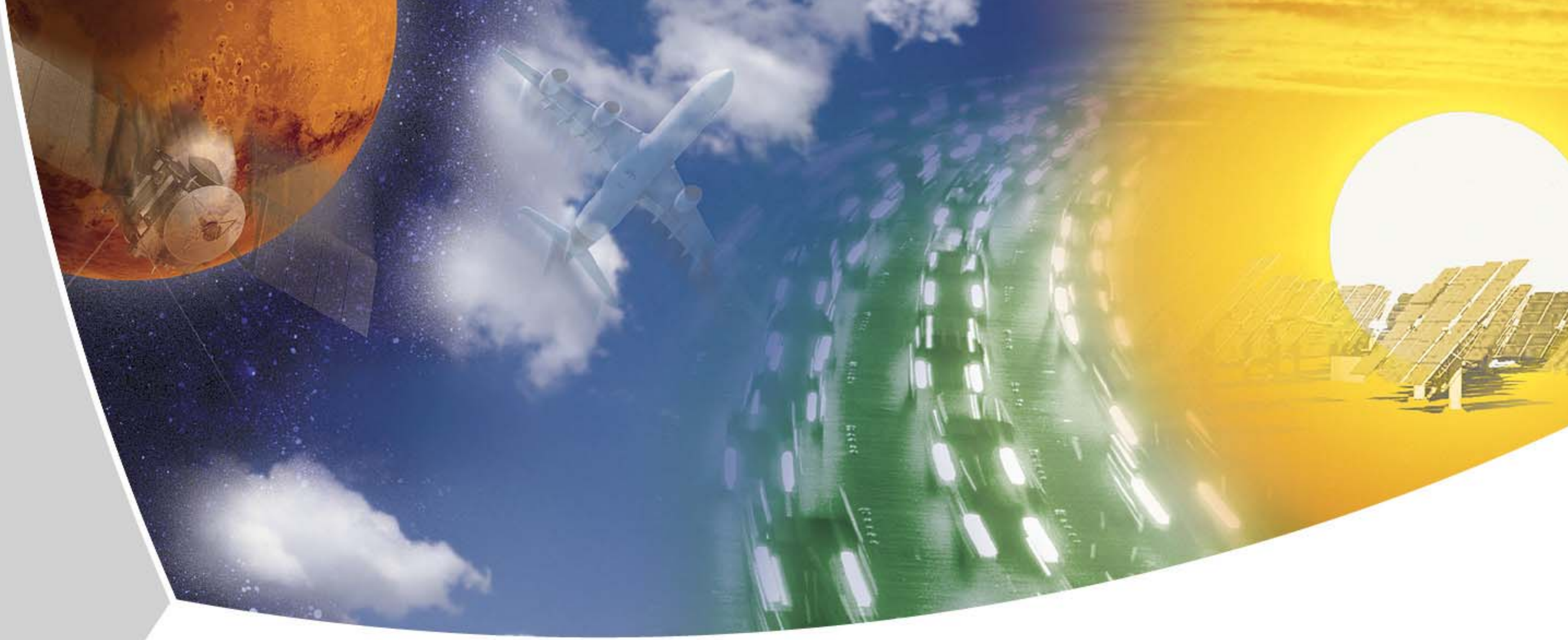


High resolution Instruments for Air- and Spaceborne Application

Dr. Andreas Eckardt, Dr. Anko Börner, Stefan Hilbert, Ingo Walter

DLR Deutsches Zentrum für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

Outline

- Camera and System Model
- Physical Basics
- SNR and TDI capabilities
- ADS40 ➔ MFC, KompSat3, LLPC
- First Step to Camera in Chip Design
- Hybrid Sensor Technology
- Conclusion

Introduction

- 5100 employees working in 27 research institutes and scientific and technical facilities
  - n at 8 sites
  - in 6 field offices
  - (7 field offices of the Project
  - Management Agency)
- Offices in Brussels, Paris and Washington.
- DLR participates in the:
  - ♦ European Transonic Wind Tunnel (ETW)
  - ◆ German-Dutch Wind Tunnels (DNW)

Astron

DLR Location in Berlin:

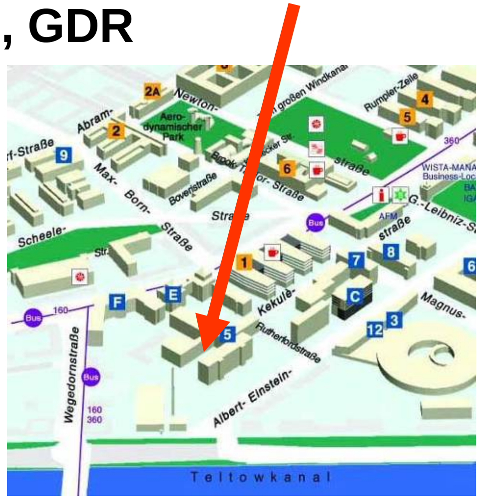
Berlin-Adlershof

Former Space Research Institute, Academy of Sciences, GDR

(East part of the old Germany)

DLR Location in Berlin was founded in 1992

DLR



Structure of the DLR Location in Berlin

Institute of Planetary Exploration

Institute of Transportation Research

Institute RM Department of Optical Information Systems [48 Scientists]

Department of Ecology of Waters (Remote Sensing Technology Institute)

Department of System Conditioning (Institute of Structural Mechanics)

Project management organisation

Used Models for System Optimisations

Camera Model

$$n_e = \frac{\pi}{4 \cdot f_{no}^{\;2}} \cdot \tau(\lambda) \cdot QE(\lambda) \cdot I_{Ground}(\lambda) \cdot T_{Atmosphere}(\lambda) \cdot \frac{\lambda}{h \cdot c} \cdot \Delta\lambda \cdot A_{\mathrm{det}} \cdot fillfactor \cdot \tau_{\mathrm{int}}$$

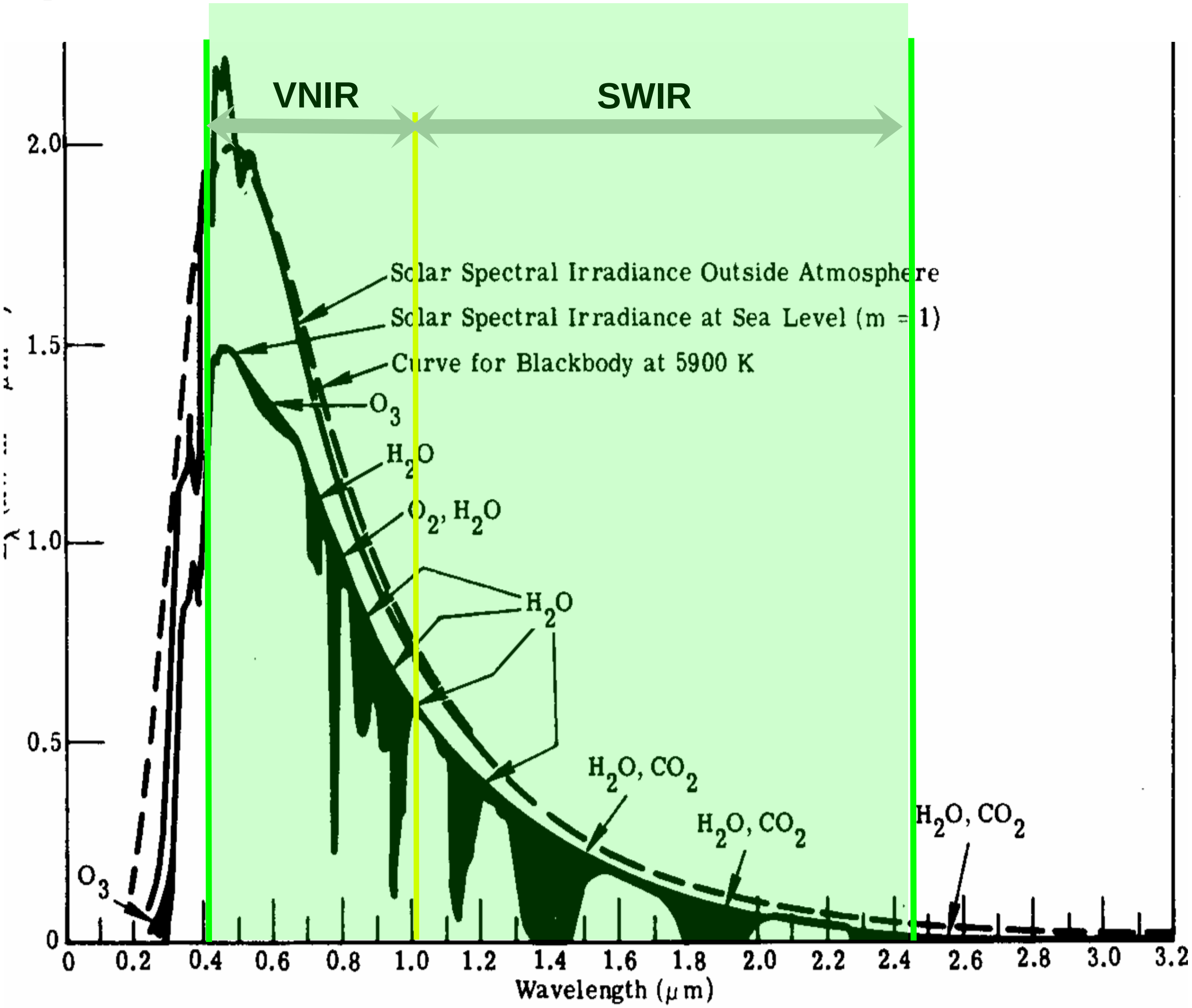
ne	*number of generated electrons of a single pixel*
fno	*F - number of optics*
topt	*transmission of optics*
QE(l)	*Quantum efficiency of the Sensor*
Isensor(l)	*sensor input radiance in W/m2 µm sr*
Dl	*spectral bandwidth of a single spectral line*
Adet	*nominal detector area*
fillfactor	*factor for effective detector area*
tint	*integration time*

System Model

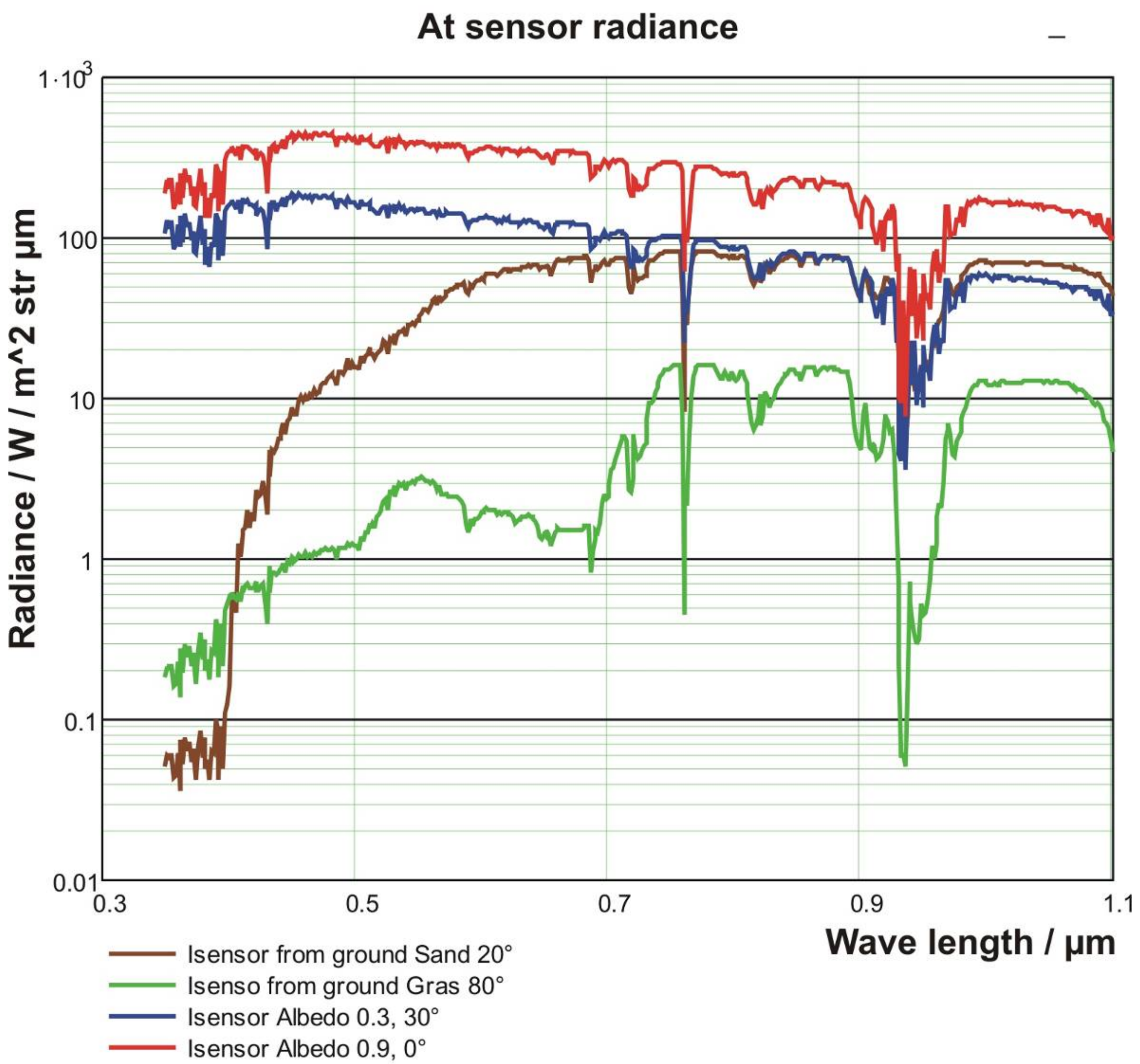
$$I_{Sensor} = T_{Atmosphere} \bullet I_{Ground} + P_{Atmosphere}$$

ISensor :	*at-sensor-radiance (W/m2 sr µm)*
TAtmosphere:	*transmission of atmosphere*
PAtmosphere:	*stray light from atmosphere*
IGround:	*scene signal*

Solar Spectrum



Typical Problem

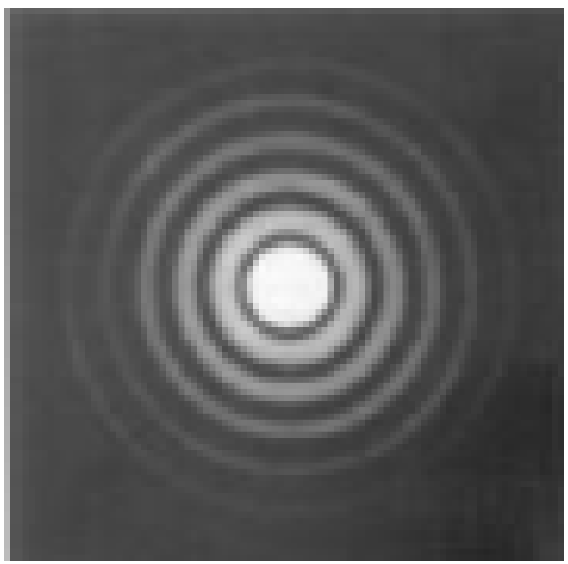


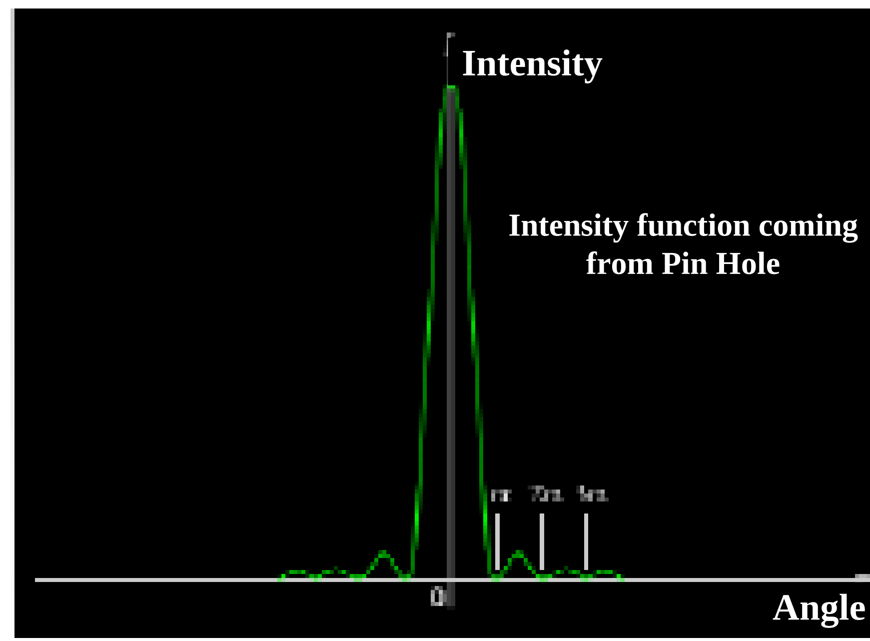
Diffraction Limit of the Telescope

Problem:

$\alpha = 1{,}22\ \lambda / D$ **(in rad)**

dPixel = $1{,}22\ \lambda$ **F# (in m)**





SNR Model

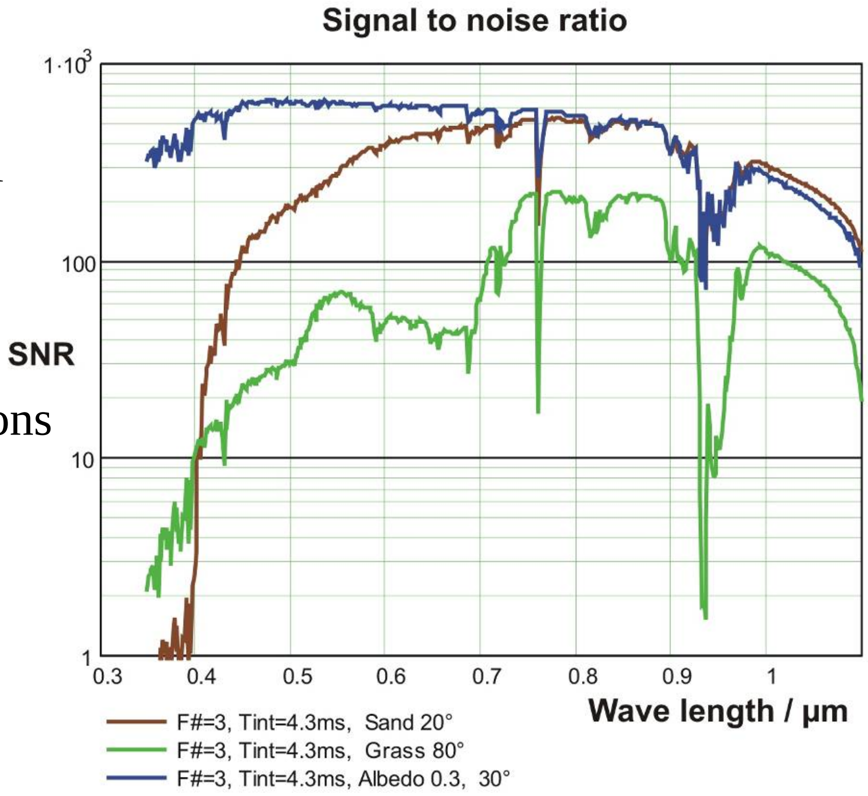
$$SNR = \frac{n_e}{\sqrt{n_e + n_{CCD\_rms}^{\;2} + n_{channel}^{\;2} + n_{ADC}^{\;2}}}$$

n_e :	Number of Electrons Photon Noise
n_{CCD_rms} :	Number of Electrons CCD rms Noise
$n_{channel}$:	Number of Electrons Electronics channel
n_{ADC} :	Number of Electrons ADC

Noise in Voltage must by calculated in electrons

$$nelectrons = Vnoise \;\; / \; fconversion$$

fcnversion is defined by the Sensor



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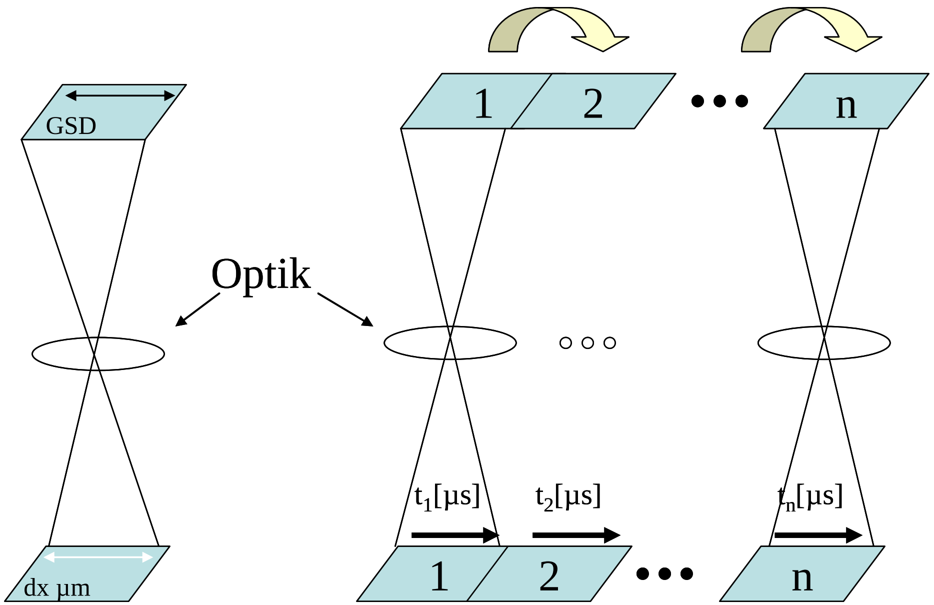
Electronically increasing of the aperture

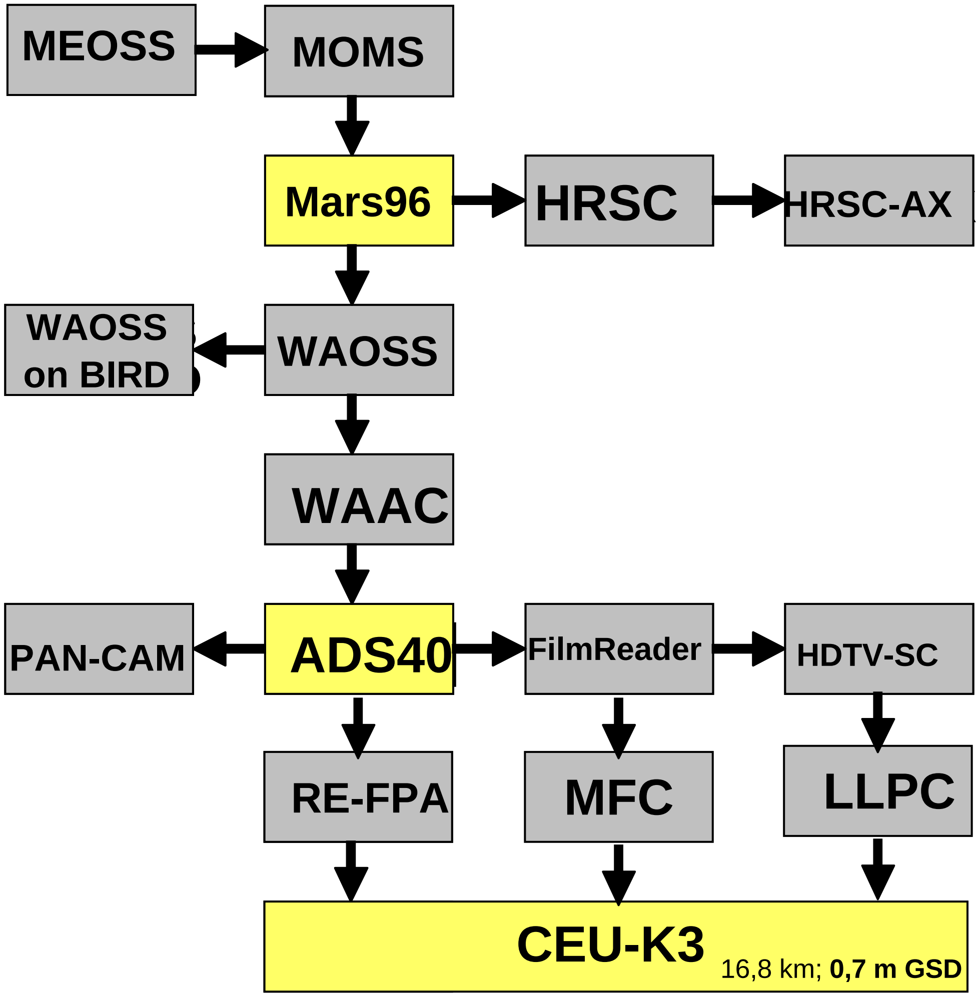
TDI Principe



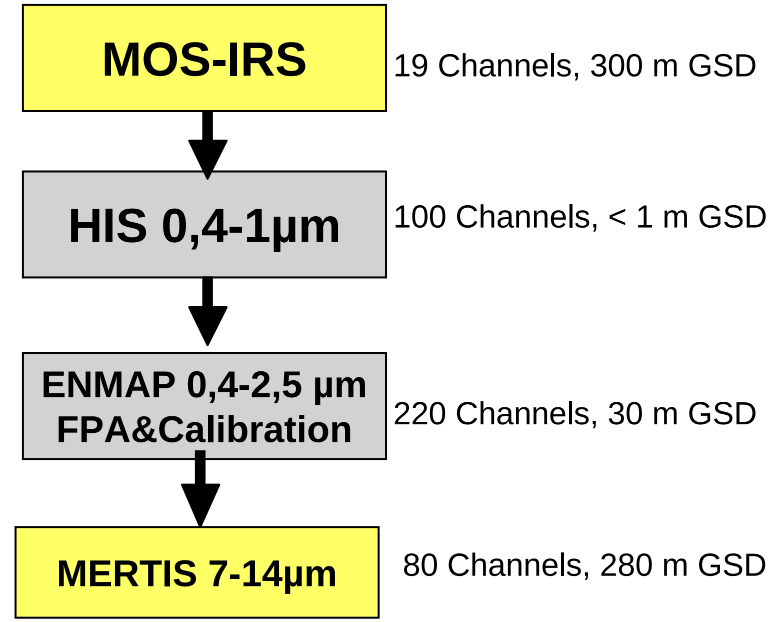
Advantage:

$$Photon\_SNR_{TDI} = Photon\_SNR * \sqrt{Nr\_TDI\_Steps}$$

Multispectral Cameras



Multi-/ Hyperspectral Imager



Key Projects

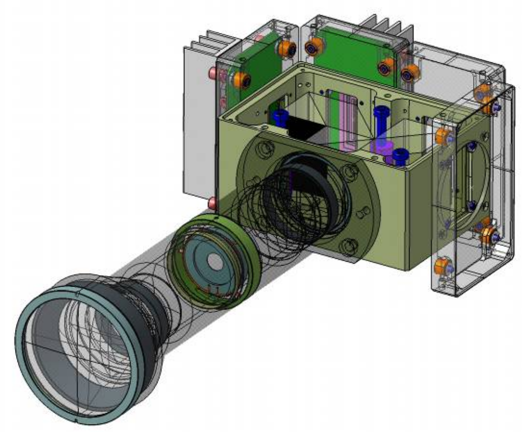
Key Development Airborne Digital Sensor (ADS) 40

Austin Texas USA 06/2002

Low Light Panoramic Camera

Designed for basic research of TDI systems has been started:

1) Synchronization Issue
2) Geometric Calibration of TDI Sensors
3) DSNU & PRNU issue in dependency to the temperature
4) MTF Measurement
5) SNR Measurements
6) TDI Sensors for Panoramic Photogrammetry?

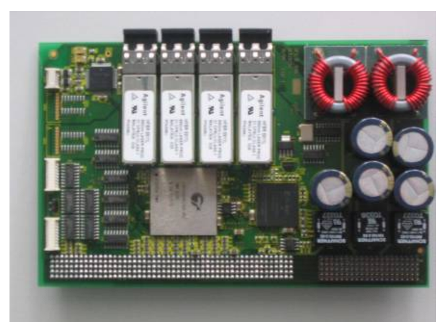


Low Light Panoramic Camera

Specification:

Focal length	62 mm / F 5,6
Pixel size	13 µm
TDI CCD line	2048 pixels
Programmable TDI steps	24, 48, 64, 96
Dynamic range	14 bit
Radiometric resolution	14 bit
TDI Line Rate [max]	39.000 lines / s
Spectral channels	
• Red	620 - 700 nm
• Green	510 - 560 nm
• Blue	400 - 500 nm
• Near Infrared	780 - 1200 nm

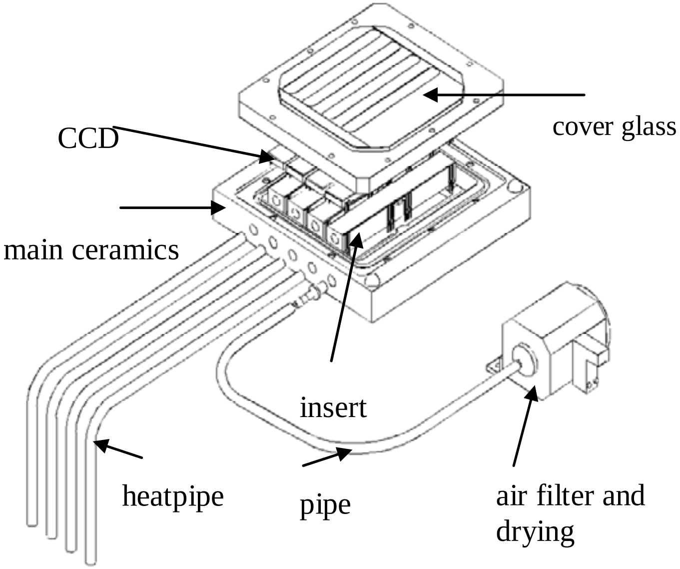
AD-Board

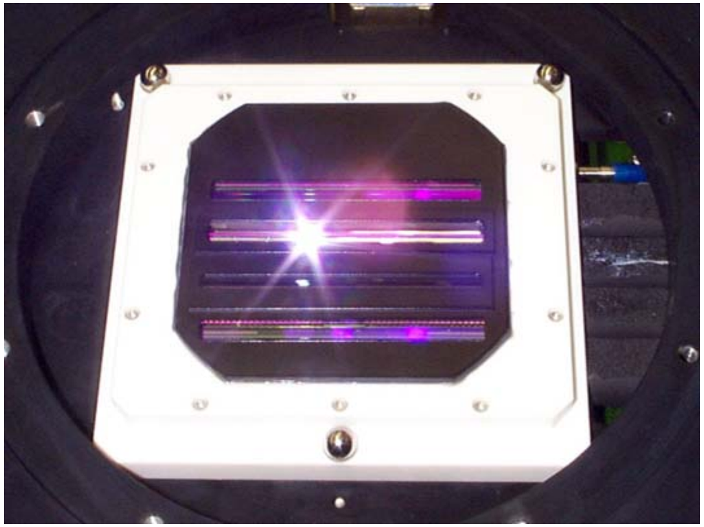


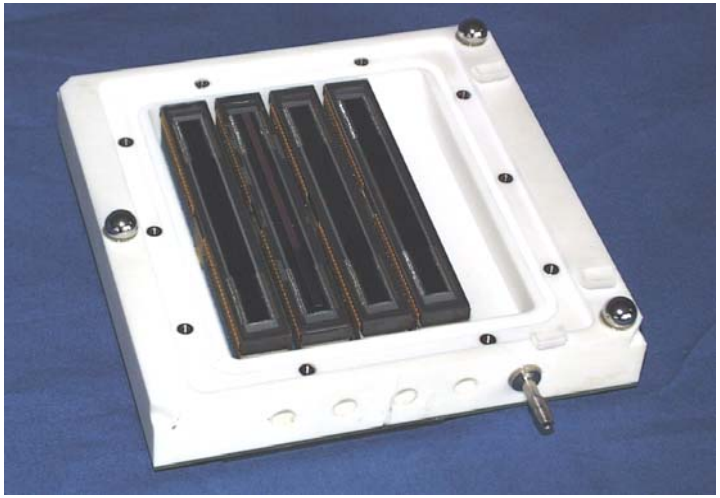
IF-Board

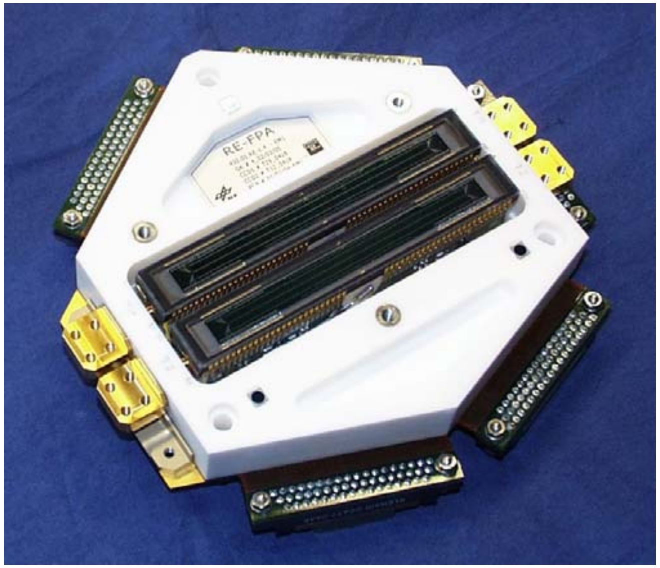
Frame Grabber

Old Focal Plane Technology

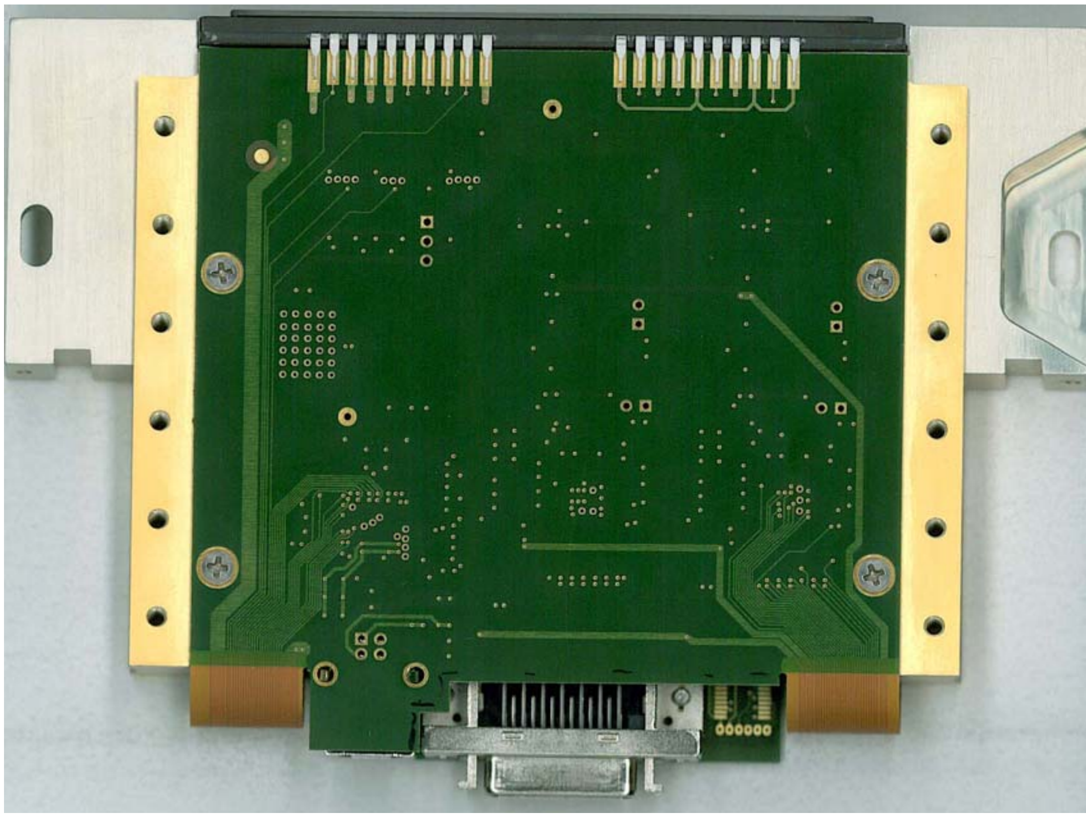


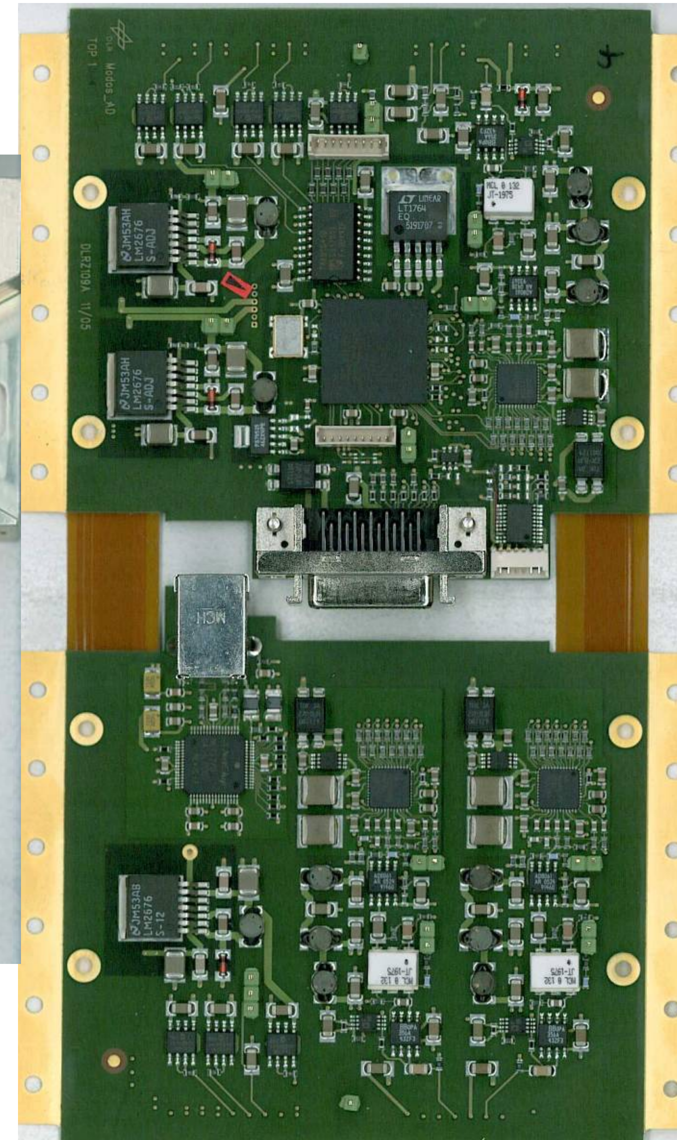






New Focal Plane Technology

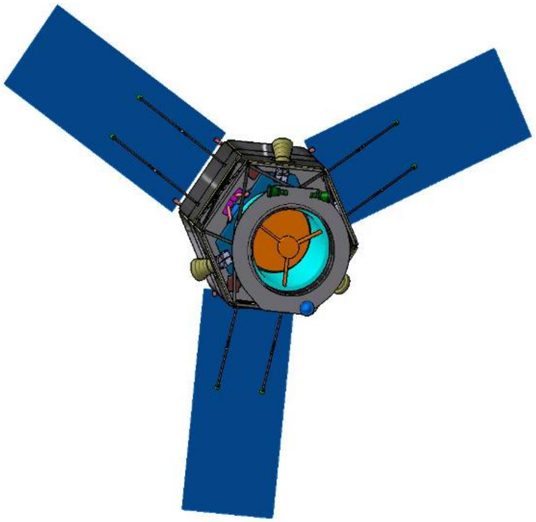




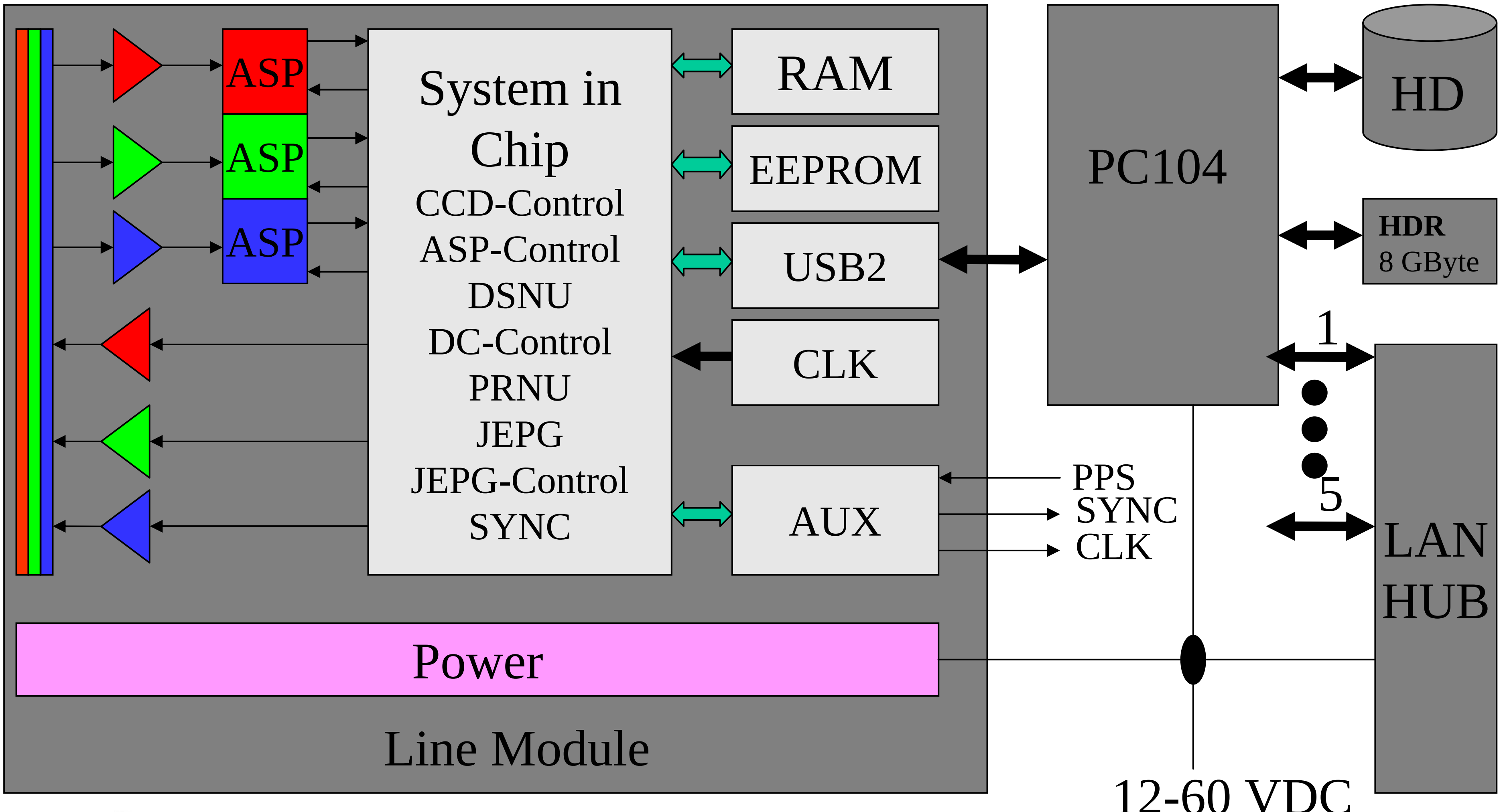
CEU Development KompSat 3 [EADS Astrium GmbH & DLR]

Nr. of Pixels PAN	24.000
PAN-Sensor	2 x 12.080-TDI
Line Rate PAN	10 kHz +5/-50 %
CCD Output Rate	16 x 15MPixel/s
Data Rate	3,84 Gbit/s
MS-Sensor	8 x 6.000-TDI
Line Rate MS	2,5 kHz +5/-50 %
CCD Outp. Rate/Colour	2 x 7,5 MPixel/s
Data Rate	4 x 240 Mbit/s
Pitch PAN	8,75 µm
Pitch MS	2 x 17,5 µm
Anti Blooming	yes
Operating temperature	10°-25°C
Image Plane dx	22 cm
Dynamic Range	14 Bit
PRNU	yes
DSNU	yes
SNR-PAN	>200
SNR MS	>200
Orbit	685 km
Focal Length	8,6 m
F-#	12
PAN	450 nm-900 nm
NIR	760 nm-900 nm
RED	630 nm-690 nm
GREEN	520 nm-600 nm
BLUE	450 nm-520 nm

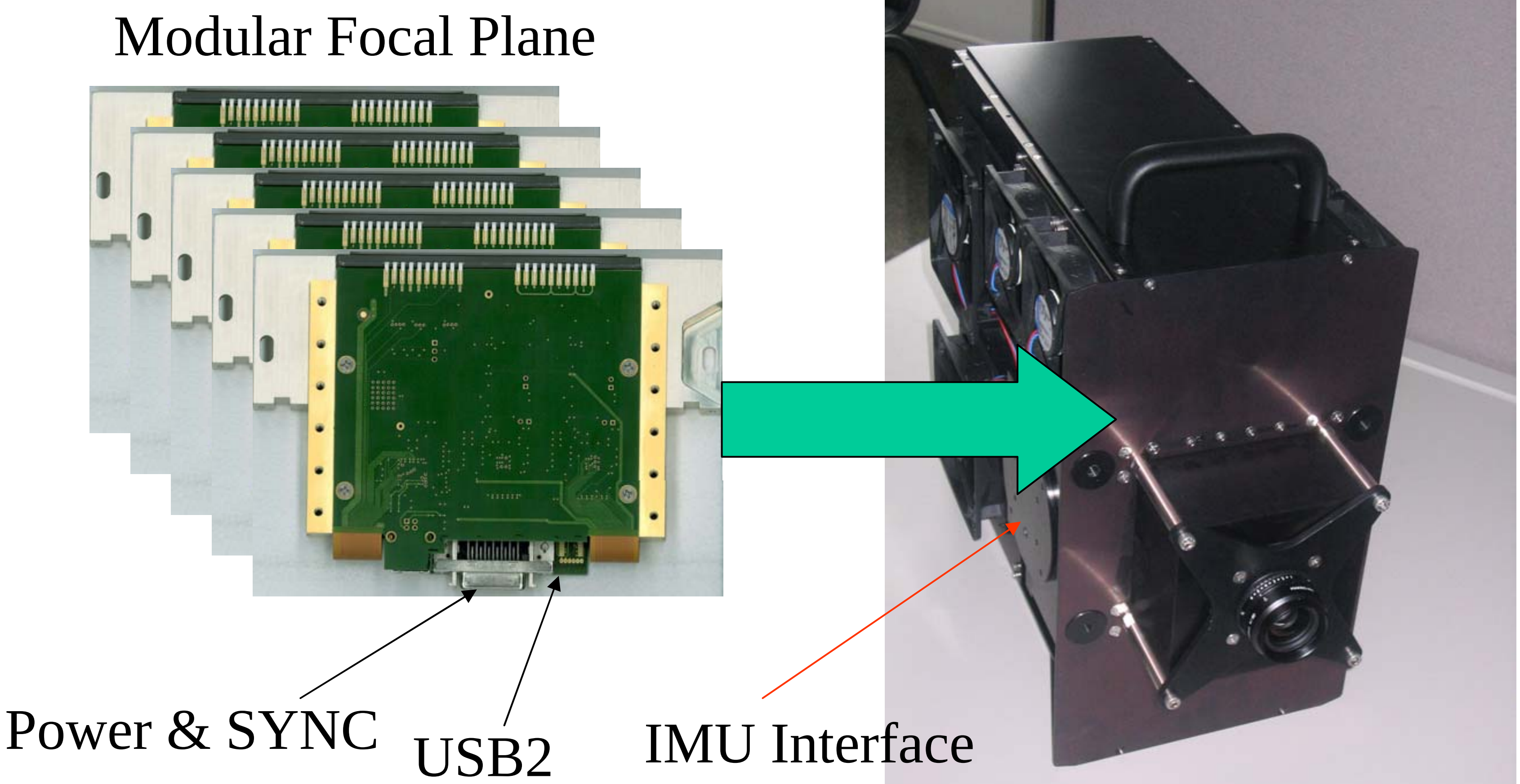
DLR is responsible for the Focal Plane and FEE development



Multi Camera Head Concept



Multi functional Camera Head Realization



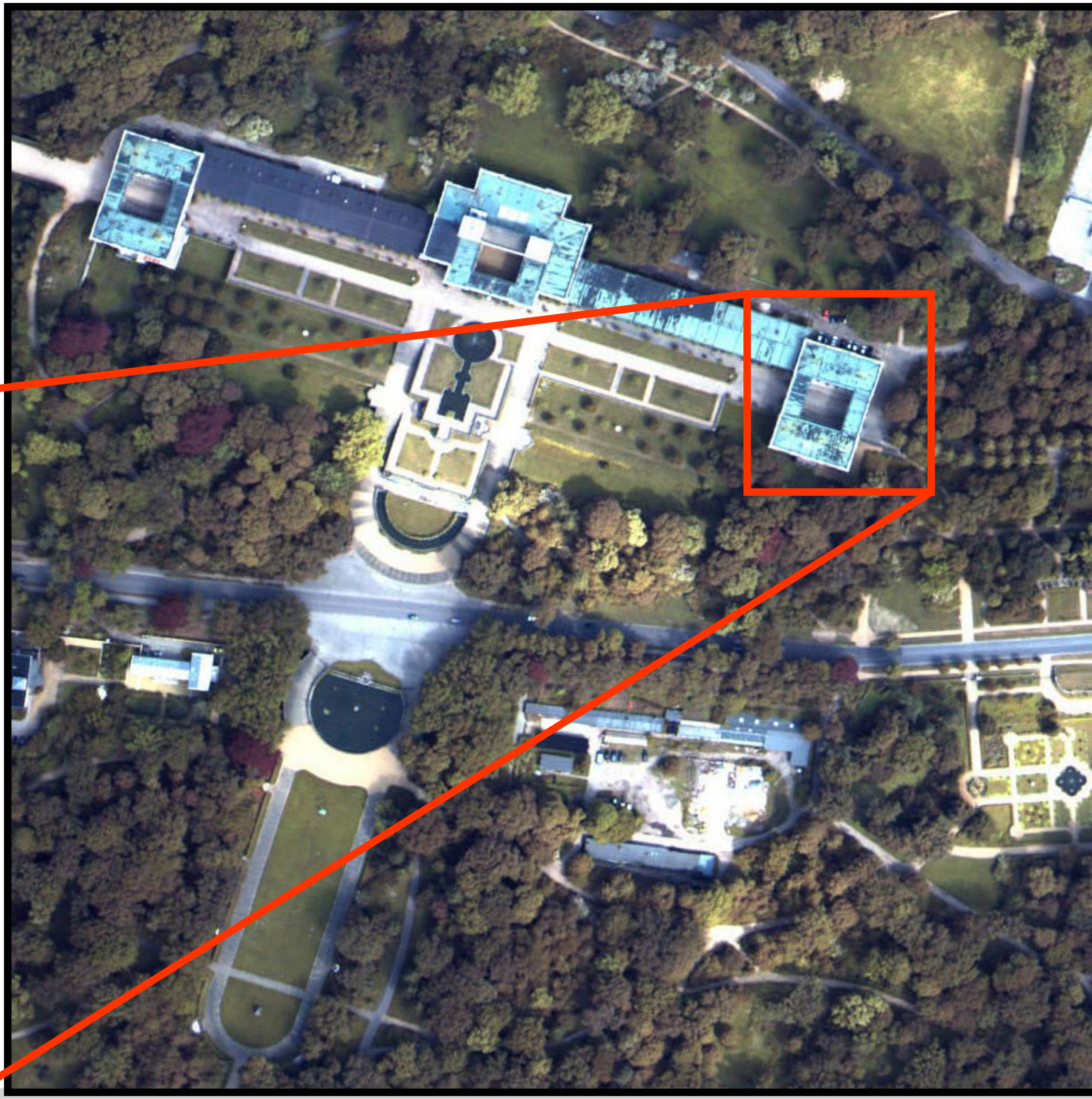
Measured Performances of the MFC

- CCD 6 k, 8 k, 10 k, 14 k exchangeable
- Shortest Integration Time

  0.6 ms [6k]; **1.3 ms** [8k]; **2 ms** [10k]; **1.4 ms** [14k]
- Exchangeable Optics
- Exchangeable IMU
- Internal Mass Memory
- Remote Control if necessary
- MEM-stick[5 x 8GByte] option
- Image data processing in one Chip as System in Chip Solution
- Weight 5 Line Version 15 kg; Power 200 W / 28 VDC

First Image of the MFC

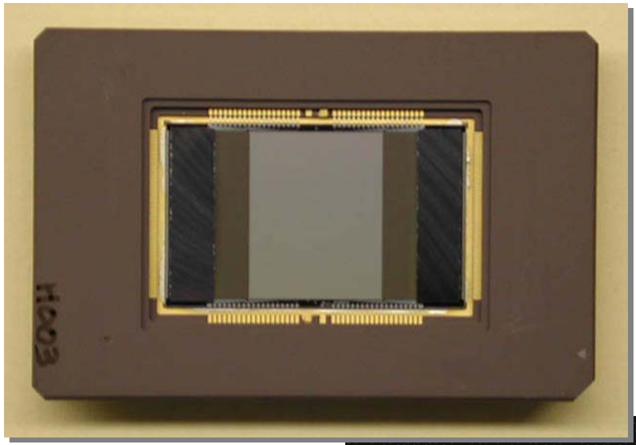
Potsdam, Orangerie
Sanssouci Garden
- GSD 25 cm
- Flight 23.6.2006
- without Platform
- IGI IMU 126
- 3 x 8 k RGB



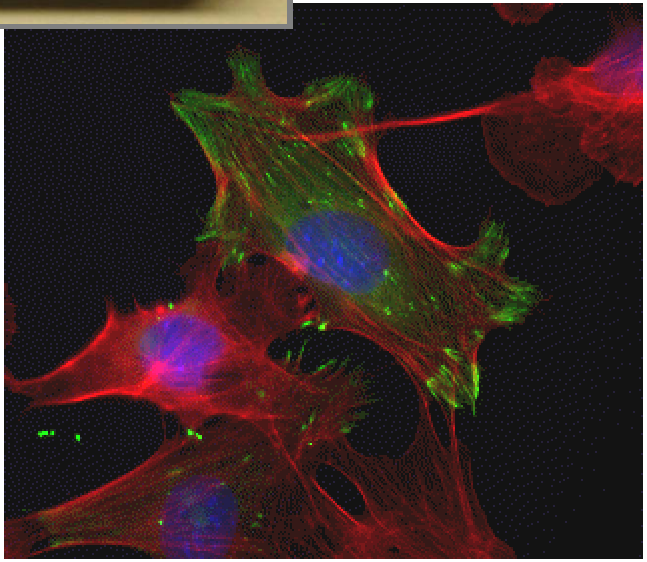
New Sensor Technologies

Hybrid Low Light Level Applications

- Microscopy
  - Live cell fluorescence
  - Fixed cell
  - Confocal
- X-ray Imaging
  - Radiography
  - Fluoroscopy
  - X-ray crystallography
    - Synchrotron
    - Laboratory
- Astronomy & Space Research
  - Adaptive optic wave front sensor
  - Startrackers
  - Environmental sensing
- Night Vision
  - Near Term -- aircraft, vehicle, fire control
  - Medium Term -- manportable



QE[400nm]:>75%



Conclusions Outlook

Conclusions

- ➢TDI Sensor Calibration and Application was shown
- ➢Advantage of new TDI Sensor Technologies was shown
- ➢Modular FPA Concepts drives the next Generation of Imager
- ➢MFC the first Step to Camera in Chip Solution
- ➢High Quality Low Cost Photogrammetric Systems are available

Next Steps

- ➢Auto Synchronisation of TDI Sensors
- ➢3D Algorithms [Hirschmüller] integration in Hardware
- ➢Real Time On Board Information Extraction inc. DTM
- ➢Real Time On Board Classification and Georeferencing

Thank you for your attention

Questions?