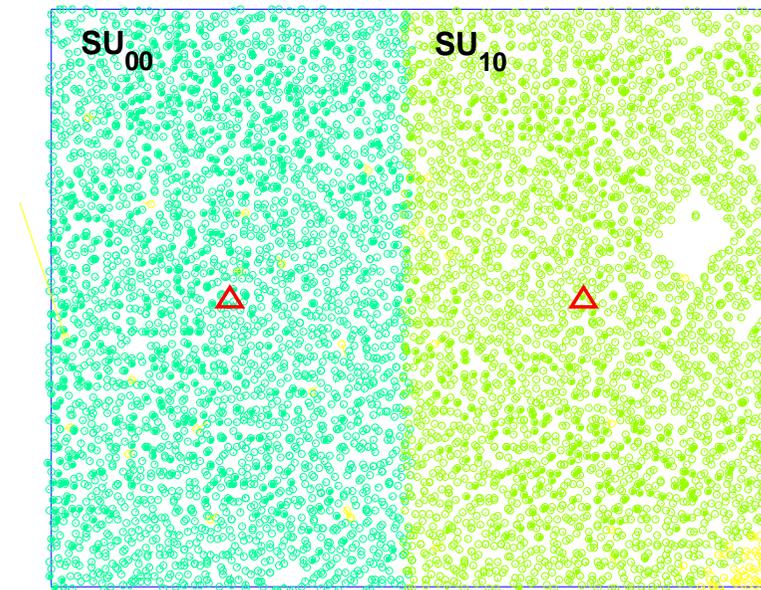
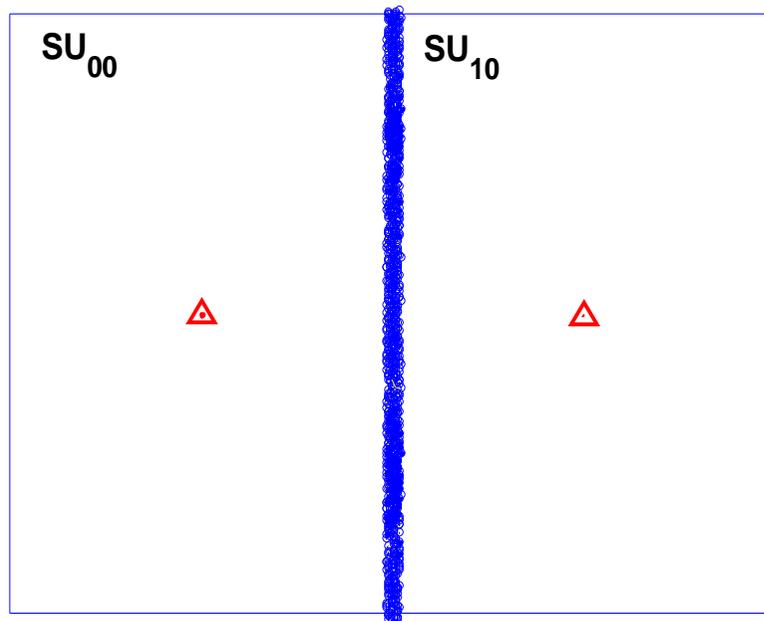
- 90 MegaPixel Mapping Camera
- Focal length 70mm
- Image format: 7920 x 11704Pixel (6,0 μm)
- Compact design (integrated DU)
- Forward motion compensation (TDI)
- 2 separated PAN cones
- RGB + NIR (PS ratio: 1:2)



Monolithic Stitching— adapted for UCLp and UCG

Microsoft

- Same basic concept as for UCXp
- PAN / Color overlap
- Results from AT: $\sigma_o < 1$

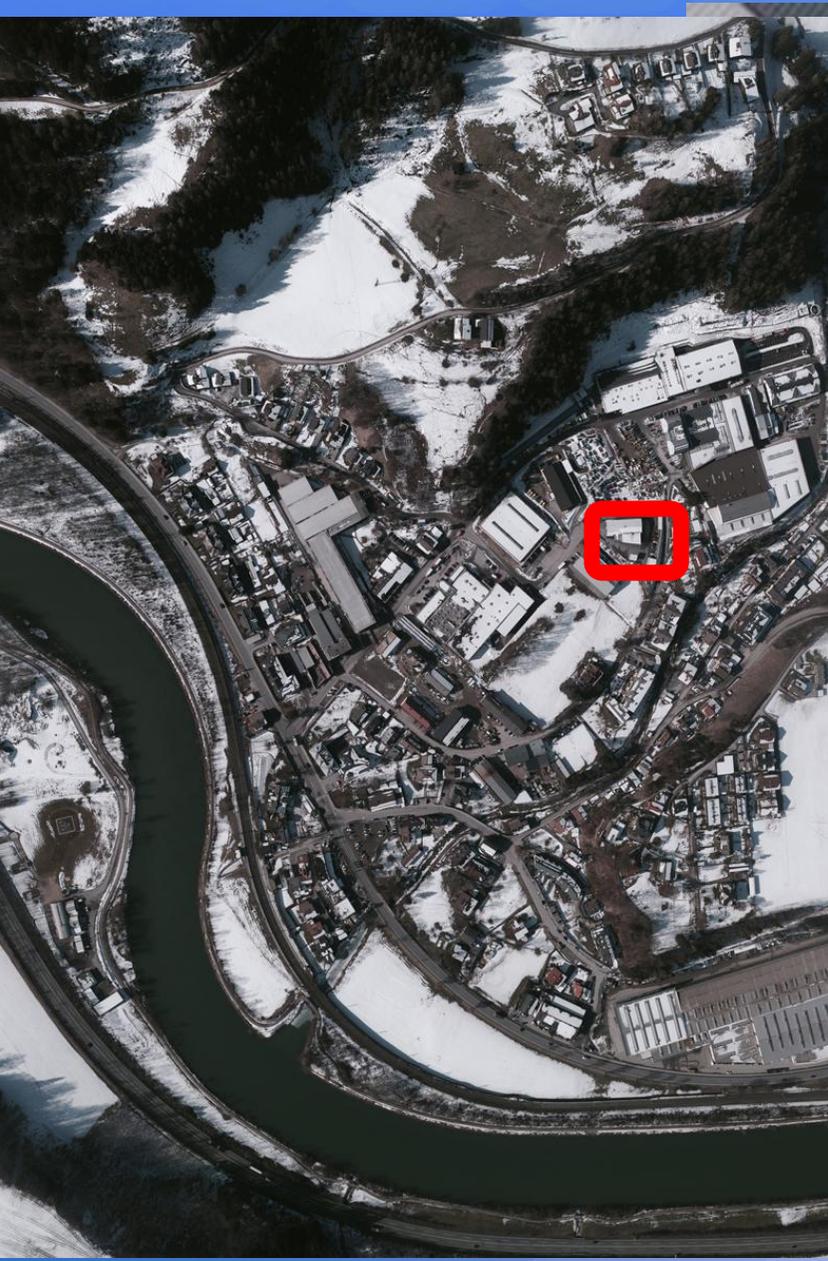


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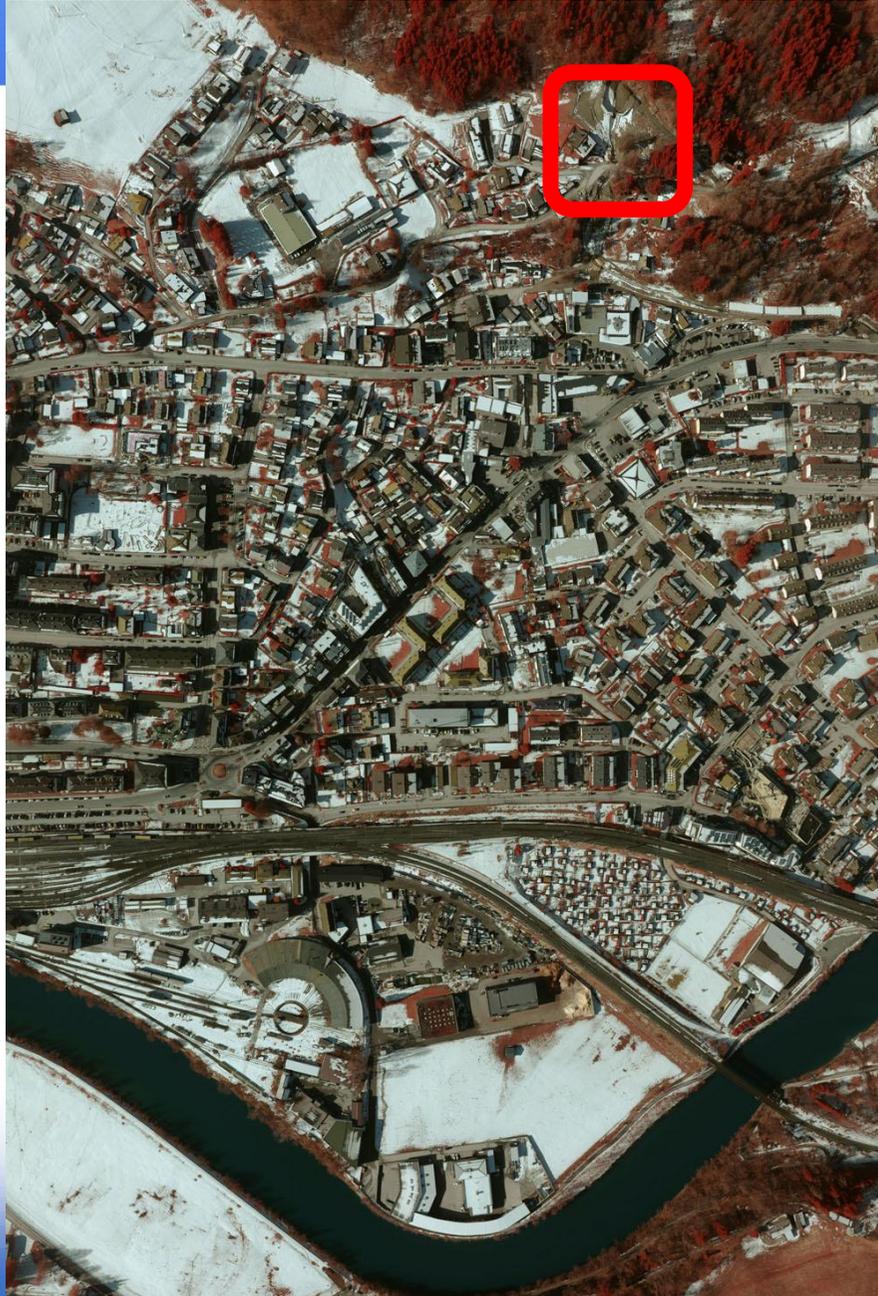
UCLp Images

Microsoft



UCLp Images

Microsoft



UltraCam G

Microsoft

Wide Area Mapping

PAN: 11280 by 7640 Pixel
NIR: 5960 by 3880 Pixel
RGB: 28200 by 3880 Pixel

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UltraCam G

Microsoft

Design Basics

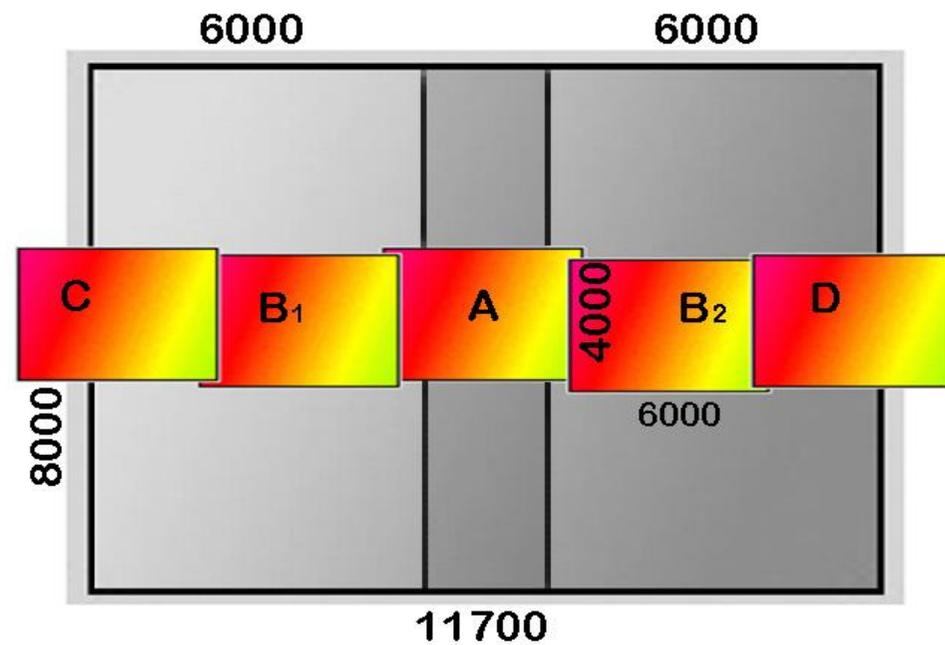
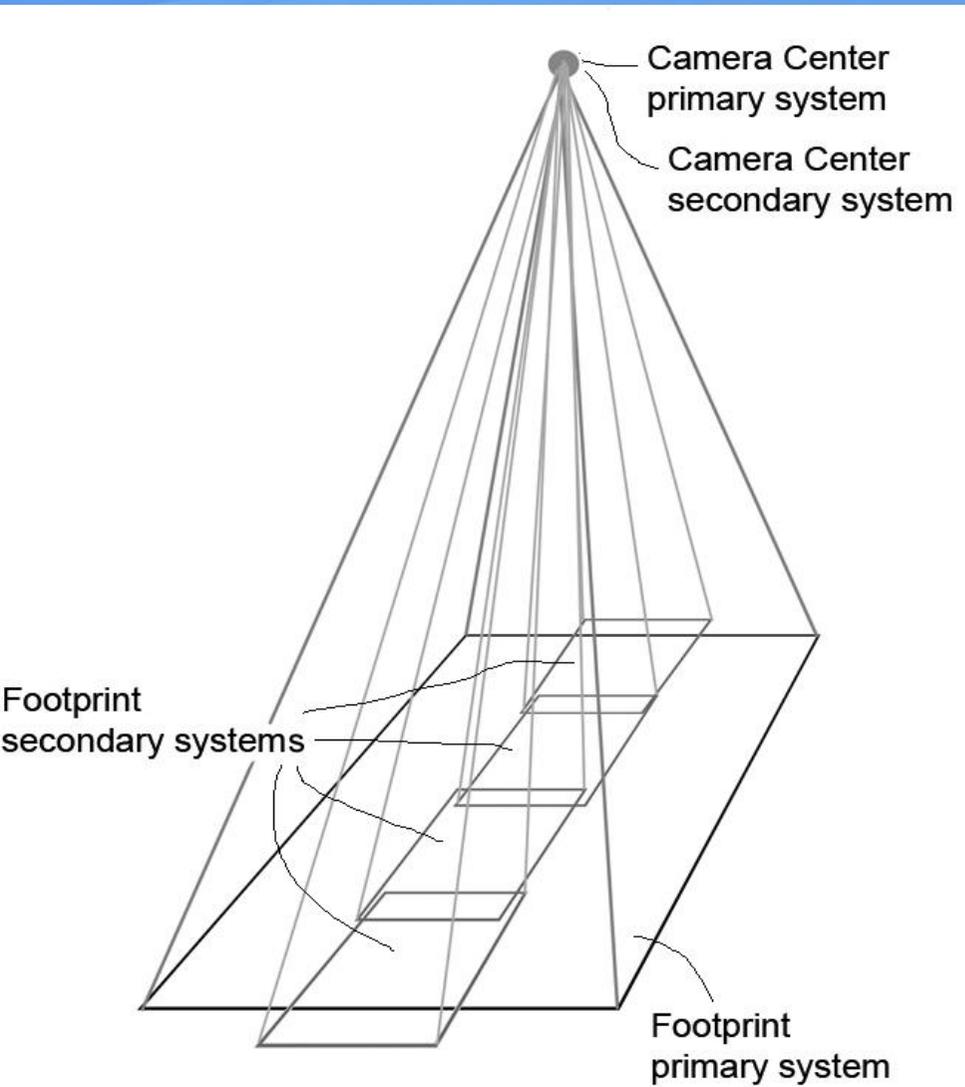
PAN: photogrammetric backbone
multiple forward overlap

NIR: slightly reduced footprint, still full coverage
adds multi spectral capabilities

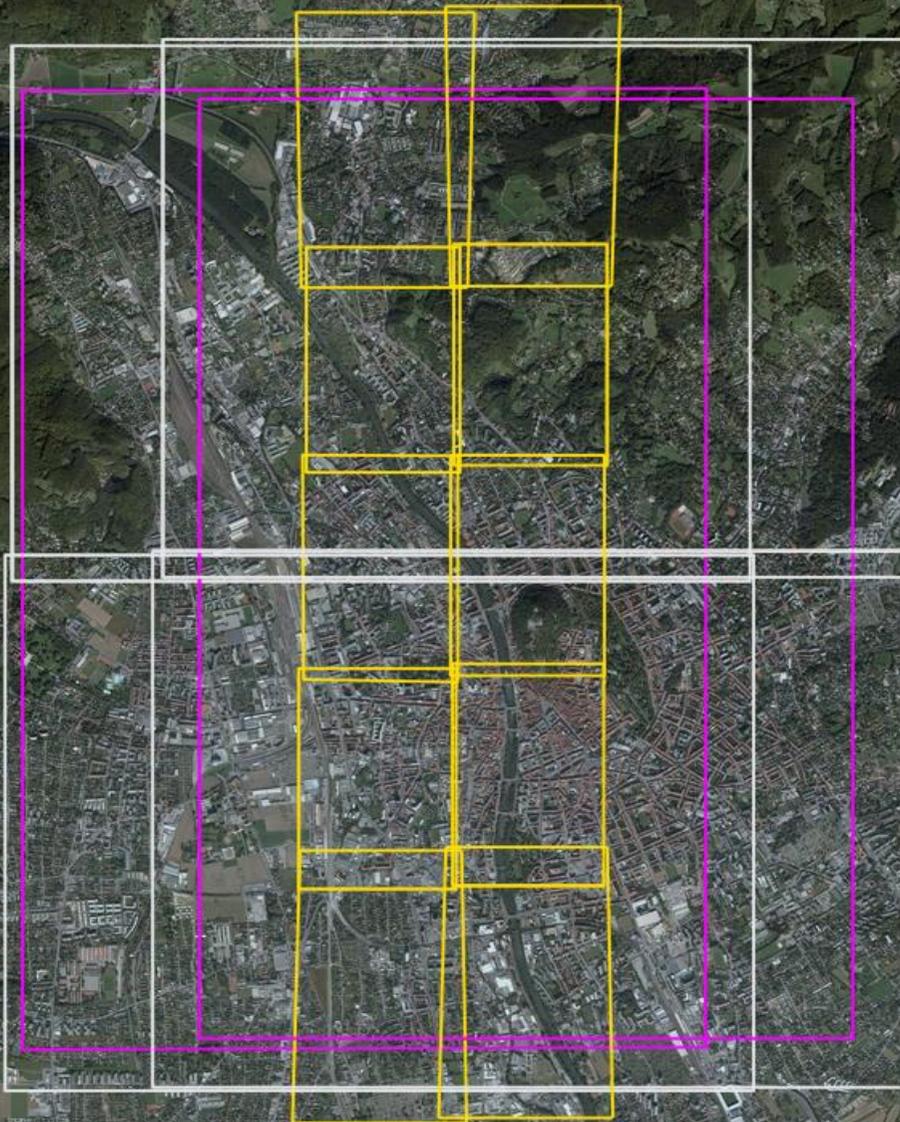
RGB: enhanced resolution for Ortho Mapping
single terrain coverage

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64 **65**



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Conclusions

The UltraCam design Concept of Software Leveraged Hardware enables us to

- **Continuously improve**
- **Focus on optimal components**
- **Flexible adapt**
- **Maintain innovation**

Thank you for your attention!

