Keynote at ICEICE, Wuhan, 16 April 2011

Large-Scale Imaging
-
From Remote Sensing to Close Range

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CITR

Hon. Dr. Wan Gang, Minister of Science and Technology of China, The University of Auckland, March 28, 2011

Large-Scale Imaging in 1926

Archiv Hansa Luftbild AG, Münster

Large-Scale Imaging in 2007

DLR Germany, Institute for Robotics and Mechatronics
Sony Center Berlin
Stereo reconstruction from aerial images
Accuracy: 7 cm on ground per pixel

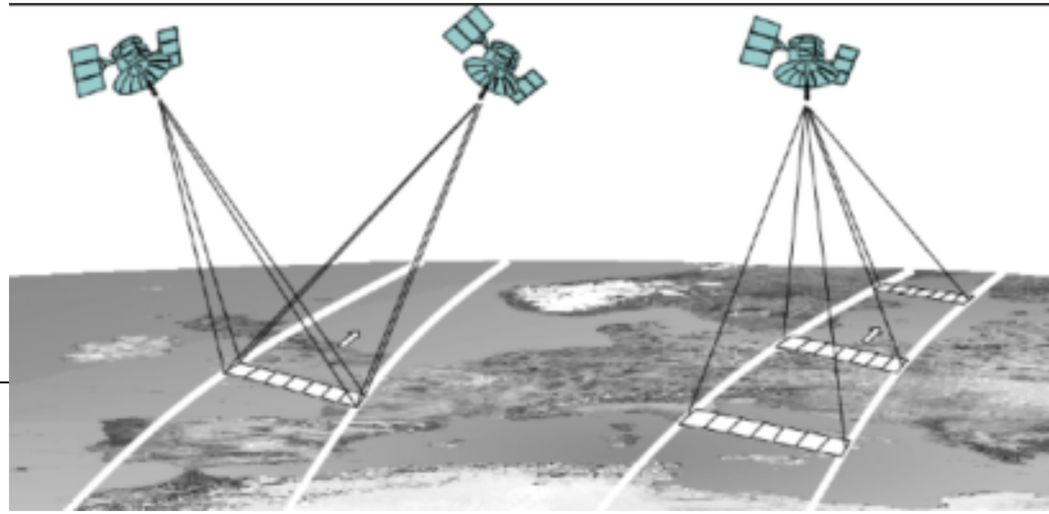
Anko Börner

Institute at Berlin-Adlershof

Design and production of airborne sensor line cameras for photogrammetry and space missions

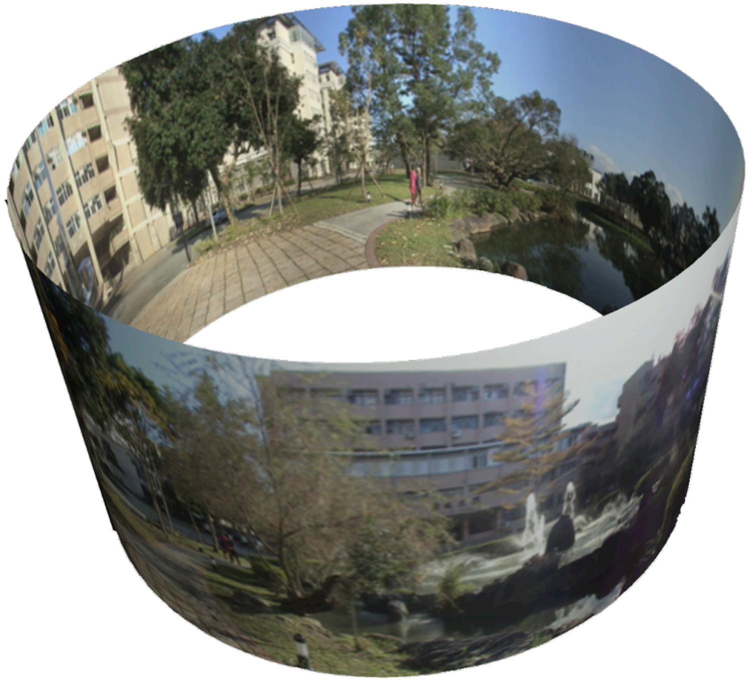
push-broom principle

stereo matching
3D visualization



Fay Huang

VRlab at National Ilan University



Animated panoramas
Motion capture for animations
Interactive development of games

CITR

The University of Auckland, Tamaki campus

Communication and Information Technology Research

Multimedia imaging

Theory of panoramic imaging, stereo matching, and 3D visualization

Anaglyphic stereo representation for an optimized stereo panorama

Former PhD students at CITR from China:

Fay Huang
Shou-kang Wei
Chia-yen Chen

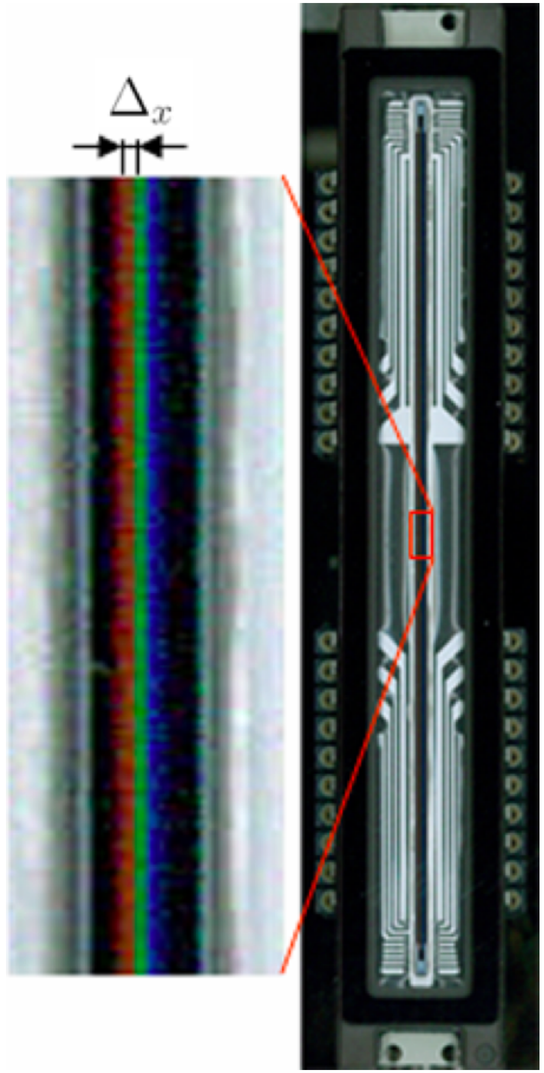
Tiangong Wei
Fajie Li
Qi Zang

Xiang Lin
Yizhe Lin
Ruyi Jiang

Applied technology: Linear cameras

2005: a 10,200 color pixel sensor-line

Example: a flat-bed scanner
runs a shorter sensor-line
accross documents



Δ_x = distance between R,G,B `sub-line'

1. Satellites, planets, remote sensing
2. Planes, aerial scanning, 3D city maps
3. City scenes, landscapes
4. Architectural photogrammetry
5. Close-range objects
6. Concluding remarks

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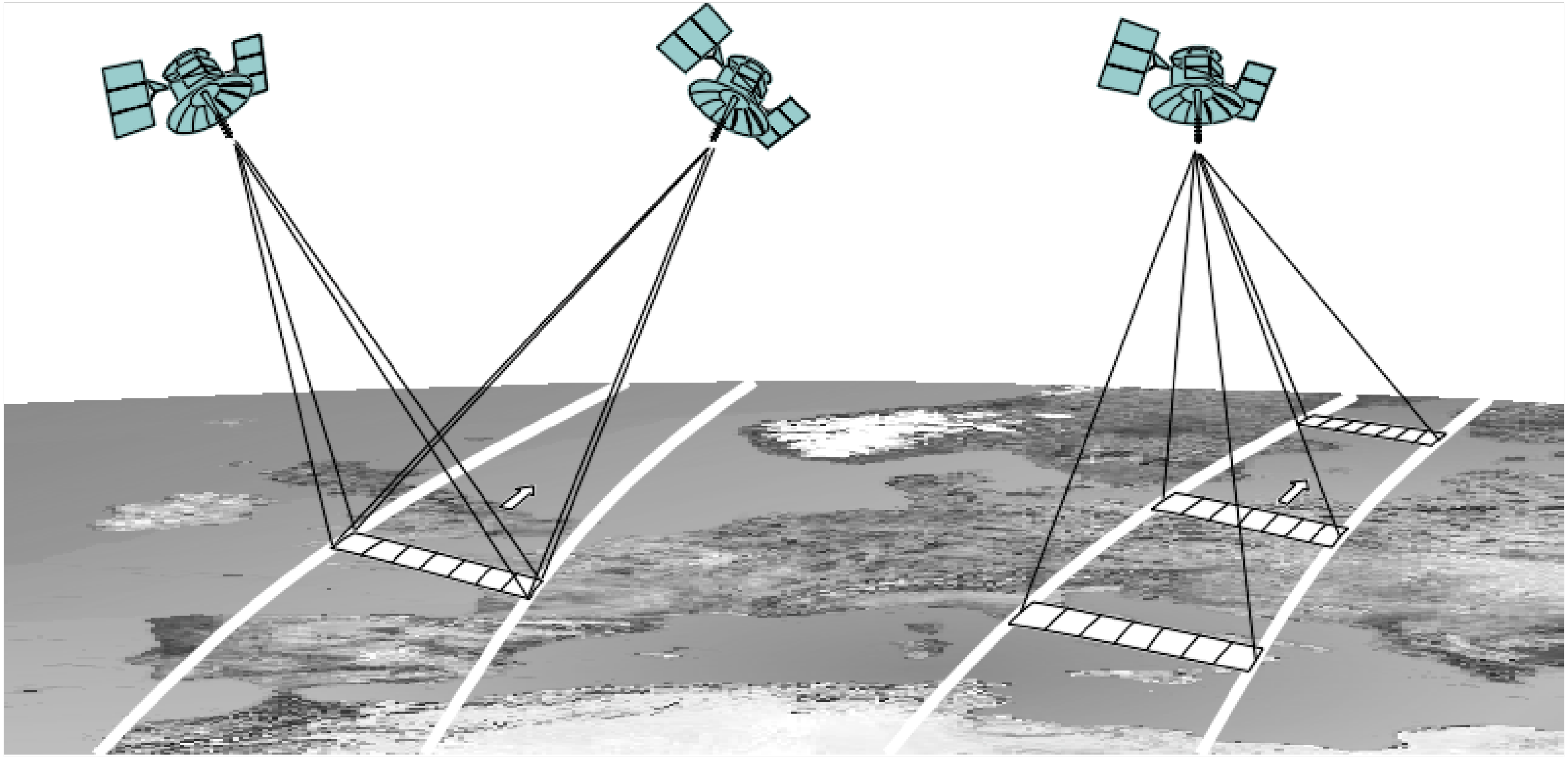
Satellites, planets, remote sensing

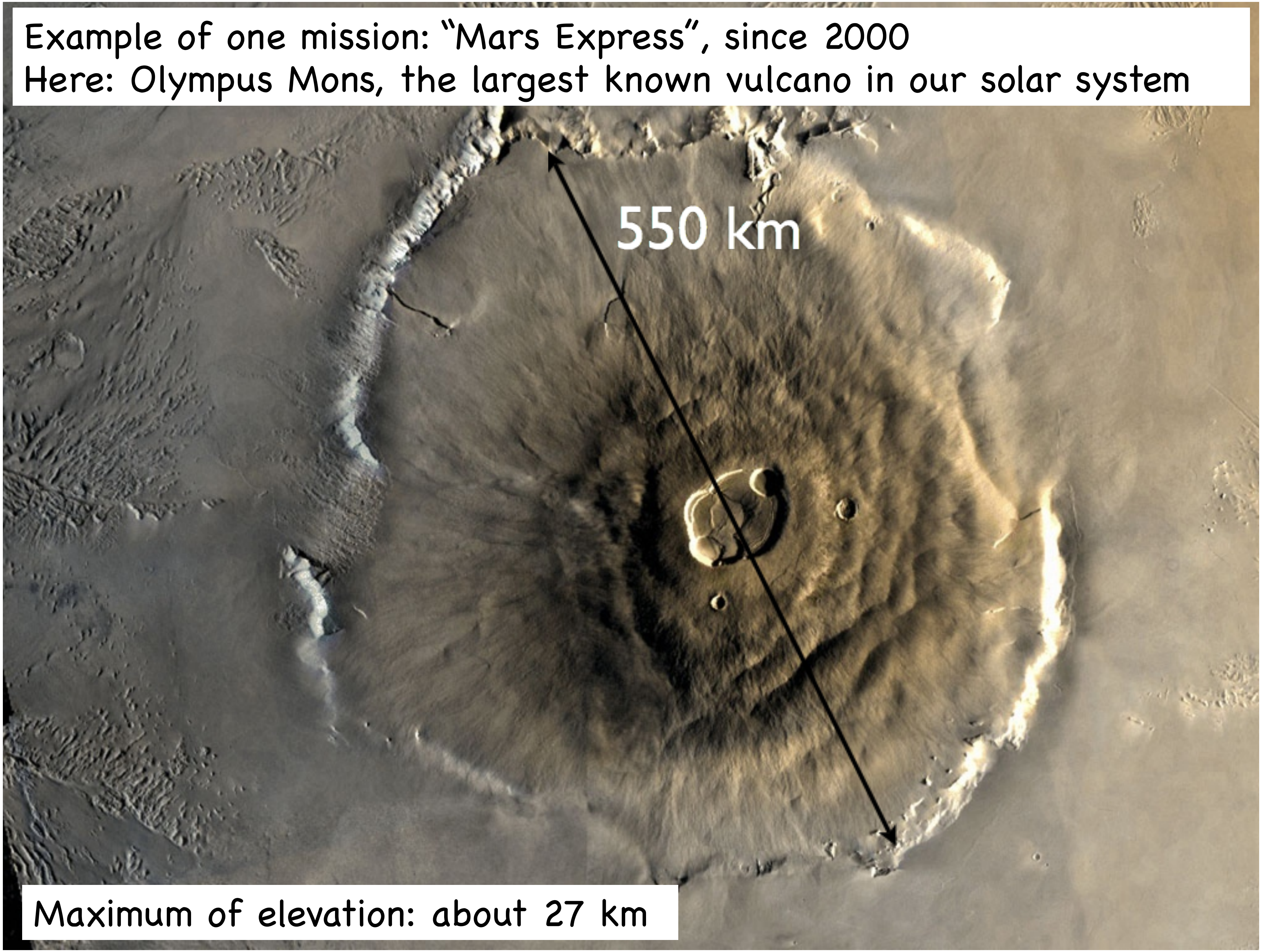
Basic recording principle and one example



The “pushbroom principle” applies sensor lines for aerial scanning.

Left:	1986 - across track	(SPOT, France)
Right:	1993 - along track	(MOMS, DLR)

Example of one mission: “Mars Express”, since 2000
Here: Olympus Mons, the largest known vulcano in our solar system



Maximum of elevation: about 27 km

3D digital surface model of Olympus Mons on Mars

Based on multi sensor-line scans (HRSC, DLR Germany), 2006

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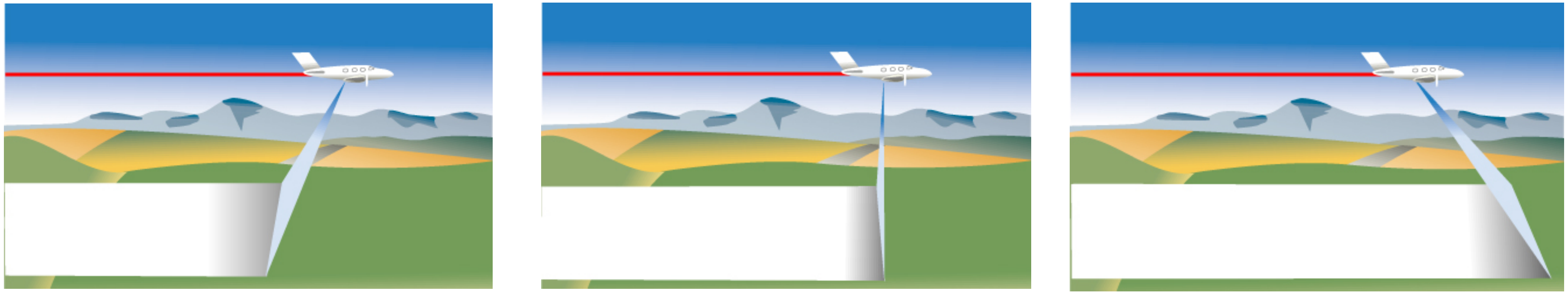
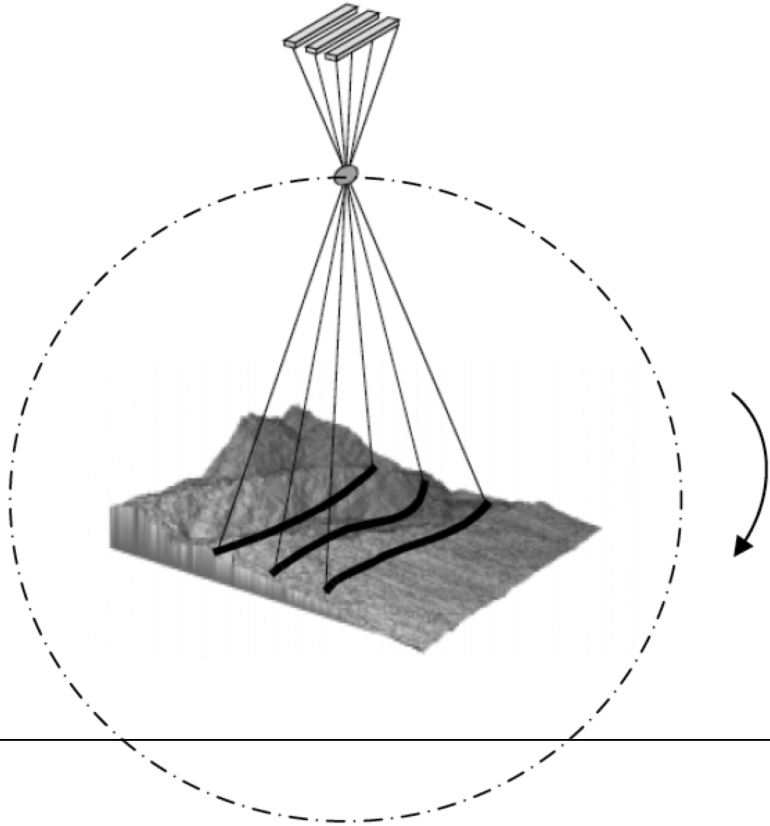
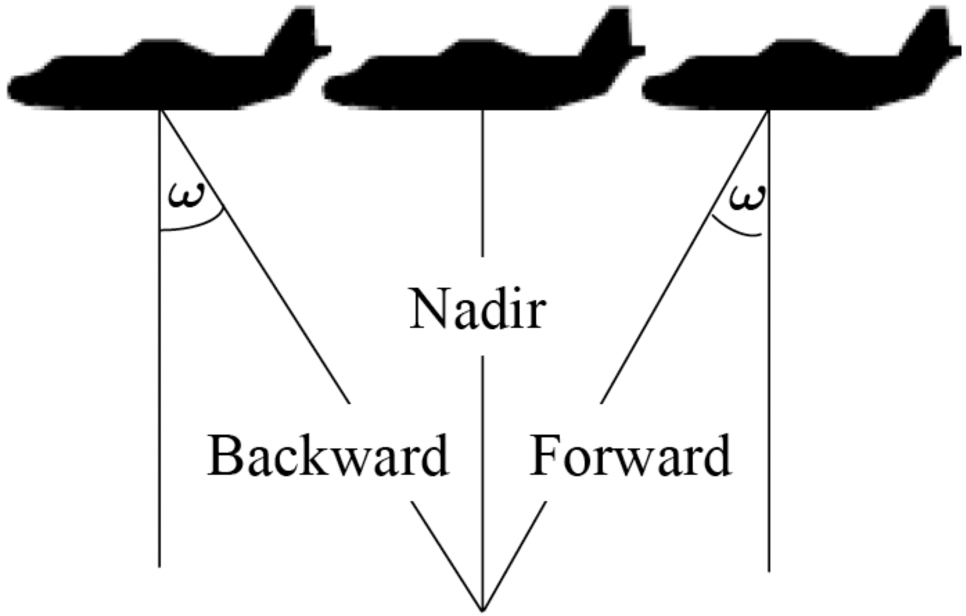
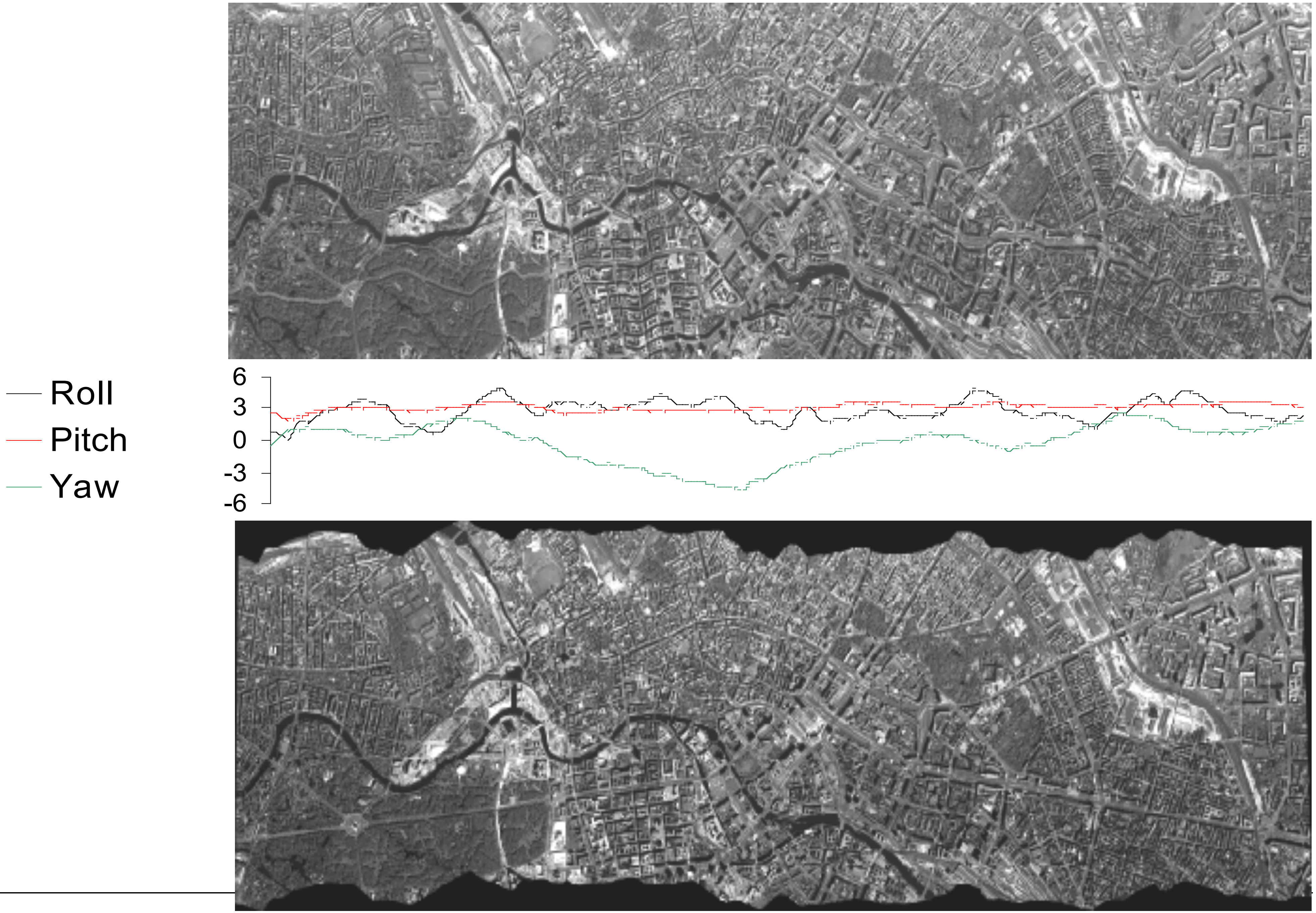
Planes, aerial scanning, 3D city maps
Workflow and the stereo matching core



Application of the "pushbroom principle" in an airplane
(now with more instability compared to satellites)

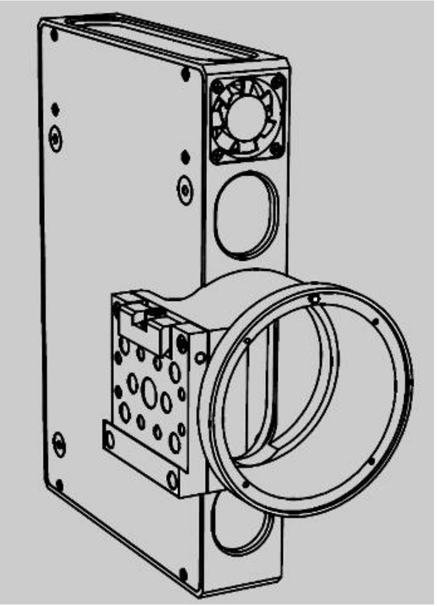






After geometric rectification, Ralf Reulke et. al, DLR Germany, 2001

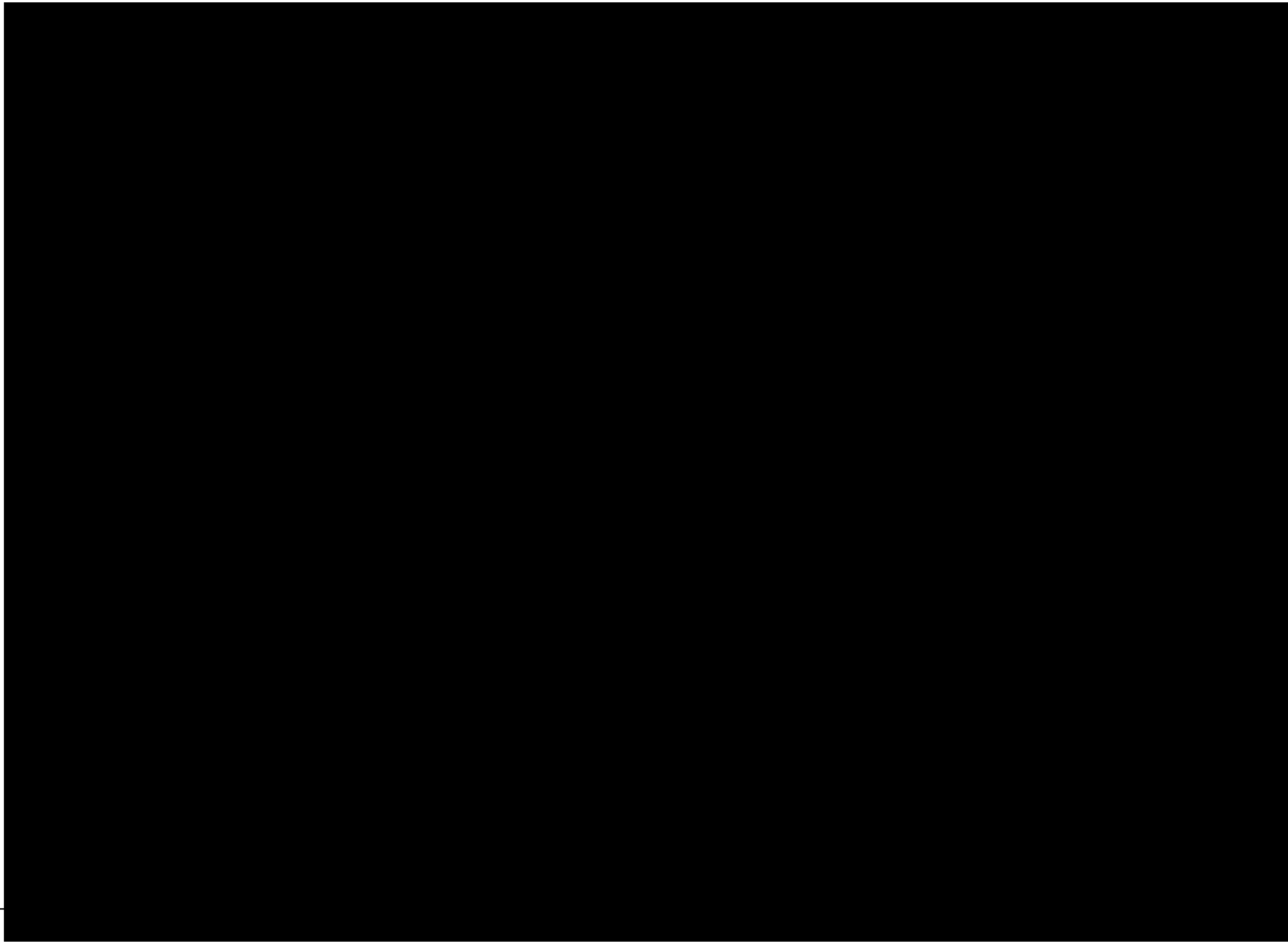
Example: MFC Sensor
(multi-functional camera)



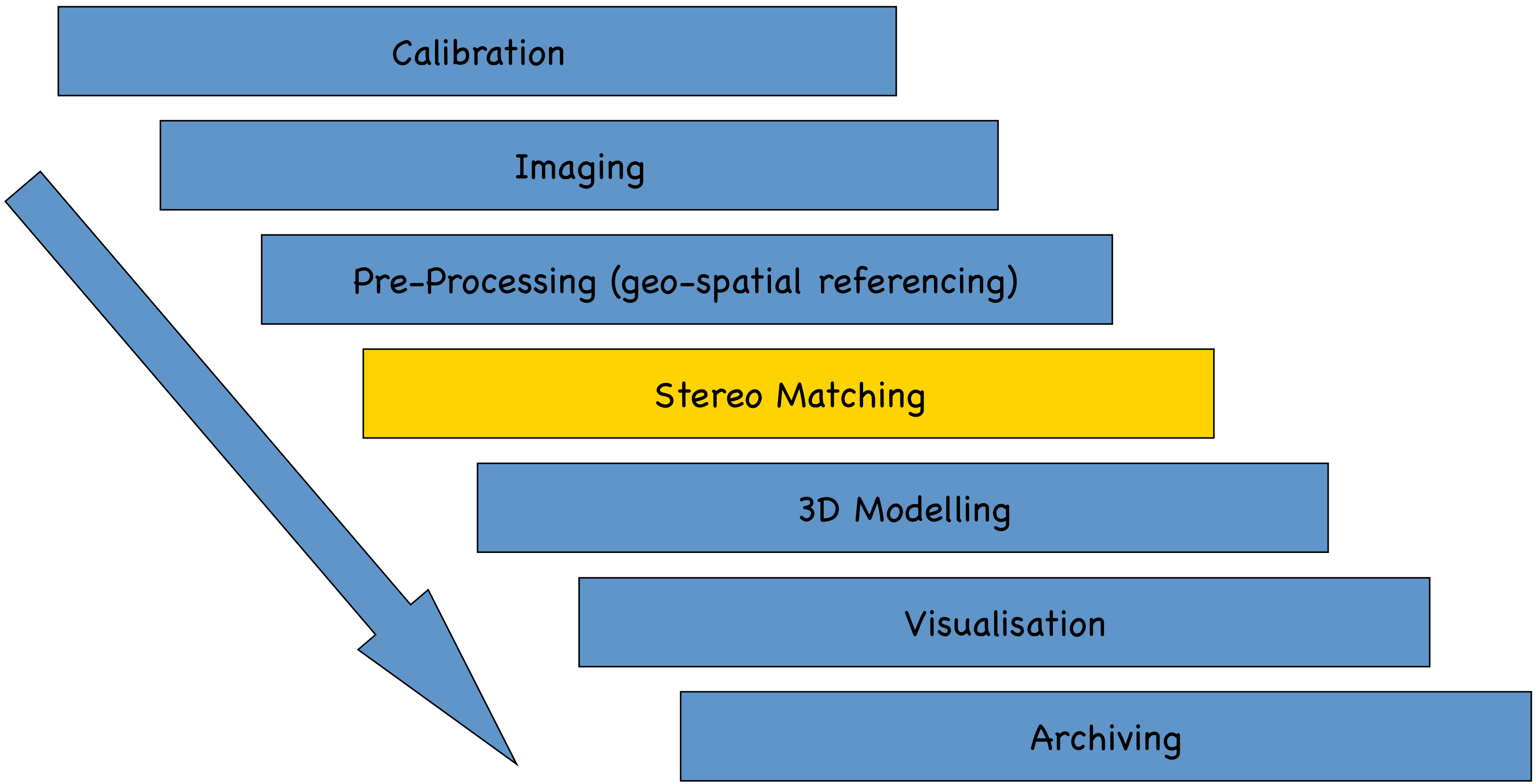
Parameter	MFC*One*	MFC*Three*	MFC*Five*
Number of lines	1	3	5
Pixel per line	2k, 6k, 8k	6k, 8k	8k, 10k, 14k
Focal length	35mm	80mm	100mm
Interface	USB2	Ethernet	Ethernet
Memory	externally	240GByte, internally	400GByte, internally
Control	Laptop	Laptop, PC104 stack, Industrial PC	Laptop, PC104 stack, Industrial PC
Size	12 x 30 x 4 cm³	30 x 30 x 20 cm³	30 x 30 x 20 cm³
Mass	1.5kg	15kg	20kg
Application	airborne, terrestrial	airborne	airborne

2007: DLR Berlin

December 2005: DLR maps aerial scans into 3D models



Workflow


Calibration
Imaging
Pre-Processing (geo-spatial referencing)
Stereo Matching
3D Modelling
Visualisation
Archiving

Stereo vision on rectified images

Left Image

Right Image

(frequently used stereo pair fromTsukuba university)

Disparities between pairs of corresponding points

Disparity calculation as a labeling problem

minimization of an error function (known from MRFs)

$$E(\Delta) = \sum_{p \in \Omega} \left(D_p(\Delta_p) + \sum_{q \in A(p)} C(\Delta_p, \Delta_q) \right)$$

labeling Δ for all pixels p in Ω

data term D e.g. $| L(x,y) - R(x-\Delta_p,y) |$

continuity term C between adjacent pixels;

often $C(|\Delta_p - \Delta_q|)$

Dominant paradigms for energy optimization

Scanline optimization stereo matching

Dynamic programming stereo

single scanline (epipolar line) in one direction

Semi-global matching

multiple scanlines (DSLs) in both directions

Belief propagation stereo matching

general BP paradigm applied to stereo vision

Graph-cut stereo matching

general GC (of combinatorial optimization) applied to computer vision

Semi-global stero matching (SGM)

[Heiko Hirschmüller, DLR, 2002]

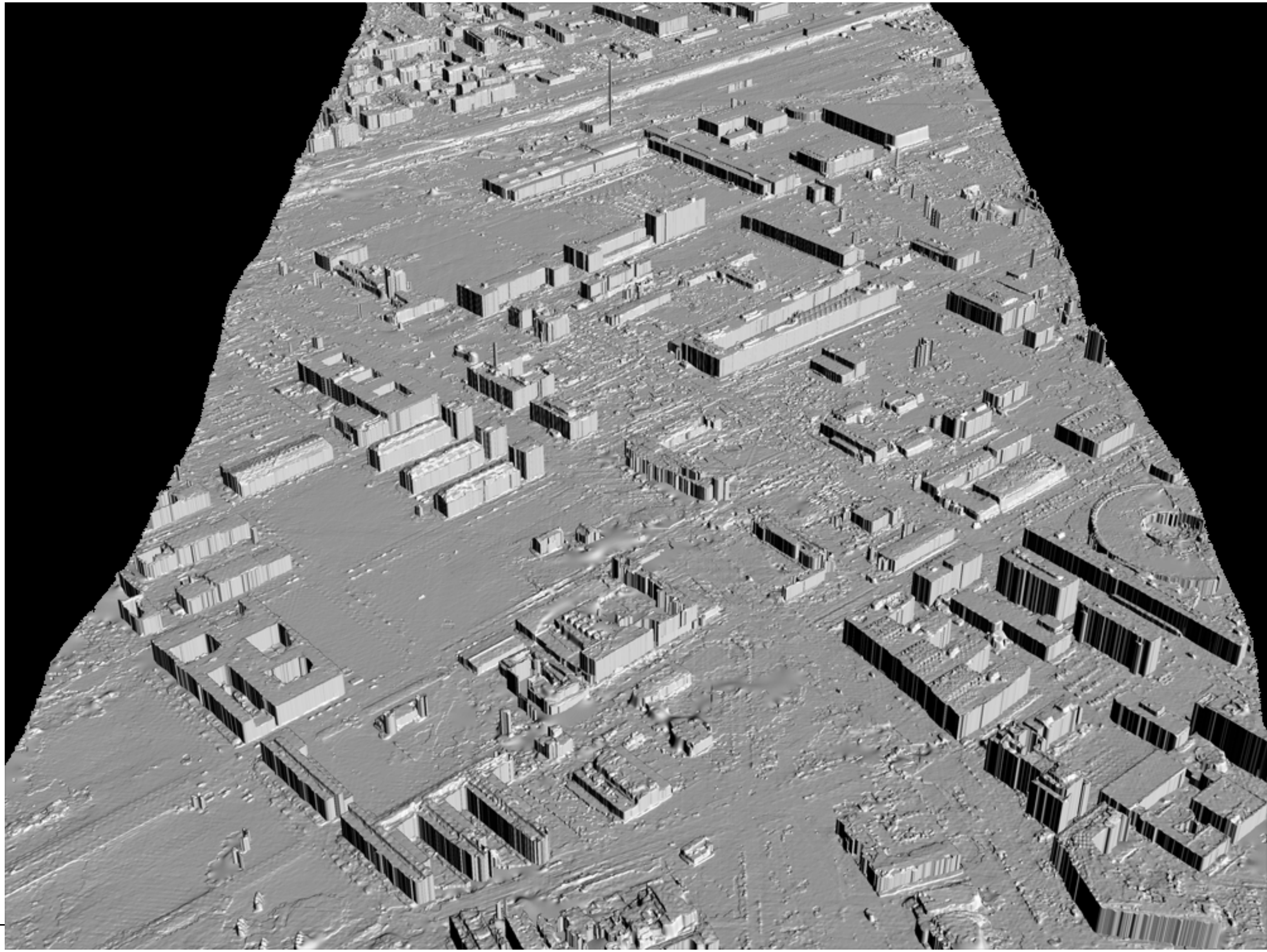
For each pixel, optimize energy along digital rays starting at this pixel. Uniform weights for all rays. Possibly add further cost functions.

Data term: common functions are, for example, the census transform or the mean-normalized sum of differences

SGM Hardware Implementations

- GPU
  - OpenGl & OpenCl
  - 6 fps @ VGA resolution (640 x 480 x 128 disparity values), suitable for real time applications in traffic and robotics
  - Maximal image size: 2048 x 2048 x 1024 disparity values
  - GPU 10x faster than normal CPU
- FPGA
  - Implementation on low-cost FPGA (AvNet ADS110 - XCV5-FXT110)
  - Image size up to 1024 x 1024 x 64 disparity values
  - 25 fps @ VGA resolution
  - High-end boards for large images in developments
  - FPGA 100x faster than normal CPU

Multi-line stereo data are mapped into a geometric model

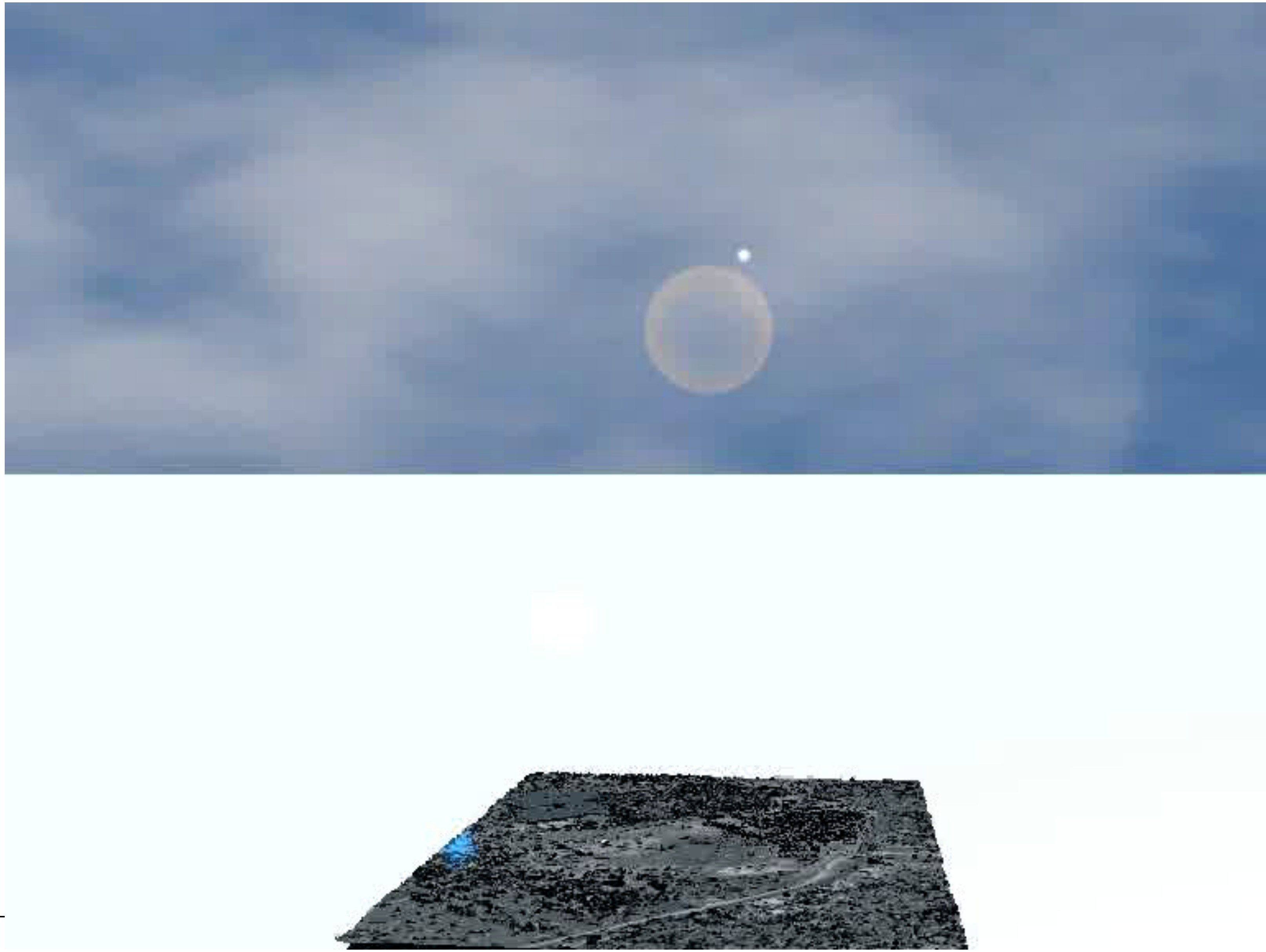


Karsten Scheibe, DLR, 2007

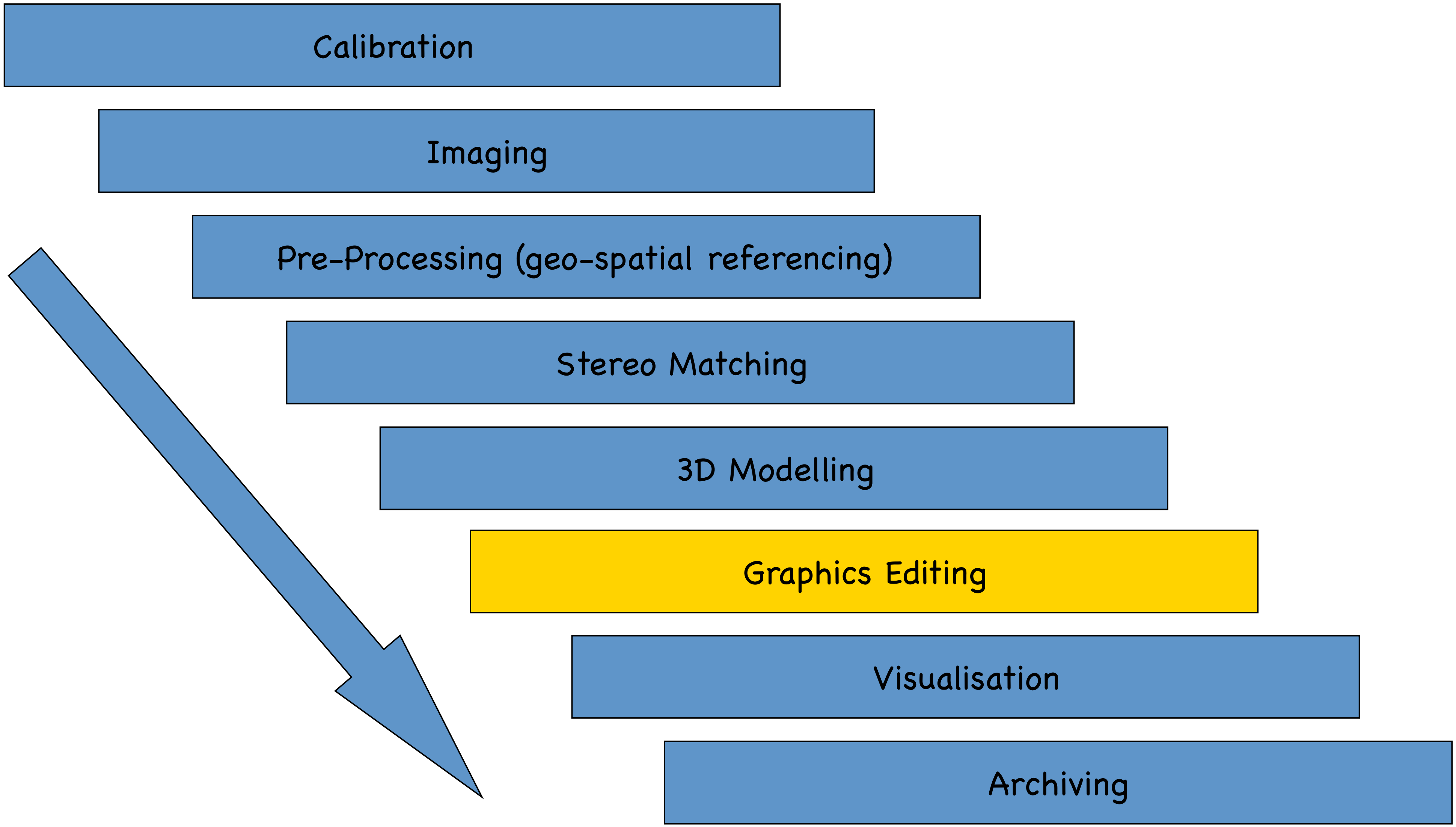
Recorded image scans are then used for rendering

Karsten Scheibe, DLR, 2007

The generated 3D model may be animated (Synchotron Berlin)



Extended Workflow



After additional editing of the automatically generated 3D Data **by a professional Computer Graphics company** what is time consuming and labour intensive:

How to replace graphics editing

partially by automated processes ?

One possible step:

registration of panoramic street views
and aerial images

=== see below ===

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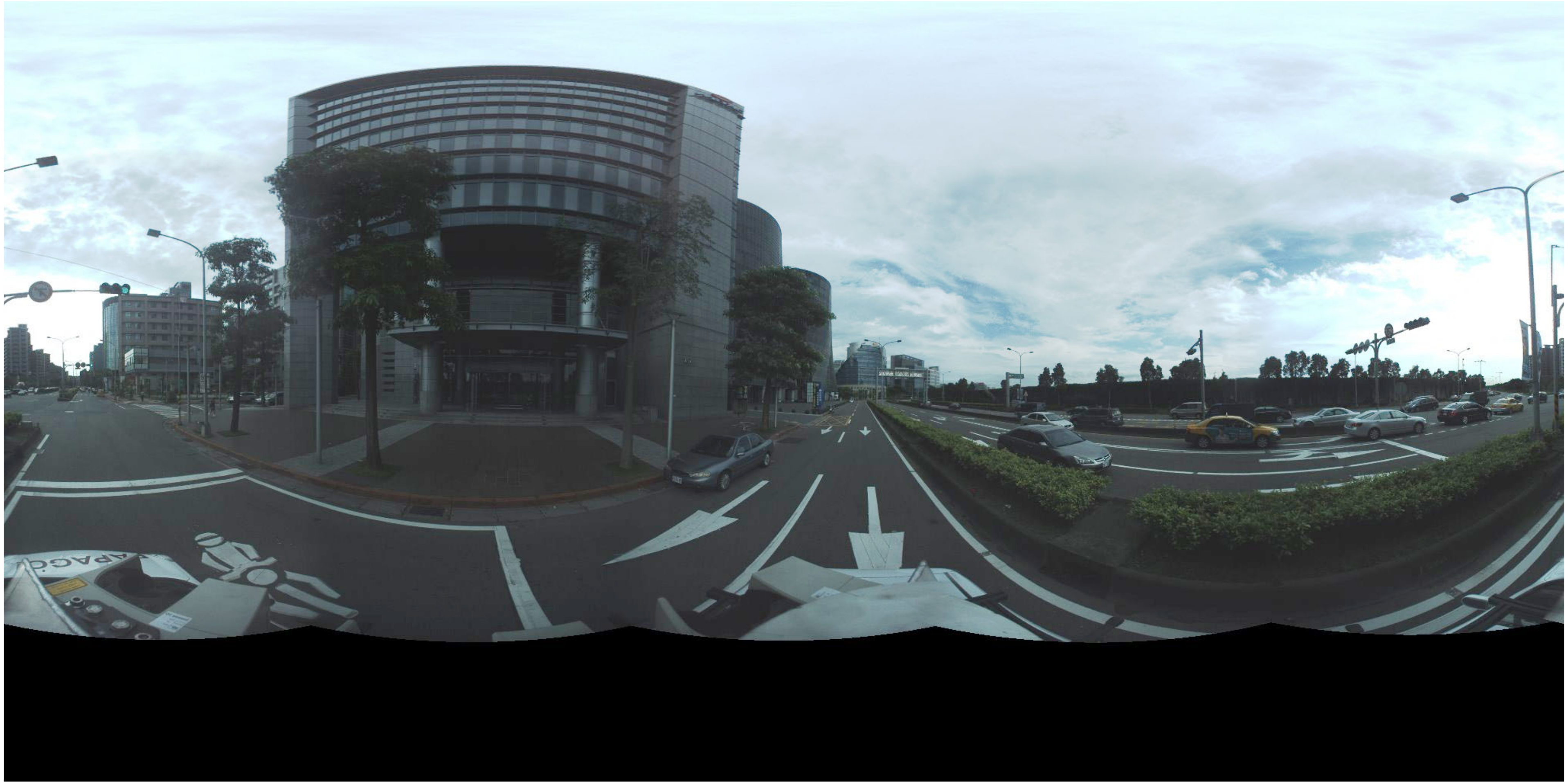
City scenes, landscapes

Registration of panoramas and aerial images

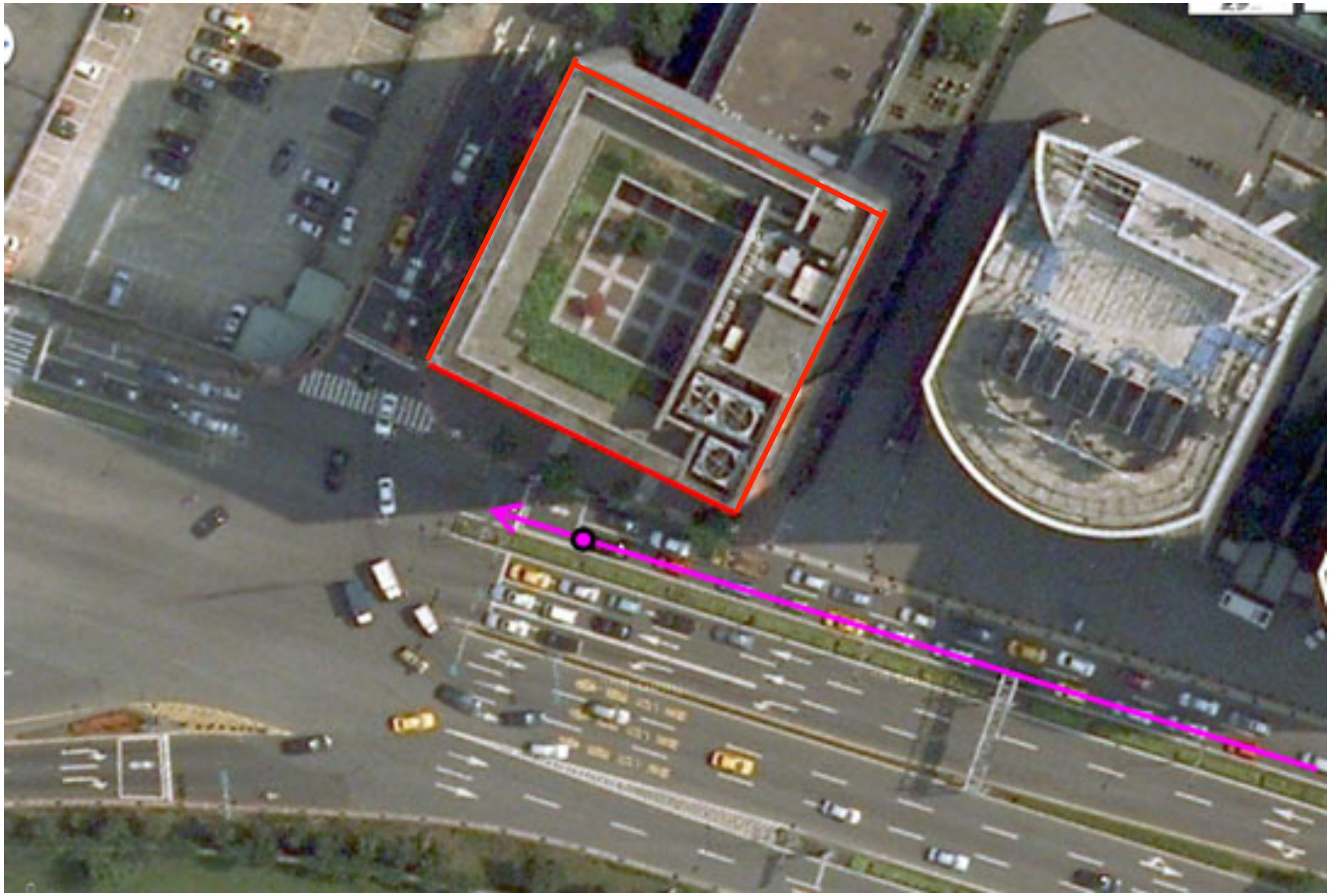
Another sensor option: Ladybug panoramic camera

Spherical Panoramic Images



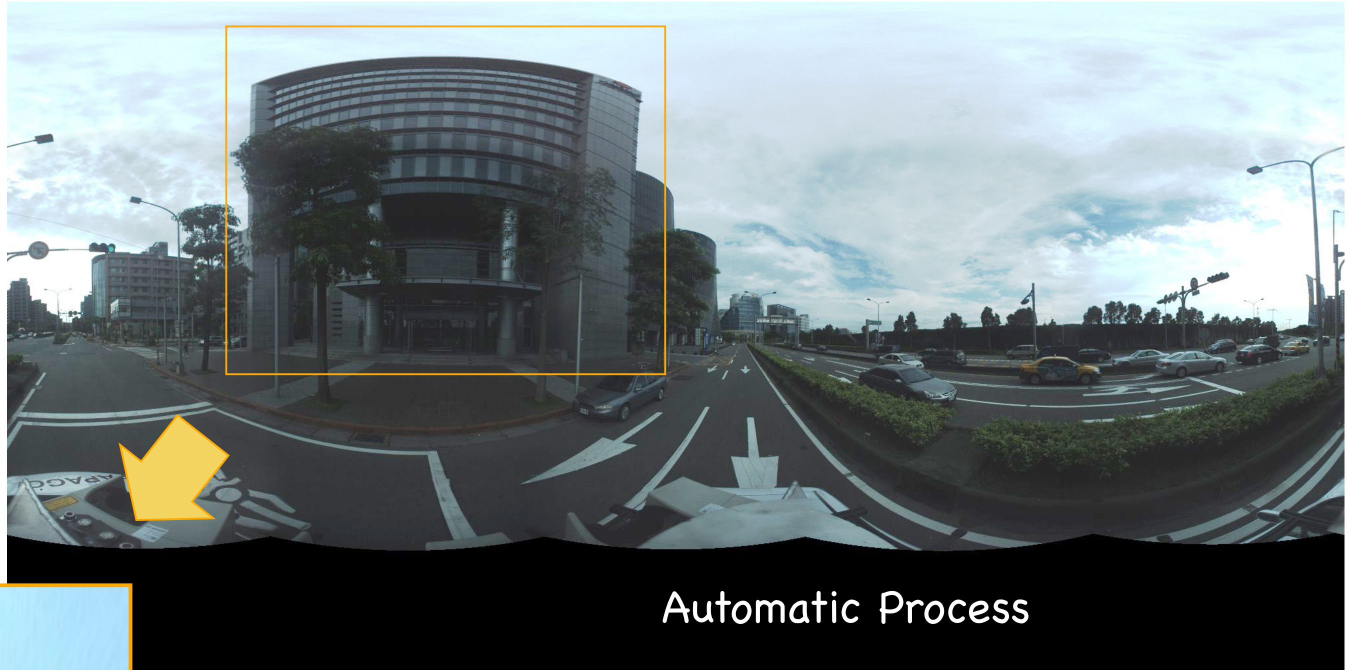
A large collection of street-view panoramic images has been captured in 2010 with a Ladybug camera.

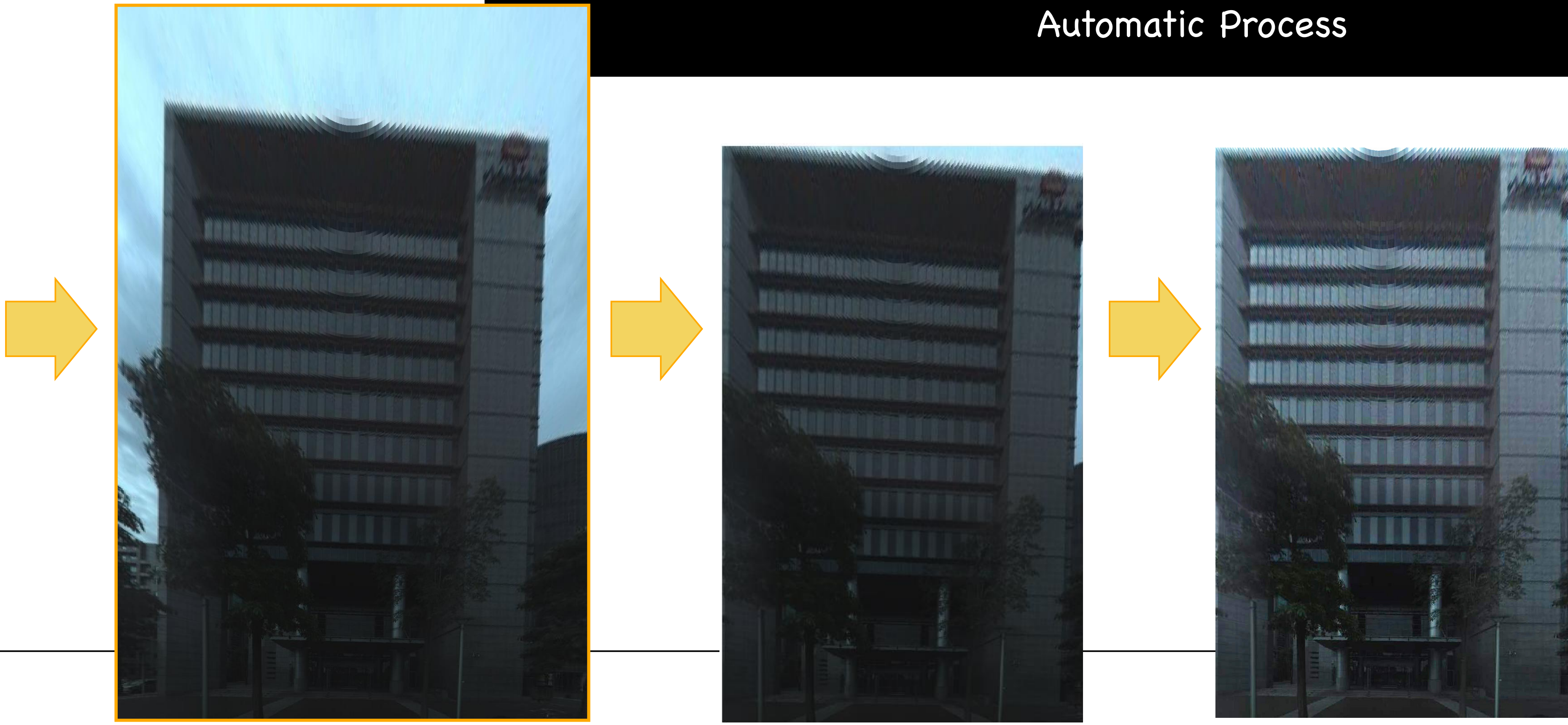
Aerial image of the same area



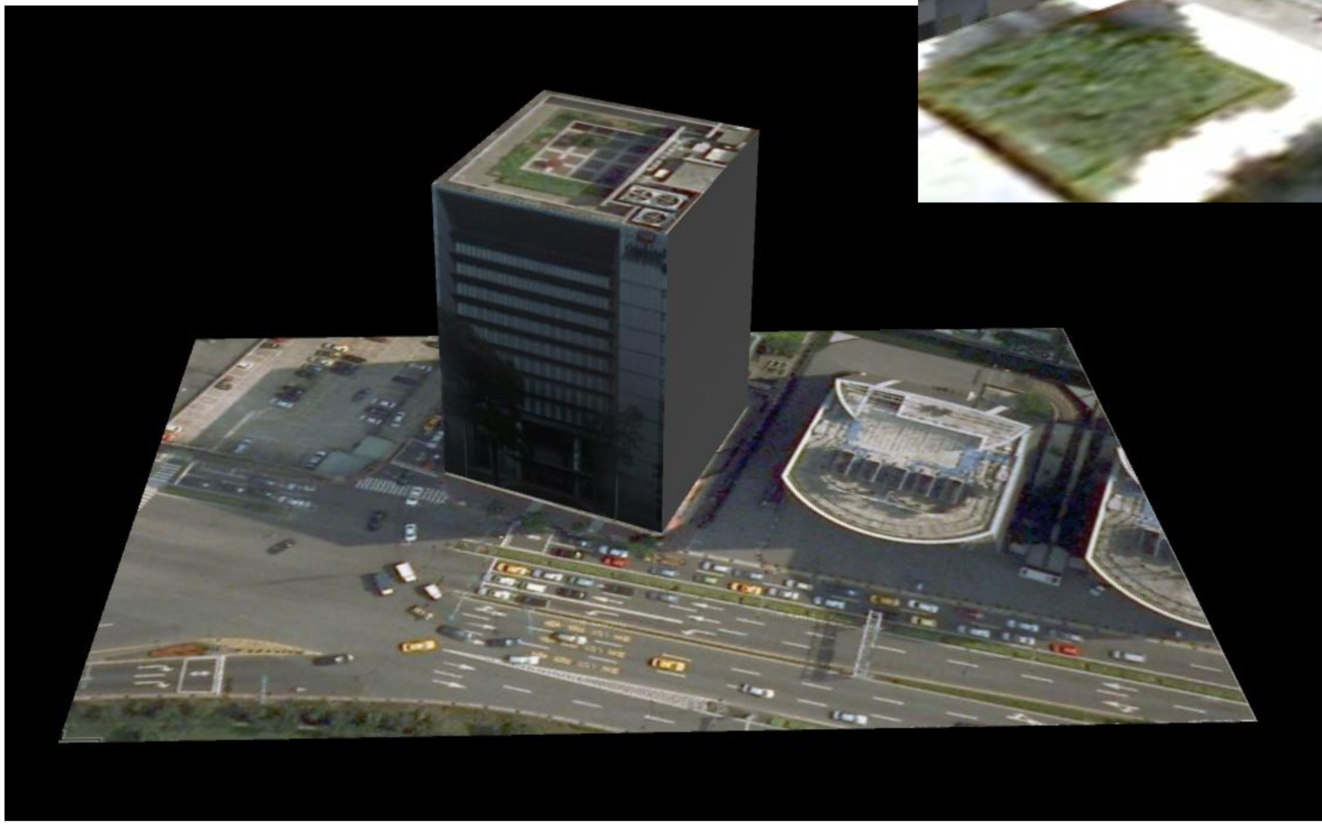
Pink line: automatically recovered camera path
Red line: boundaries of the building to be reconstructed (manually specified)

Output: Building Front-face Texture





Examples: 3D Models with Texture Mapping



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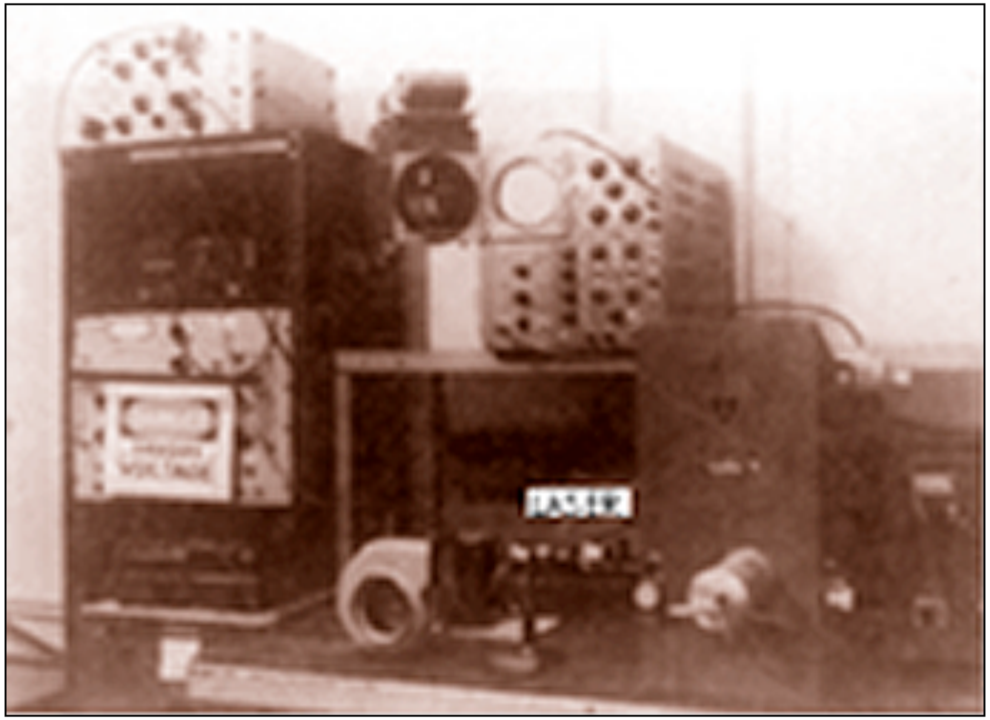
Architectural photogrammetry

Combining laser scans with panoramic images

3D reconstruction project 2001-2004 (Illustrated Architecture, Berlin)

Castle "Neuschwanstein", Bavarian Alps, Germany

Laser Range Finder (LIDAR)



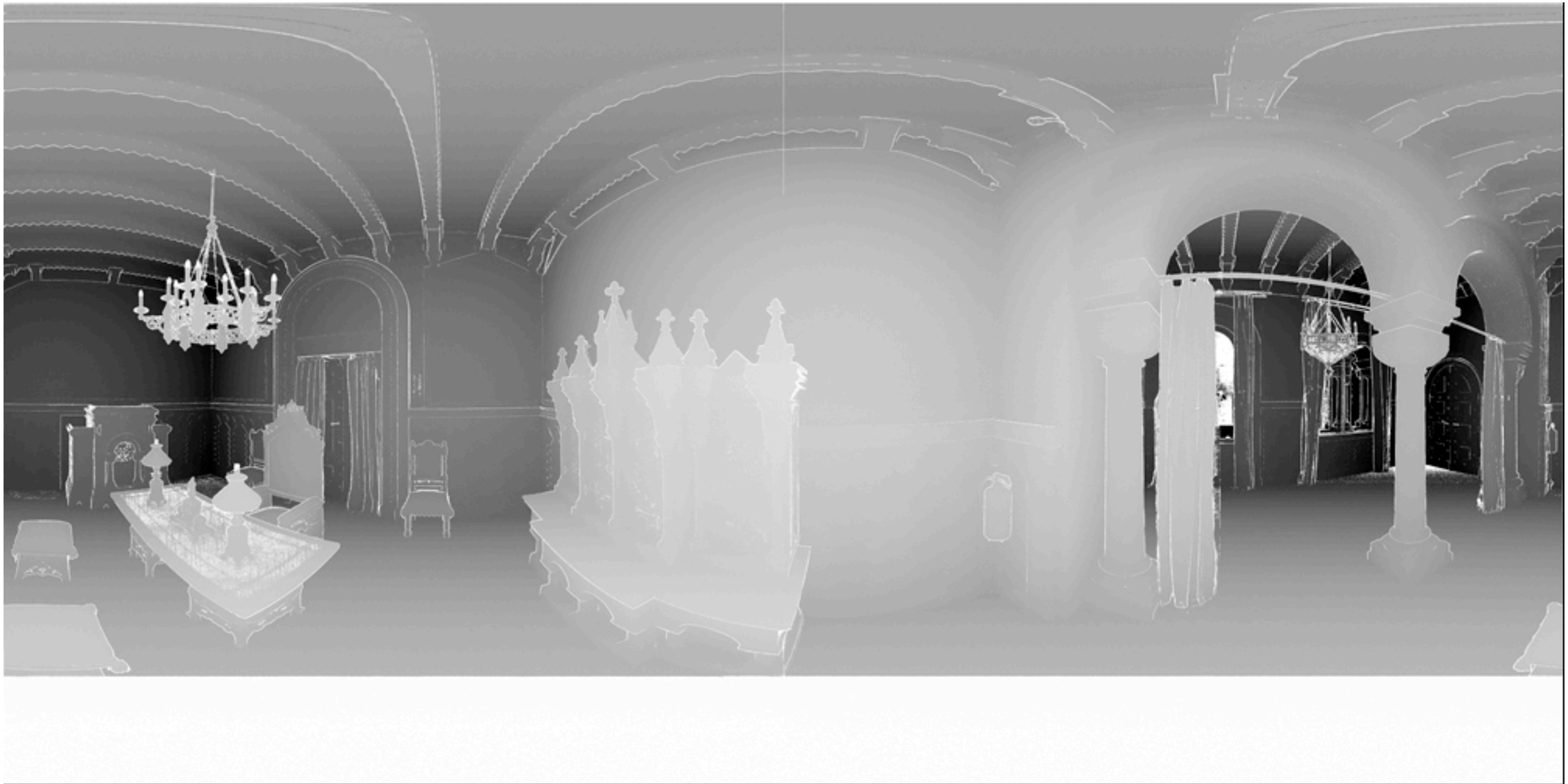
1960: original lab set-up for the ruby laser

the *first laser range finder* (LRF):

it used ruby lasers and was demonstrated less than a year after the laser's discovery in 1960 at Hughes (time-of-flight LRFs)

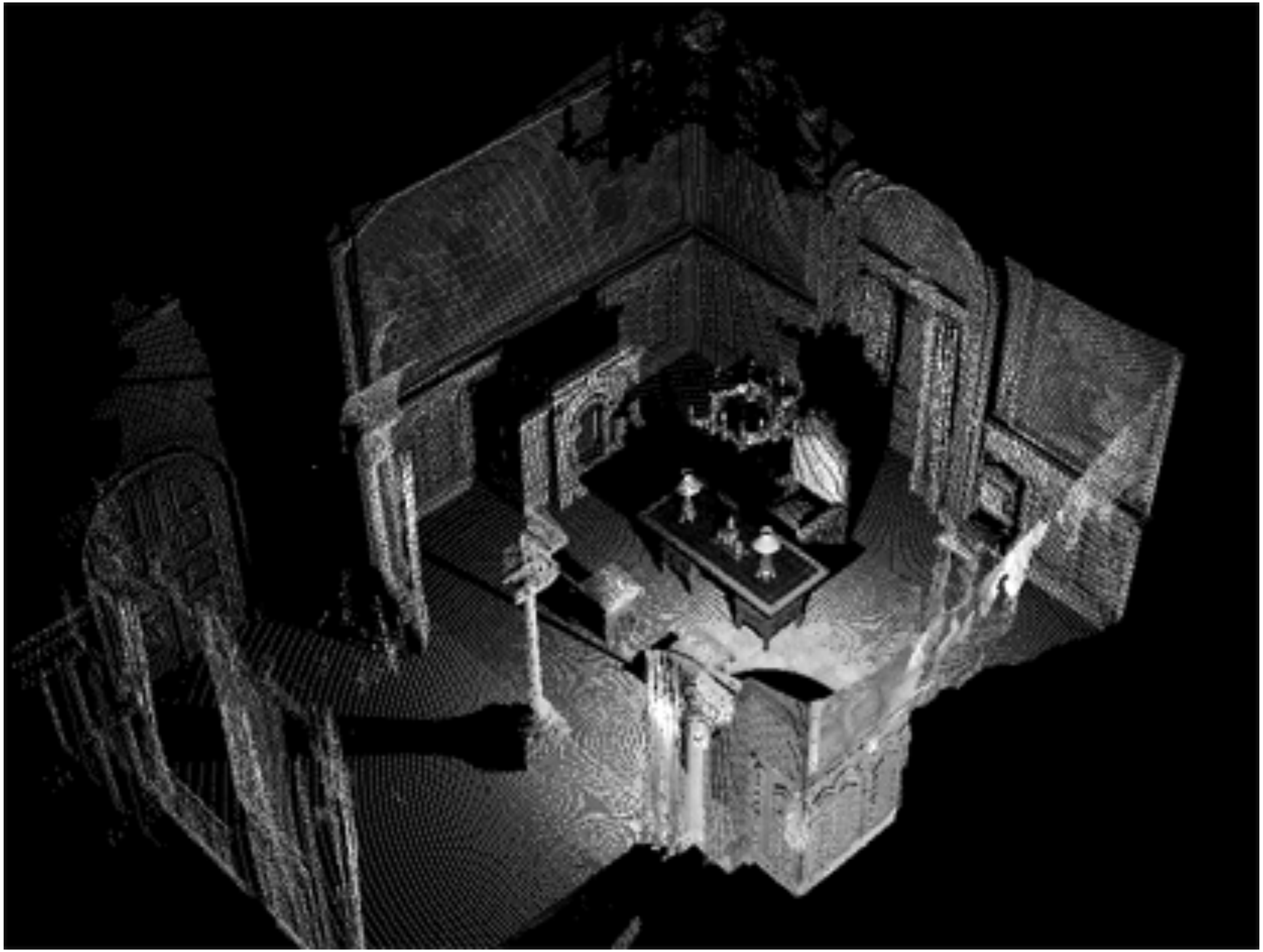
2005: laser scanner Cyrax 2500
with build-in color camera

Intensity data



Range data

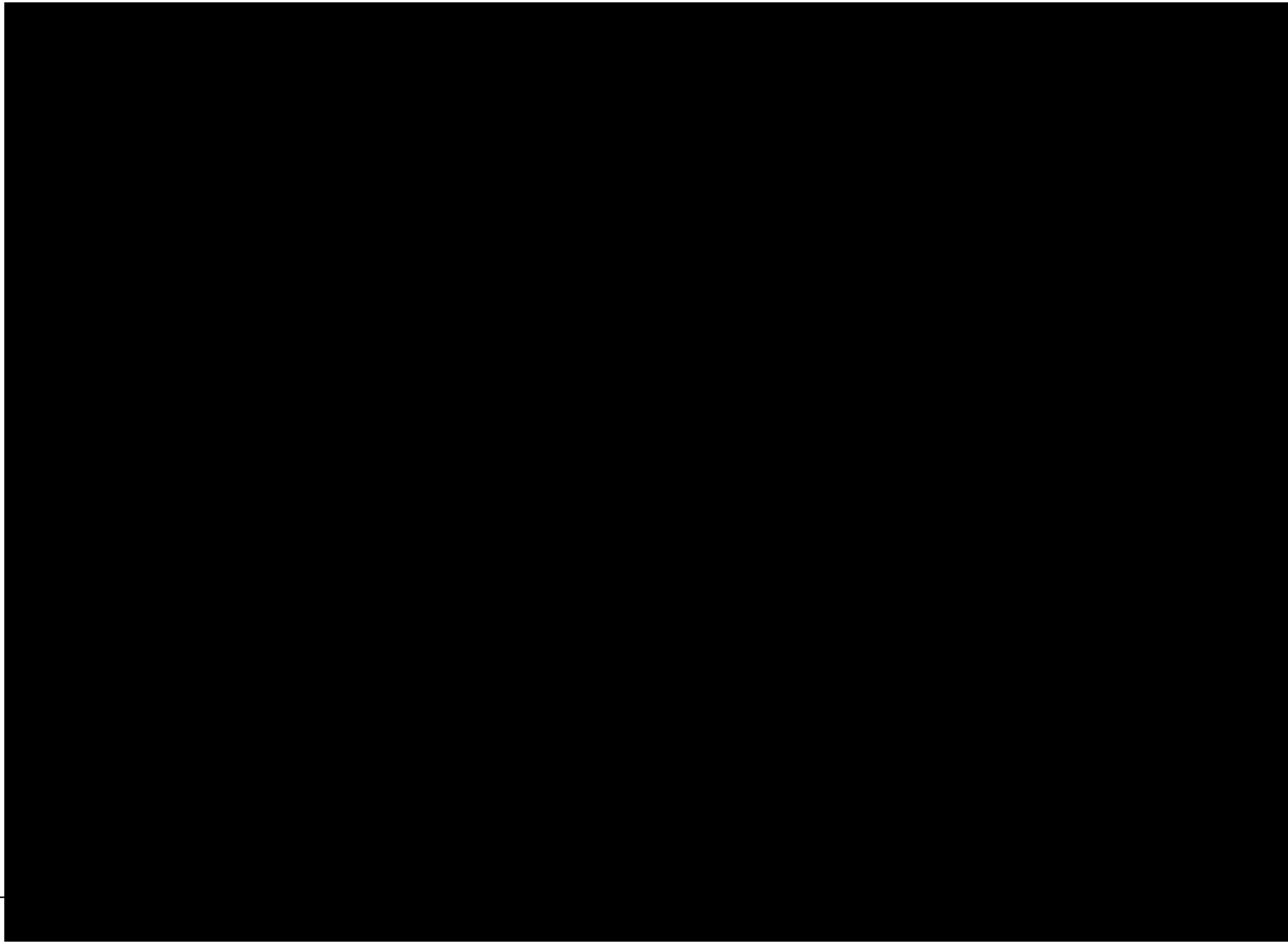
Office of King Ludwig in castle Neuschwanstein



Data Fusion Workflow

- Calibration: LIDAR+panorama
- Image acquisition: LIDAR+panorama
- Fusion: LIDAR + panorama in world coordinates
- Triangulation and meshing: 3D points into DSM
- Optimization: reduce complexity and noise in DSM
- Texture mapping: panorama onto DSM
- Visualisation
- Archiving

Example of one reconstructed hall of Neuschwanstein: the throne room



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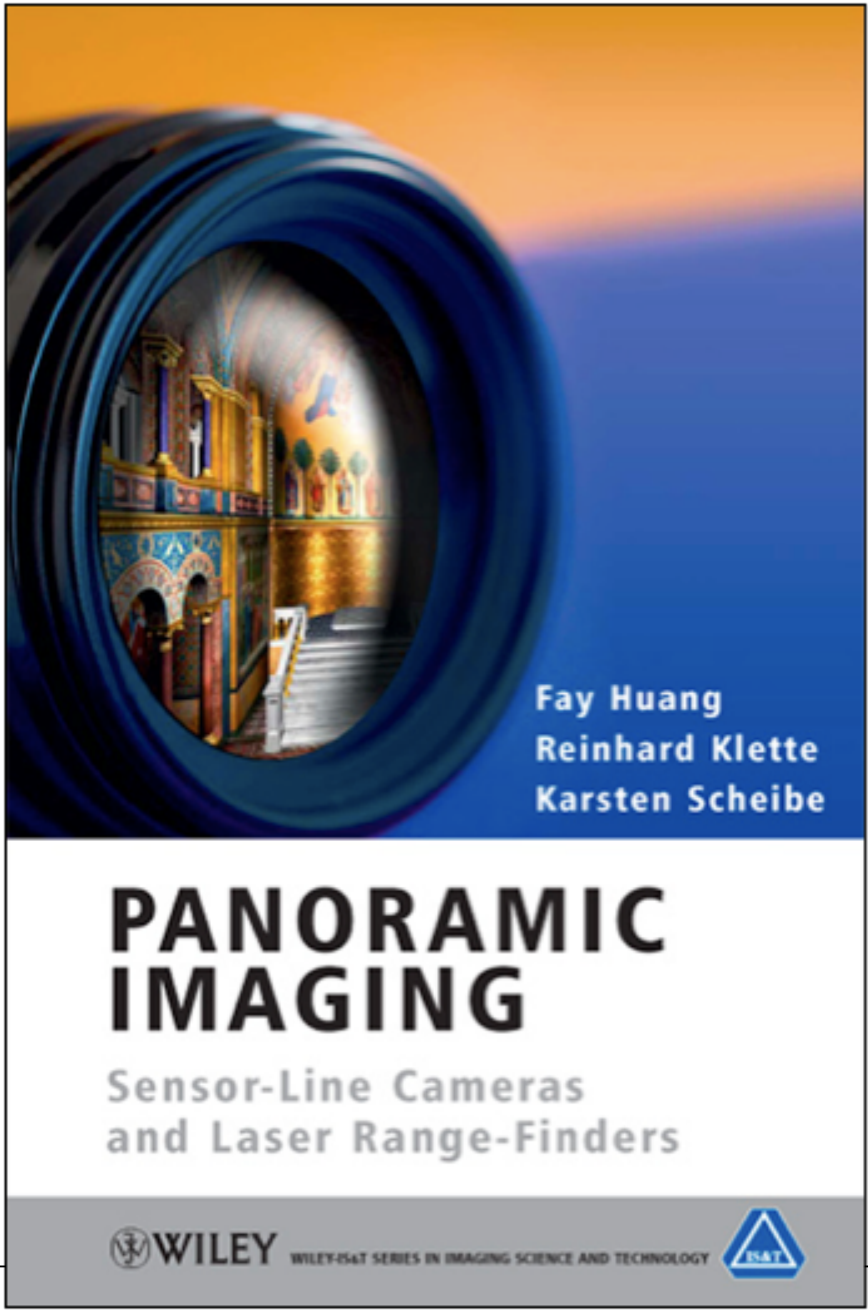
Close-range objects

Just one final example about options

Turn a 40 people workshop “Robot Vision” into a 100 people conference

one colleague made it 7 times into this image

Book with Wiley, 2008



Karsten Scheibe is now
supervising satellite
missions at DLR.

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Concluding remarks

DLR Berlin, VRlab Ilan University, and CITR Auckland

do have the knowledge and the cameras for generating

large-scale images and 3D models automatically.

High-quality 3D city maps still require additional

graphical editing.

DLR Berlin, VRlab Ilan, and CITR Auckland are

interested in partners for doing 3D city models

with academic goals (e.g. modelling temporal changes)

Goal:

High-resolution 3D interactive visualizations of cities or landscapes

Munich
The Alps (Zugspitze)
Berlin