

Optische Sensoren und Elektronik für Luft- und Raumfahrt

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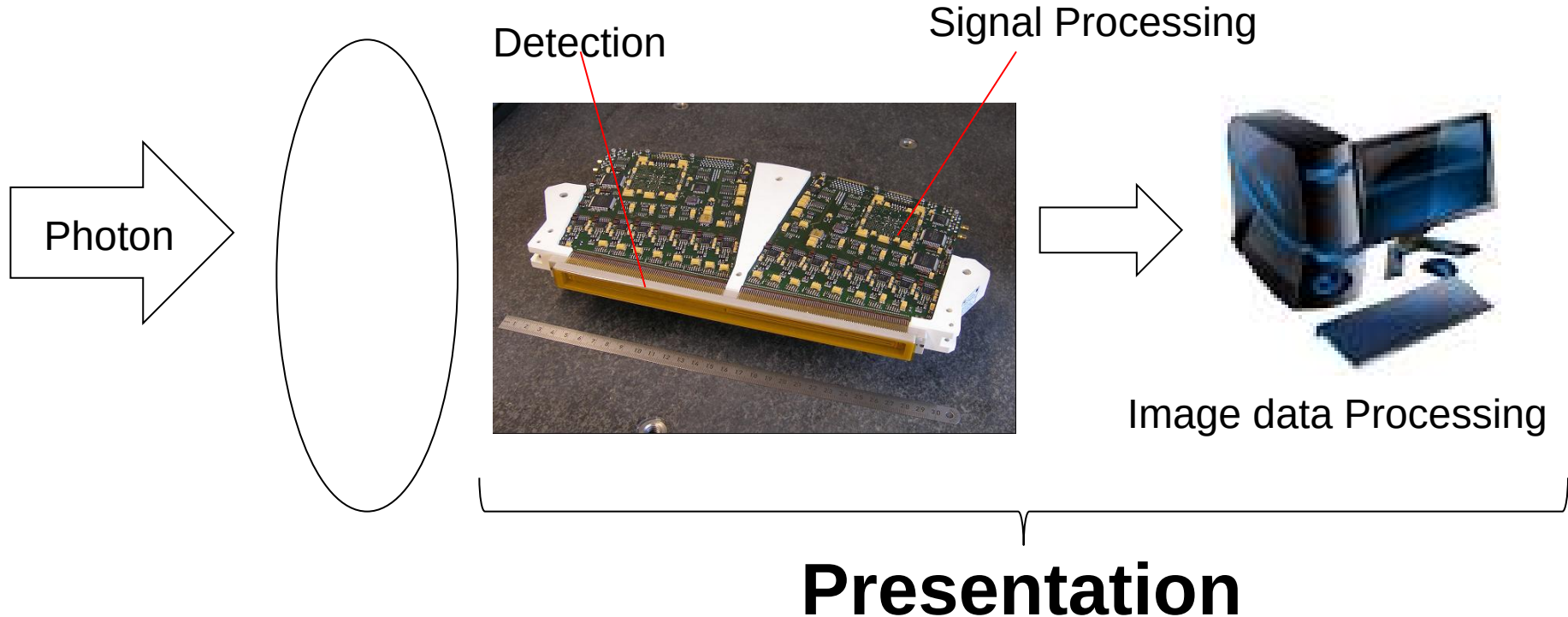
Wissen für Morgen



Outline

Photonics

The science of **photonics** includes the generation, emission, transmission, modulation, signal processing, switching, amplification, and detection/sensing of light



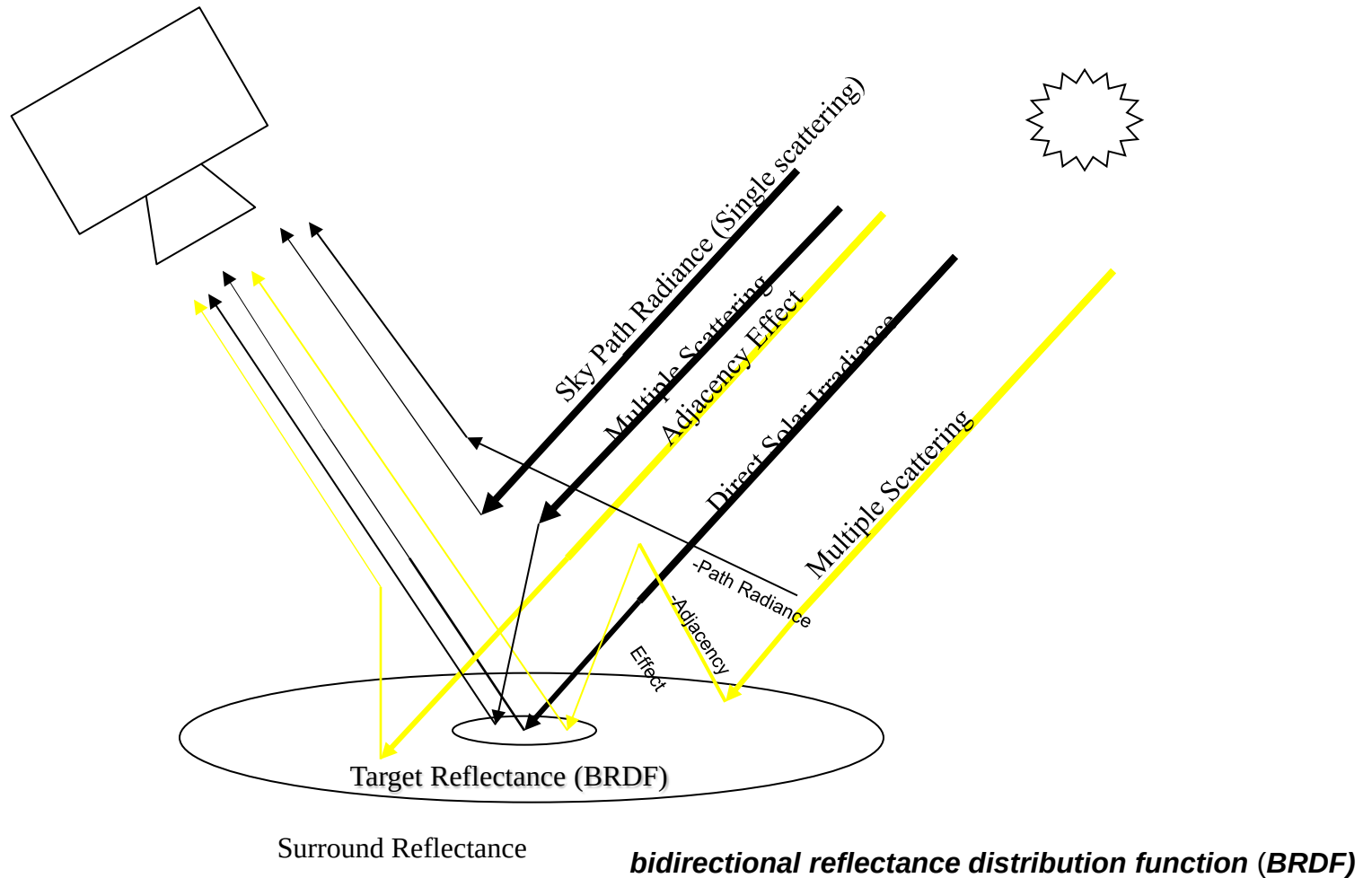
System of System Application Motivation for HR/VR-Systems

GIS System of Padang

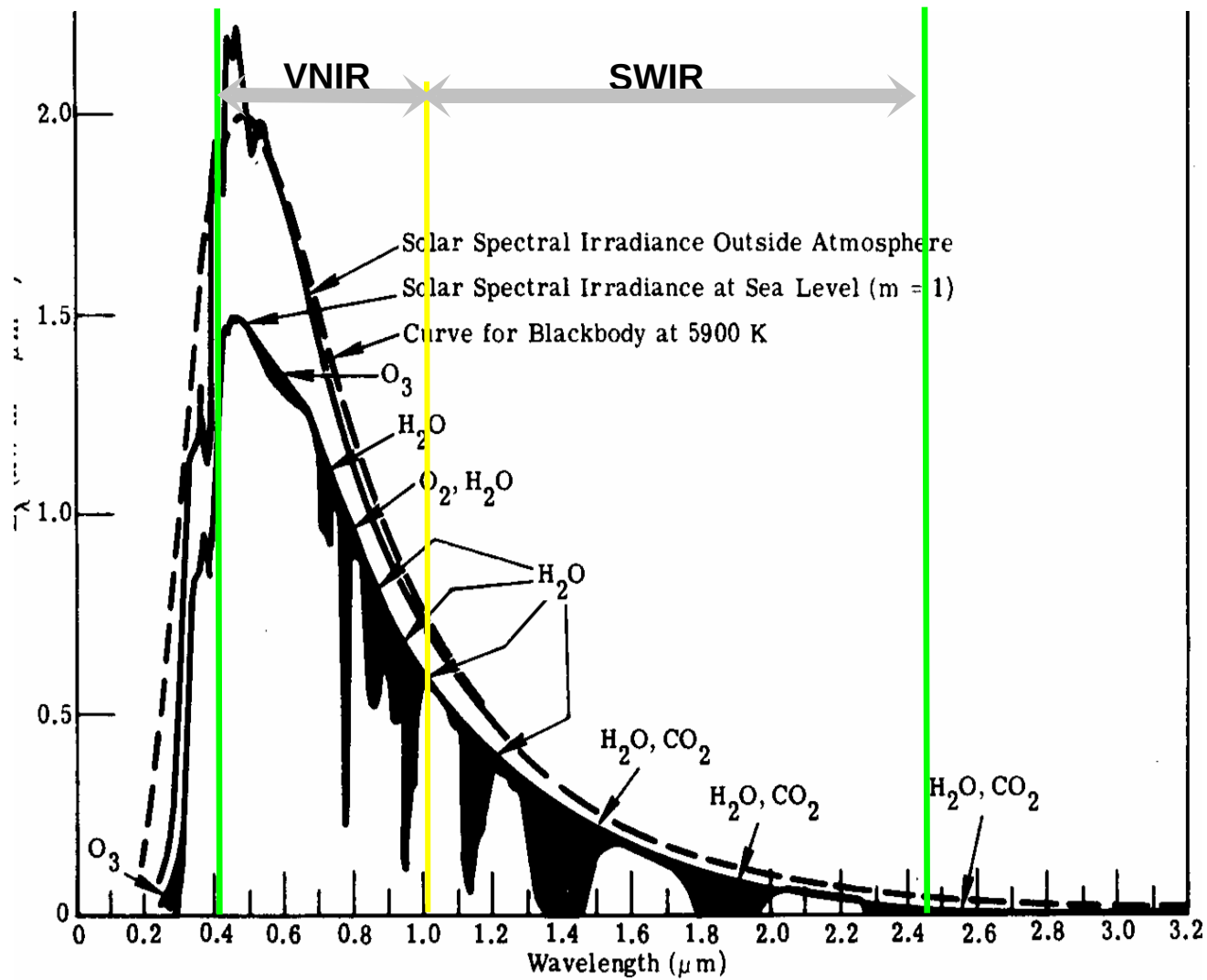


Radiometric Effects of the Atmosphere

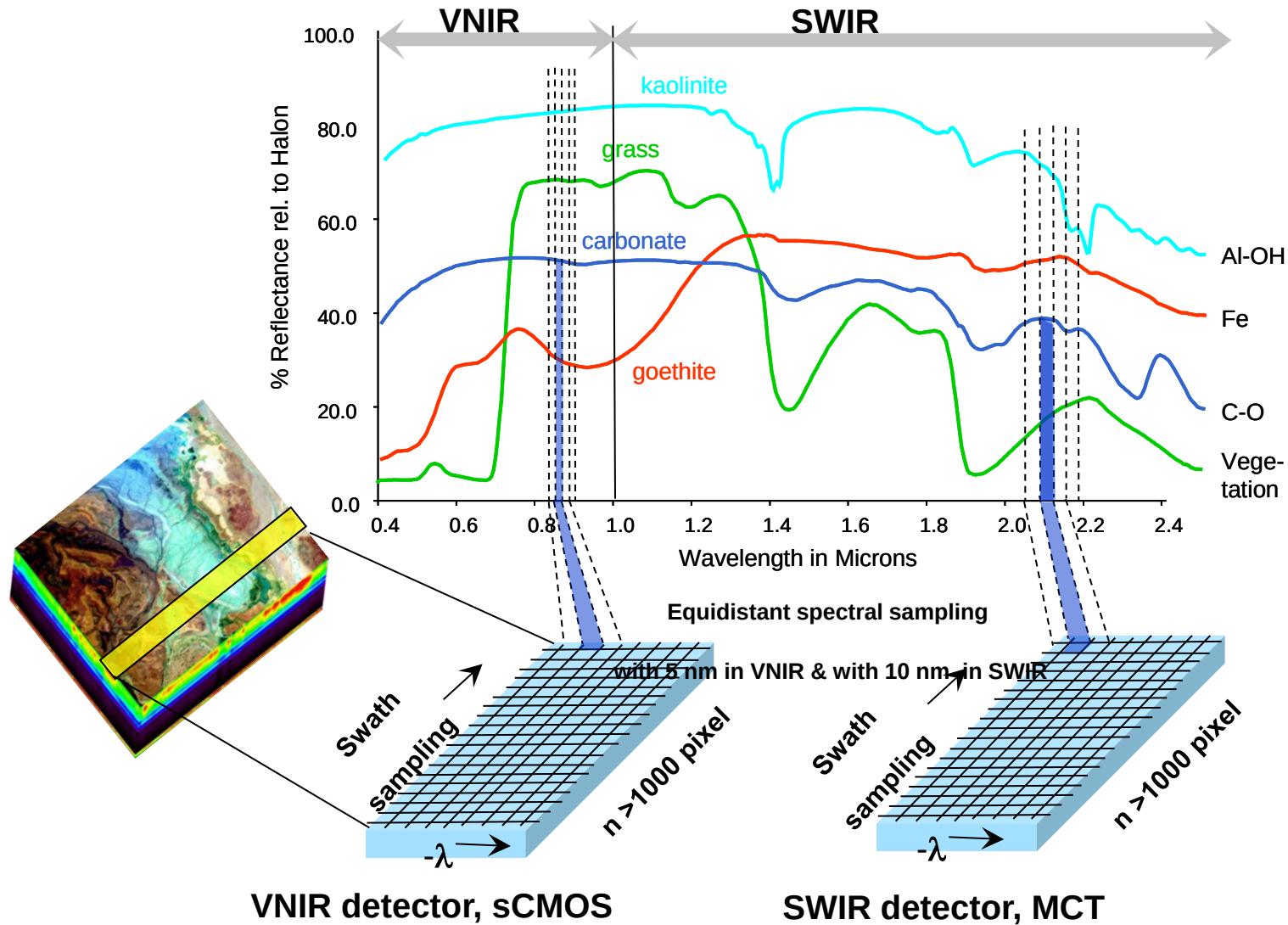
- Radiative transfer model



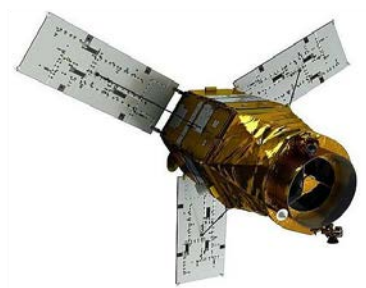
Solar Spectrum



Spectral Sampling Principle



System Theory Modell



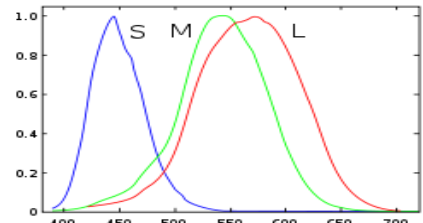
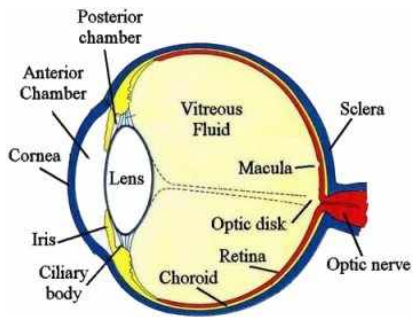
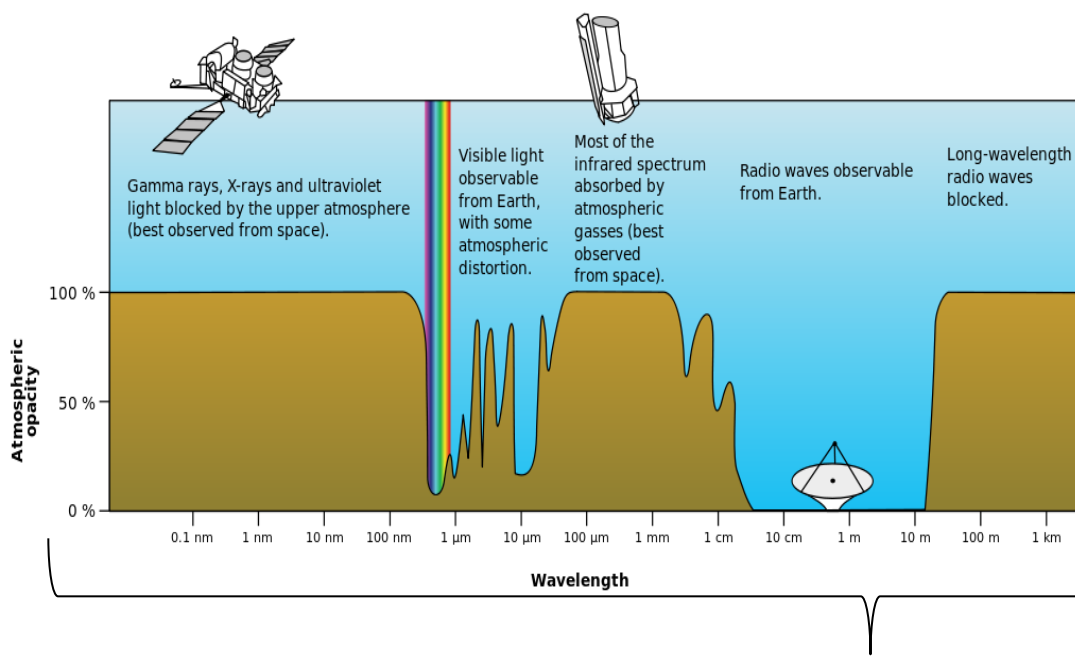
AOCS
TDI Sync
LoS Jitter
Atm-Corr.



Data Processing



Information



End to End System Model is necessary



Airborne Digital Sensor (ADS)40 involved in the ADS100

ADS40 Airborne Digital Sensor

Photogrammetric accuracy and remote sensing insight combined



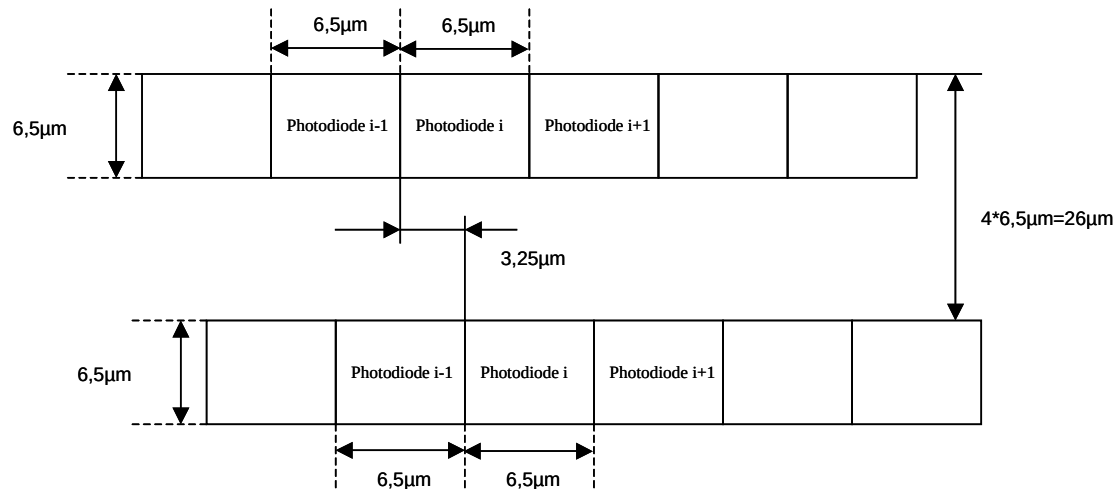
- 3 panchromatic CCD lines each 2 x 12,000 pixels, staggered by 3.25 μm
- 4...6 multispectral CCD lines, each 12,000 pixels
- Pixel size: 6.5 μm x 6.5 mm
- Field of view (FoV) or swath angle: 64°
- Focal length: 62.77mm
- Stereo angles: 14°, 28°, 42°



Capitol Austin, Texas, USA 06/2002



ADS40 based new Detector Design



$$I(x, y) = \sum_{i,j} I_{i,j} * \sin c \left[\frac{\pi}{\Delta} (x - i\Delta) \right] * \sin c \left[\frac{\pi}{\Delta} (y - i\Delta) \right]$$

MTF[NY] : $1 / 2(3,25 \mu\text{m})$ at 154 lp/mm > 10 %

Line Rate: based on the higher Resolution

➔ Resolution will increase based on this technology by a factor of 1.7



High Resolution

High Resolution Imaging System

Spatial High Resolution

Spectral High Resolution

Spatial and Spectral
High Resolution

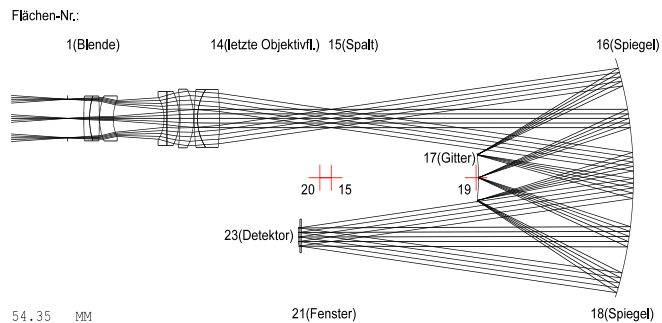
Presentation



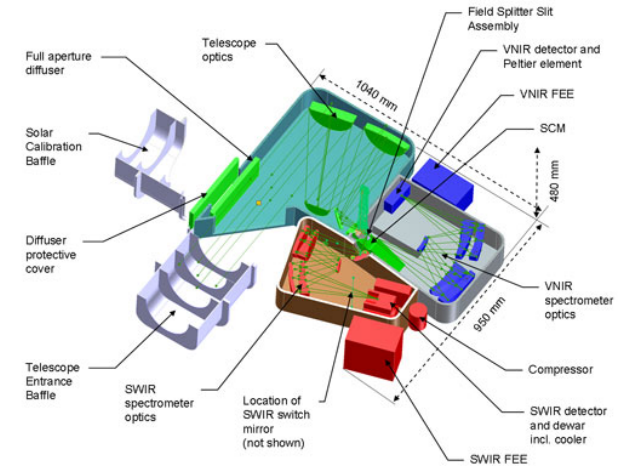
Spectral High Resolution

Spectral High Resolution

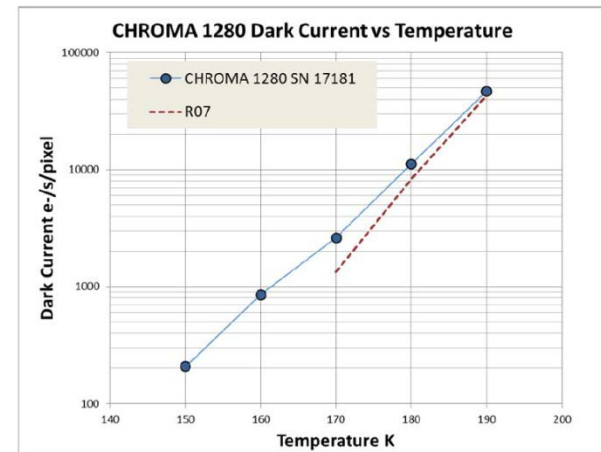
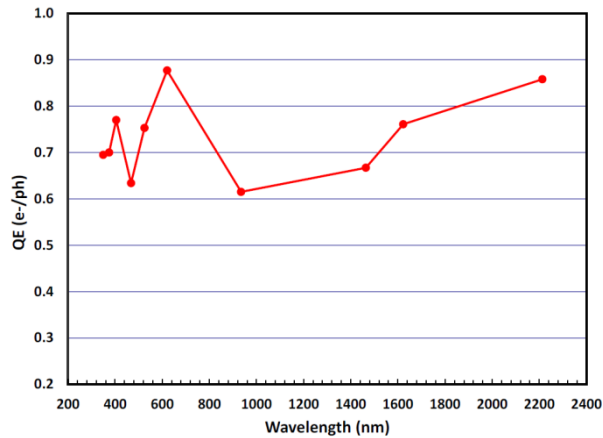
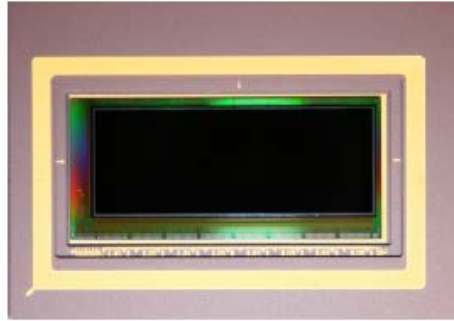
Grating-Spectrometer



Prism-Spectrometer



Teledyne new MCT Detector Technology



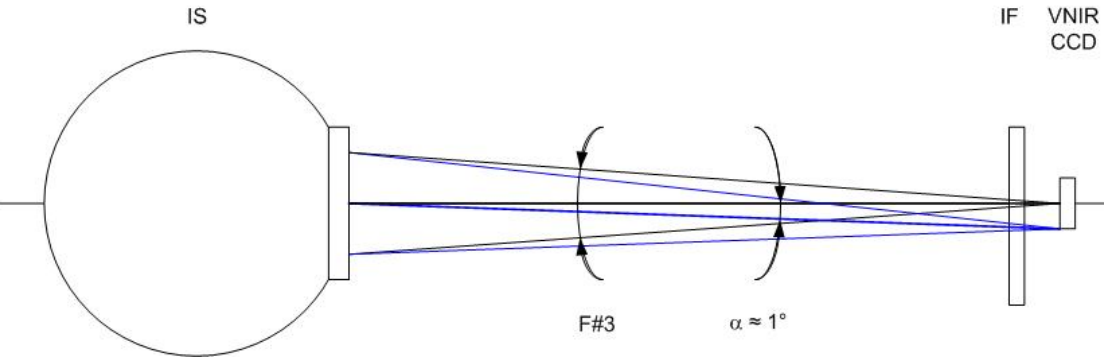
New MCT detector technology open the door for one Detector UV/NIR/SWIR Spectrograph design

SPIE2013-SanDiego: The CHROMA Focal Plane Array: A Large-Format, Low-Noise Detector Optimized for Imaging Spectroscopy

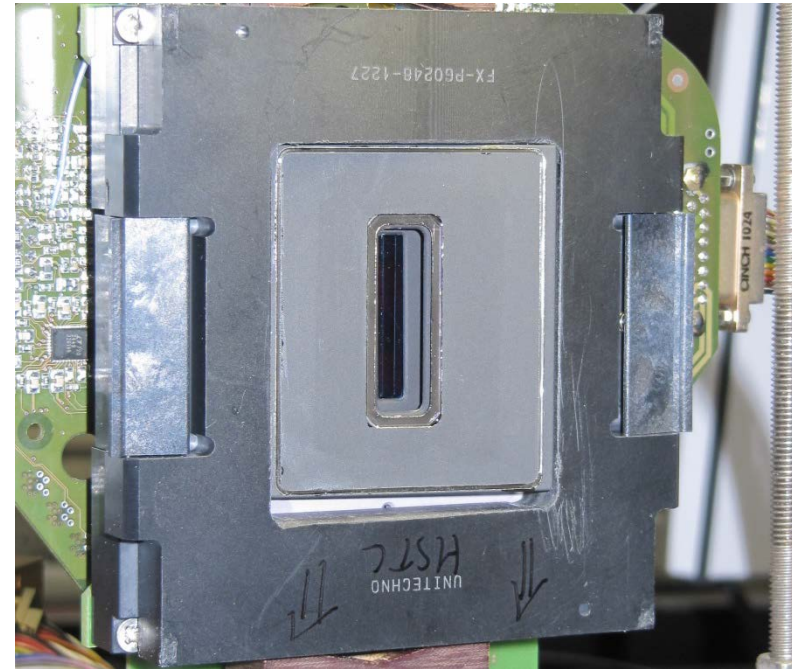


EnMAP VNIR Test Setup

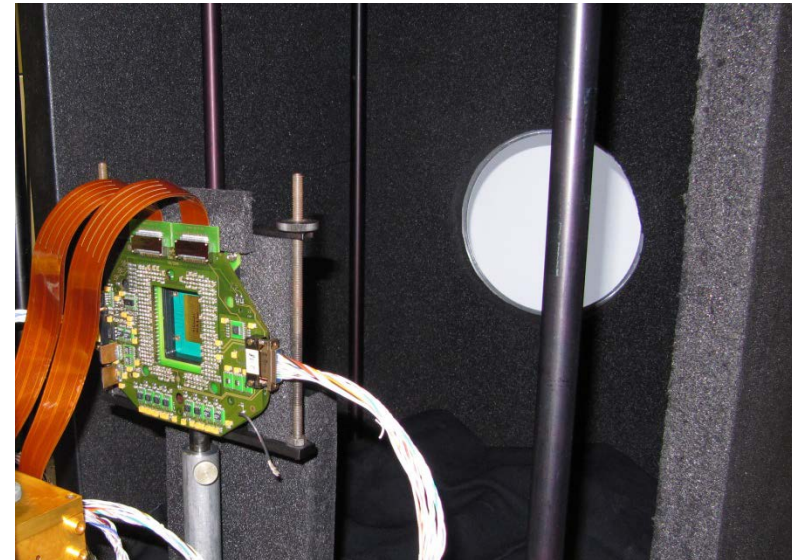
EnMAP: Test setup for measurement of radiometric performance data with integrating sphere UMBB500var (IS) and interference filter (IF)



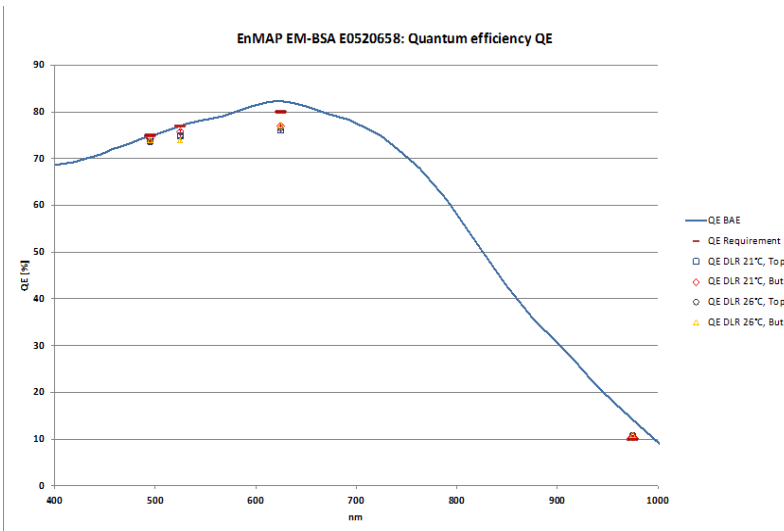
Sphere port: 200mm diameter, distance sphere - VNIR CCD: 600mm



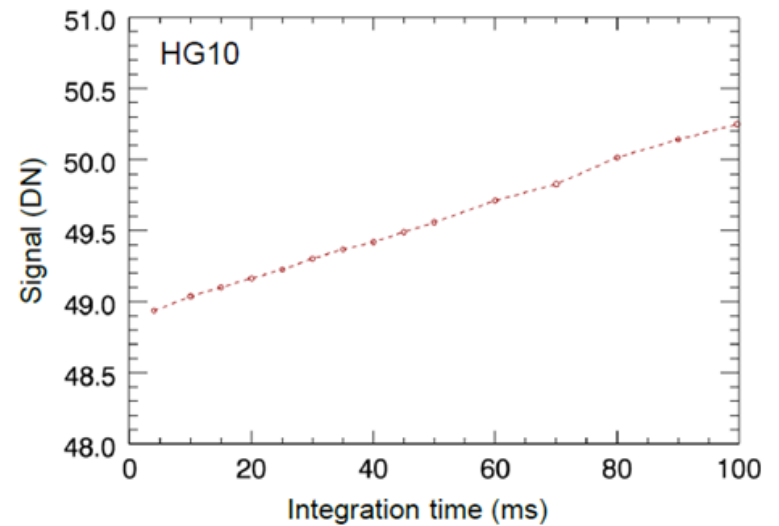
corresponds to F# 3



EnMAP sCMOS VNIR Detector



Quantum Efficiency



Dark Current

Next Generation of sCMOS detector technology enables the new UV/VIS/NIR Spectrograph design

SPIE2013-SanDiego: sCMOS Detector for imaging VNIR spectrometry



Goal of Hyperspectral data products



Motivation for special high resolution Systems



Identified Very high

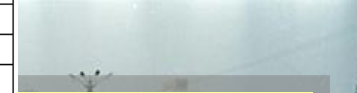
1. Urban Mapping

2. On Demand
(Natural & Man-made)

3. Defense & Intelligence
Damage Assessment



Crisis type	Spatial information required	Detailed level (1:5,000-1:25,000)		Overview level (1:50,000-1:100,000)	
		Desirable	Acceptable	Desirable	Acceptable
Floods	Flood extent	1 m	5 m	3 m	10-20 m
	Asset damage	1 m	2.5 m	-	-
Landslide	Slide scars	1 m	5 m	-	-
	Asset damage	<1 m	2.5 m	1 m	2.5 m
Hurricanes and storms	Flood extent	1 m	5 m	3 m	10-20 m
	Forest damage	1 m	5 m	5 m	10-20 m
	Slide scars	1 m	3 m	-	-
	Asset damage	< 1 m	2.5 m	-	-
Forest fires	Burnt scars	1 m	3m	5 m	10 m
	Fire lines	2.5 m	10 m	10 m	30-50 m
Earthquakes	Asset damage	< 1 m	1 m	-	-
	Slide scars	1 m	5 m	-	-
Volcanoes	Lava flows	1 m	3 m	5 m	10 m
	Asset damage	< 1 m	2,5 m	2 m	10 m
	Hot spots	-	-	5 m	10 - 1000 m
Tsunamis	Flood extent	1 m	5 m	3 m	10-20 m
	Asset damage	< 1 m	2.5 m	-	-
Oil spills and sea accidents	oil spill extent	n/a	n/a	10-20 m	50 m
	Ship identification	1 m	2.5 m	-	-
Complex emergencies	Refugees camp mapping	1 m	2.5 m	-	-
	Population gatherings	< 1 m	1 m	-	-
	Population movements	< 1 m	1 m	-	-
	Asset damage	< 1 m	2.5 m	-	-
Civil operations of ESDP	Population gatherings	<1 m	1 m	-	-
	Population movements	<1 m	1 m	-	-
	Asset damage	< 1 m	2.5 m	-	-
	Asset damage	< 1 m	2.5 m	-	-



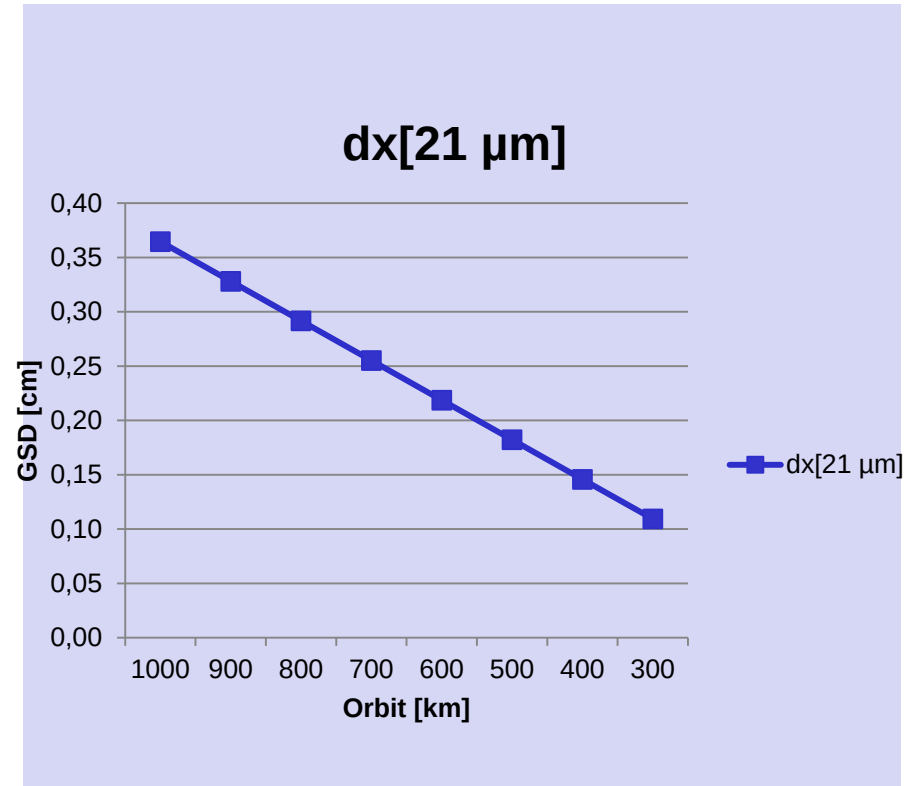
IS:

emergencies

ssance



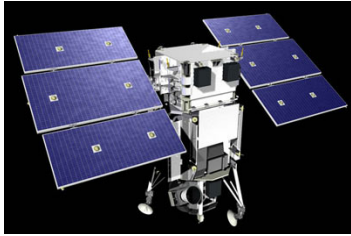
Hubble Space Telescope



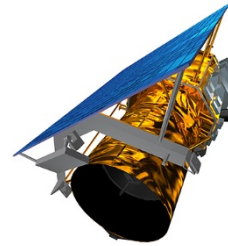
D: 2.4 m, f: 57.6 m, F#: 24,
400 nm : 11.7 μm [erri diffraction]



Commercial or dual use optical space segments



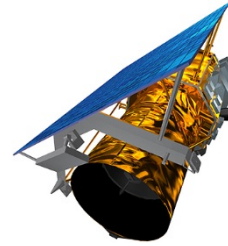
WV1: 0.5 m GSD
mission ends 2014



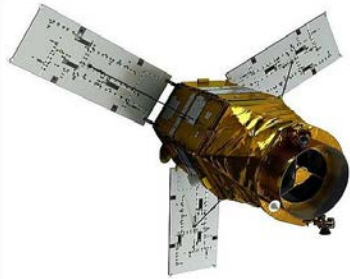
Geo Eye [I] 0.41 m GSD
mission ends 2014



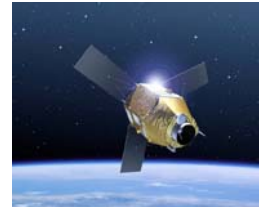
WV2 0.5 m GSD
mission ends 2016



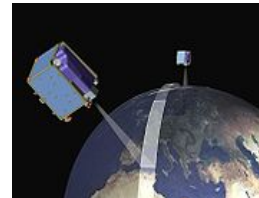
Geo Eye [II] 0.25 m GSD
mission begin 2013
mission ends 2018



KompSat3 0.7 m GSD
mission ends 2017



Pleiades 0.67 m GSD
mission ends 2018



RapidEye 6.5 m GSD
mission ends 2017



Optical High Resolution System

Typical Mission Characteristics

Long Life Time: 5 – 8 years

High Revisit Time: update of any point on Earth every day

- Polar SSO (400 - 1000 km, LTDN 10:00 – 14:00)
- satellite constellation (also as system of system)
- High duty cycle 10 min per orbit

High Agility / Operability

- One- Pass Stereo Imaging (along track viewing angle of $\pm 10^\circ$ to $\pm 30^\circ$)
- Wide Area Imaging (3 up to 8 strips of swath, in flight direction and cross track)
- Multi Point Imaging (Multiple small area coverage in one path)

High Down Link Capability

- Steerable X / Ka– band antenna (1000 Mbit/s encrypted)
- Simultaneous downlink & imaging



German(KARI) Heritage on Kompsat3

KompSat3 with H-IIA launched

Tanegashima 18.05.12 01:39 Uhr



Instrument

Telescope Design	Astrium
Telescope Structure	Astrium
Focus Mechanism	DLR
Mirrors	SESO (Fr)
FPA	DLR
Real time correction	DLR
Image data Handling	Astrium
Formatter	Astrium
X-Band Modulator	USA
X-Band Antenna	Astrium

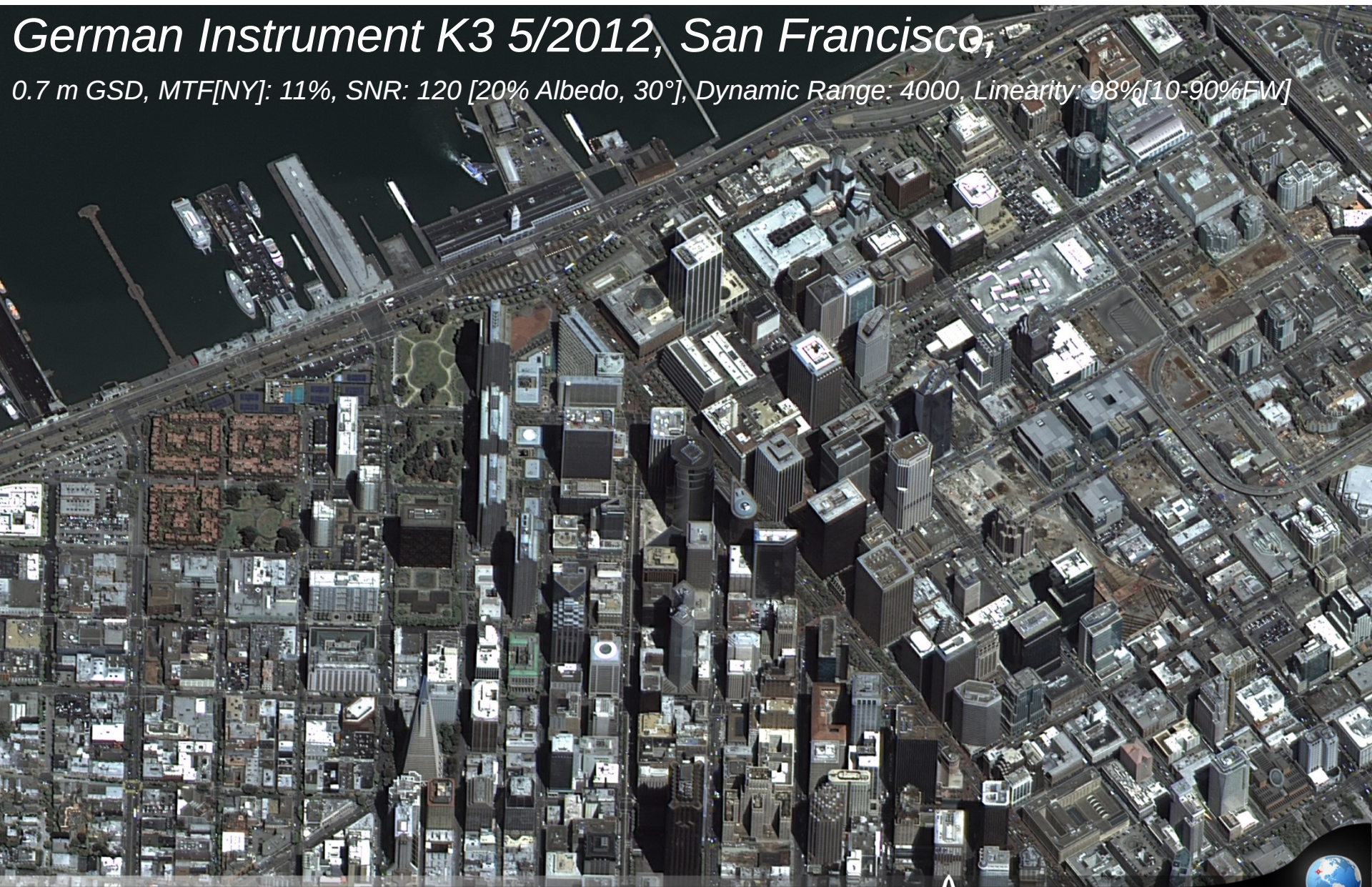
Next Modifications

Mirror	Zeiss
X-Band Modulator	TeSat



German Instrument K3 5/2012, San Francisco,

0.7 m GSD, MTF[NY]: 11%, SNR: 120 [20% Albedo, 30°], Dynamic Range: 4000, Linearity: 98%[10-90%FW]



> 아리랑 위성으로 촬영한 '샌프란시스코, 미국'

KOMPSAT-3 AEISS

KARI KOREA AEROSPACE RESEARCH INSTITUTE



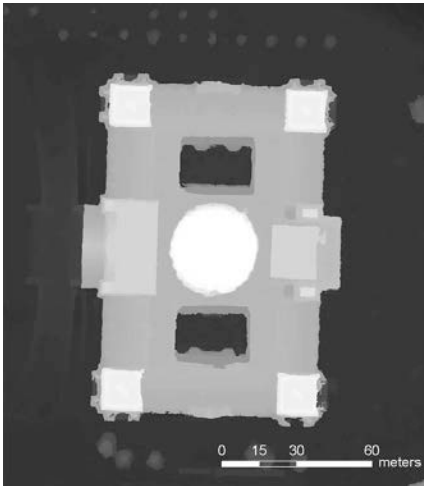
0.5 m true ortho satellite image (right) / airborne (15 cm) data (left)



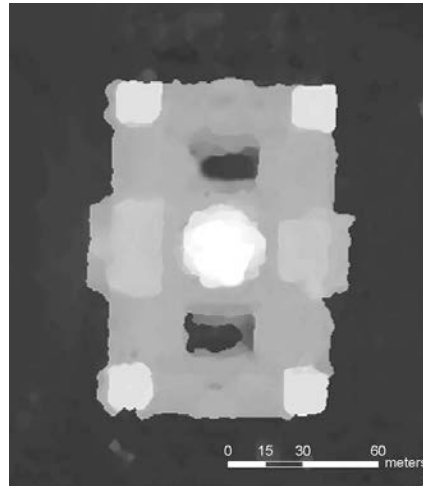
True ortho airborne image



True ortho satellite image



DSM (airborne 15 cm)



DSM (spaceborne 50 cm)

Statements:

1) DLR process whole Berlin 3D after reception of the data in a ½ h

2) Accuracy of the 3D Model will be better than 0.5 m

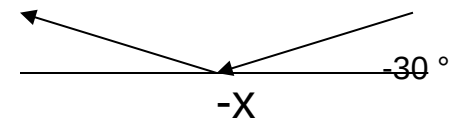
3) DLR can also support a mobile station because of the hardware processing capability



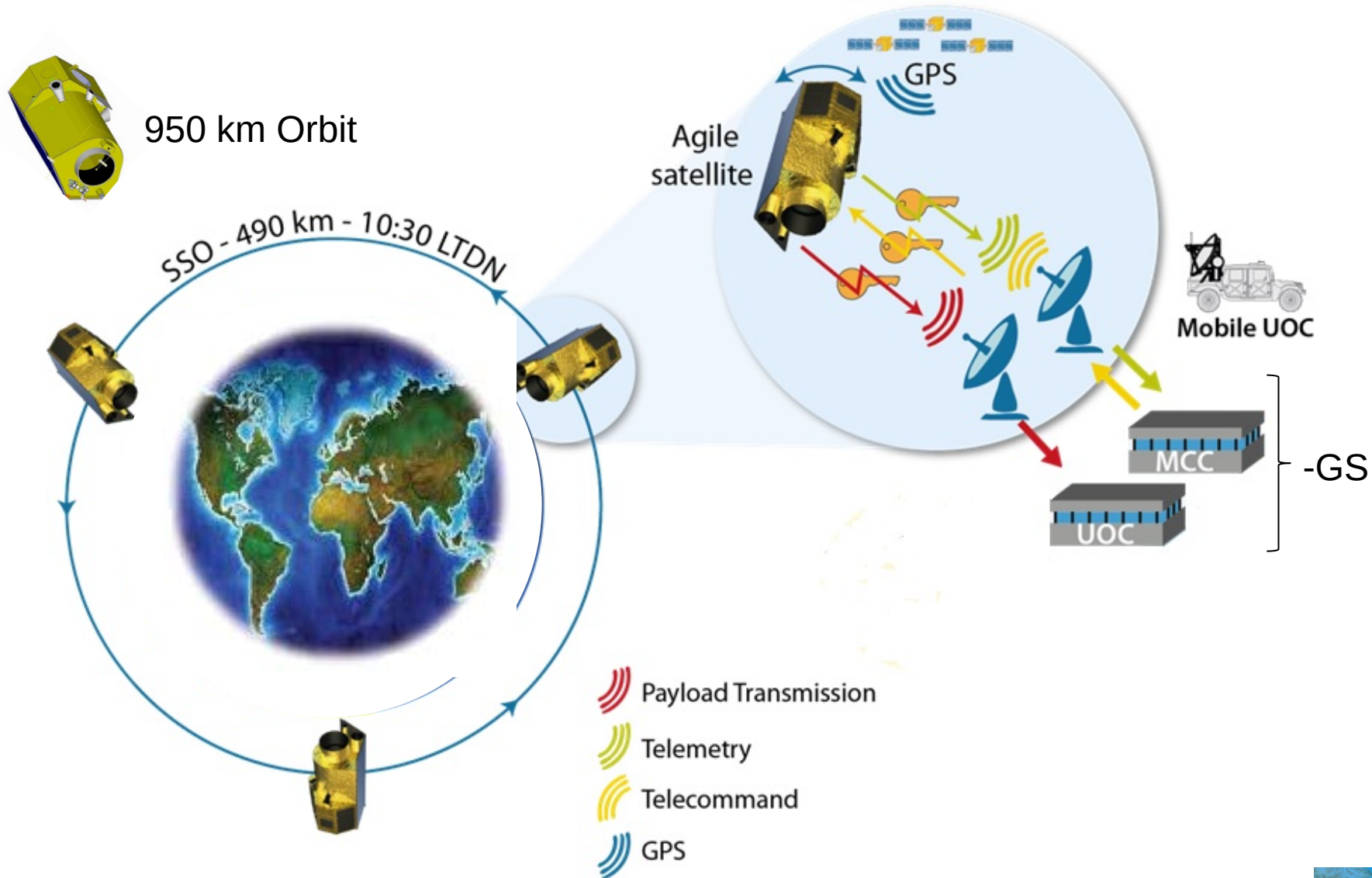
Typical key Parameter

	Satellite HiROS	SoA System
Orbit [km]	490	950
VIS/NIR GSD [m]	0.5	0.5
IR GSD [m]		5
Aperture [m]	0.8	1.2 m
VIS Spectral	R,G,B,NIR	R,G,B,NIR
Stereo Views	-30°, -10°, 0°, +10°, + 30°	-30°, -10°, 0°, +10°, + 30°
TDI-Direction	bidirectional	bidirectional
Nr. Pixel PAN	24000	30000
Nr. Pixel MS	6000	15000
MWIR & LWIR	possilble	possible
Max Line Rate [kHz]	14.2	23
MTF	> 12 %	> 12 %
SNR	> 100*	> 100*
Revisit time	3 Satellites / 24h	1 Satellite / 24 h
Revisit Swath[km]	830	1600
Swath[km]	12	15

(* at 20 % albedo, (30 ° sun angle, 30 ° view angle), 10:30 Berlin)



System Overview and System Architecture



Typical User Parameter

PAN GSD	0.5 m
MS GSD	2.0 m
Spectral Response PAN	400-900 nm
Spectral Coastal	400-450 nm
Spectral Response Blue	450-510 nm
Spectral Response Green	510-600 nm
Spectral Response Red	630-690 nm
Spectral Red Edge	700-750 nm
Spectral Response NIR	760-900 nm
Selectable TDI Steps	1-128
SNR Berlin 10:30, August, 30° view angle)	> 100
In Orbit System MTF [Ny]	> 12%
Scanning Direction	bidirectional
Dynamic Range	14 Bit
Data Encryption	AES 256
Command Encryption	AES 128
Duty Cycle	10 min
Wide Area Imaging	$\geq 6000 \text{ km}^2$
Max. Data Generation Orbit/Satellite	$\geq 63,000 \text{ km}^2$
Geo Location	$\pm 4 \text{ m (CE90)}$
Max. Processing Time on Ground	$\ll 0.5 \text{ h}$



Revisit time distribution by latitude

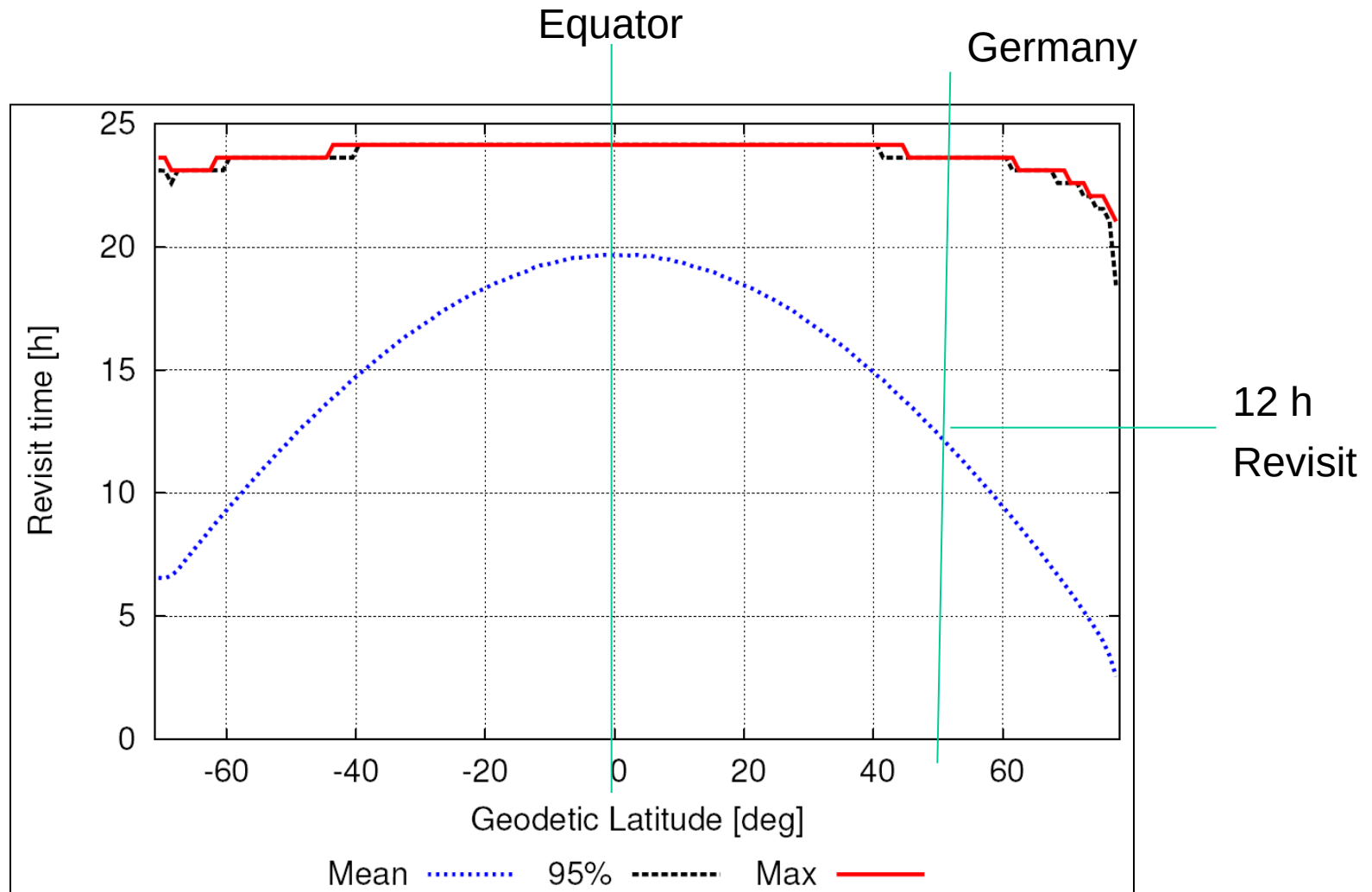


Image Modes

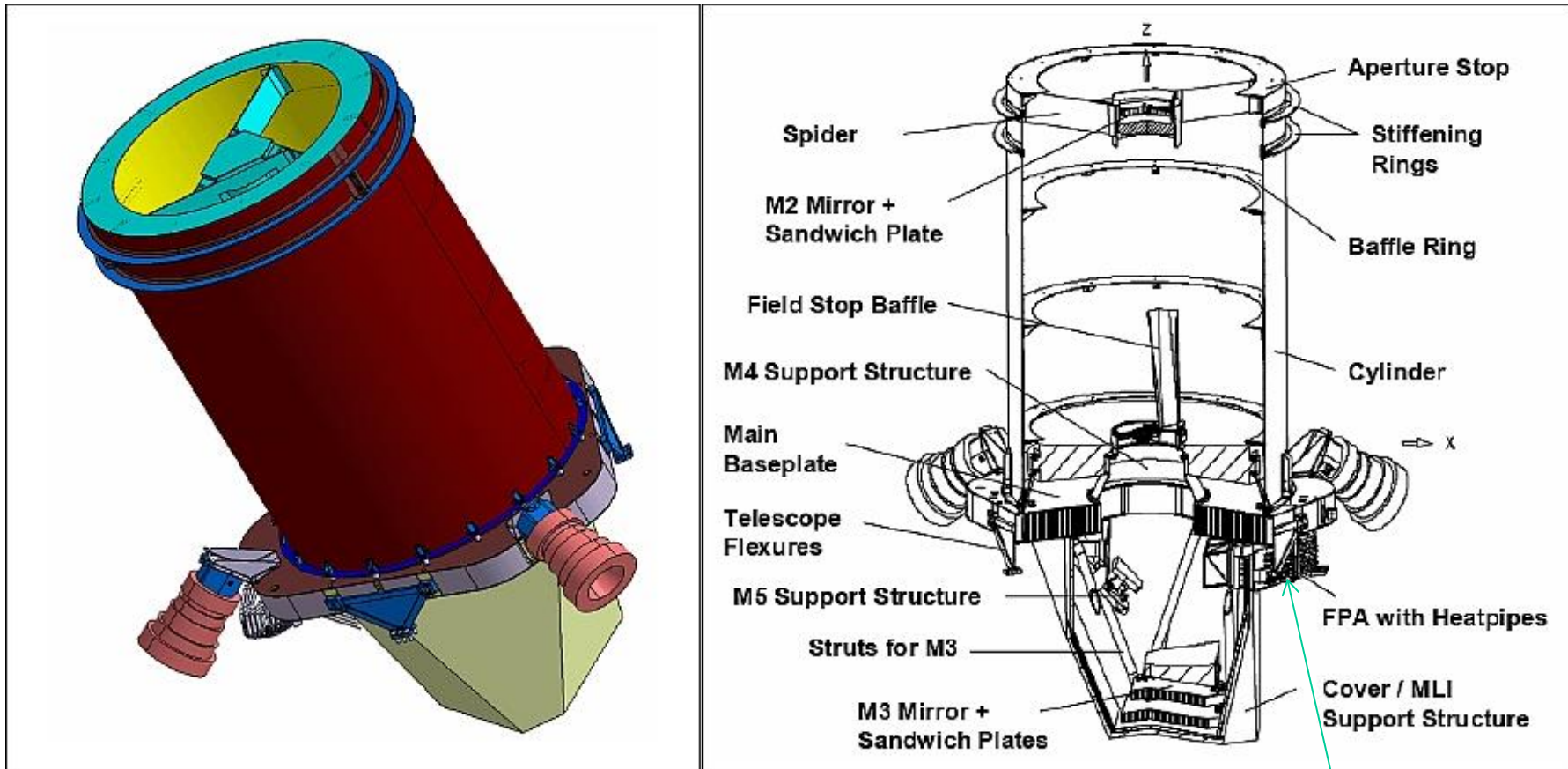


Space Segment – Electro-Optical Payload Function & Design Parameters

Optical Configuration	Four-mirror onaxis telescope in offaxis use
Optomechanics	High Stability Telescope Structure (HSTS) in dimensional stable light weighed CFRP design
Mirror Substrate	Light weight Schott ZERODUR
Coating	Protected Silver
Wavelength	400-900 nm
Effective Focal Length	13300 mm
Entrance Pupil Diameter	1200 mm
Obscuration of Entrance Pupil	260 mm
Field of View	across-track: 0,9°, along-track: 0.6°
Field Size	across track: 210mm, along track: 94mm (for 2 Pan + 12 MS)
Nyquist Frequency	71 lp/mm Pan, 35 lp/mm MS



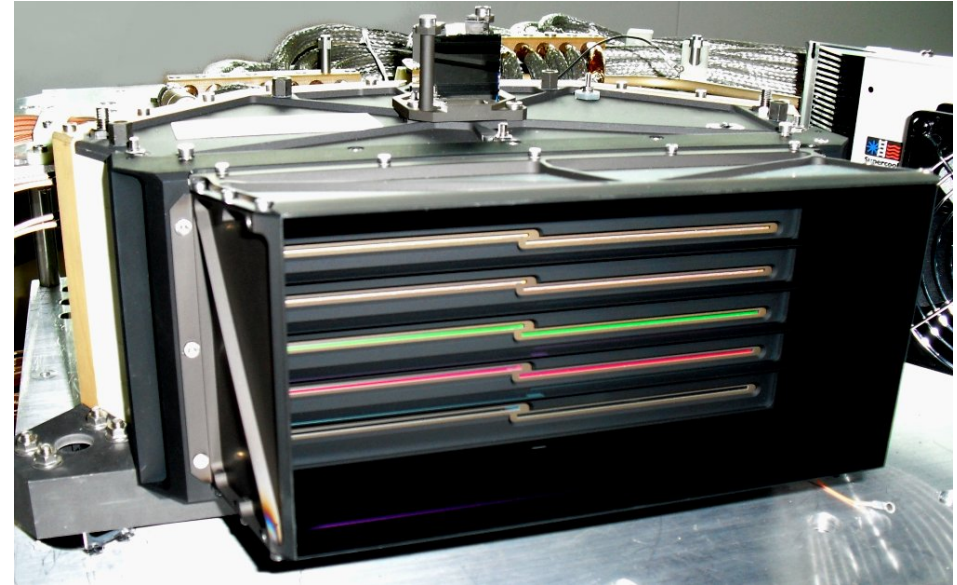
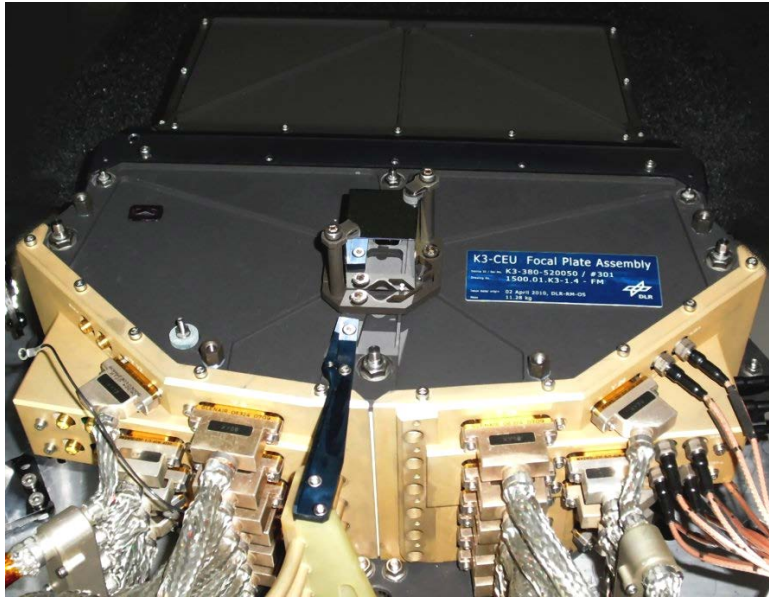
Modern Optical K3 Space Telescope Design



FPA from DLR



DLR FPA Design for 0.5 m GSD



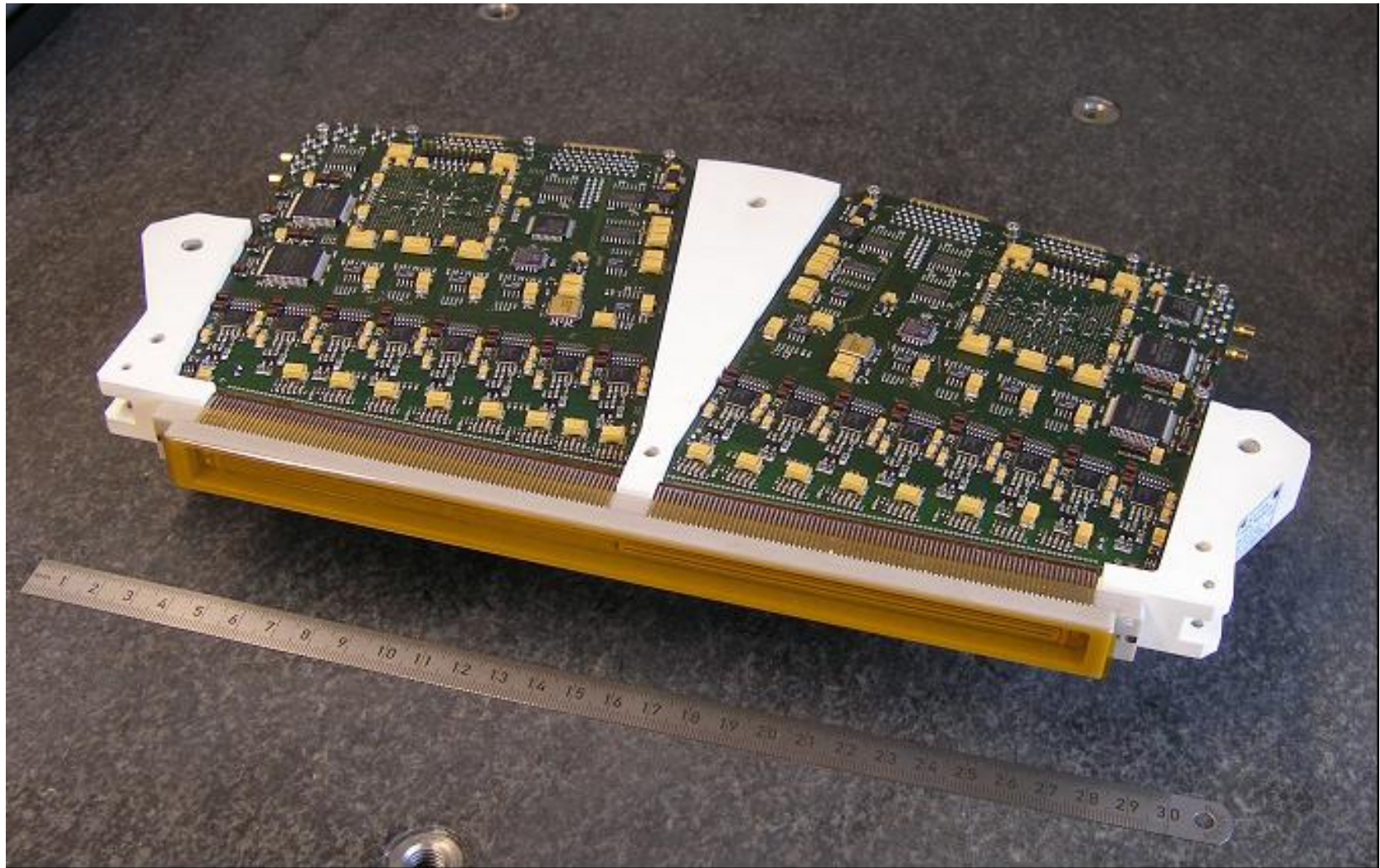
FPA Key Parameter

Nr. Pixel PAN	24160	Anti Blooming	yes	PAN	450 nm – 900 nm
Nr. Pixel MS	6040	DSNU	yes	NIR	760 nm – 900 nm
Line Rate PAN	14,2 kHz	PRNU	yes	RED	630 nm – 690 nm
Line Rate MS	3,6 kHz	MTF[NY]	52%	GREEN	520 nm – 600 nm
Pixel Pitch PAN	8.75 μm	SNR-PAN	>100*	BLUE	450 nm – 520 nm
Pixel Pitch MS	17.5 μm	SNR-MS	>200*	Reliability	0.94
TDI Steps	1,8,32,64	Flatness	< $\pm 15\mu\text{m}$	Power	< 200W/28VDC
CTR-IF	MIL1553	Data-IF	Ch-Link	GPS-Sync	yes

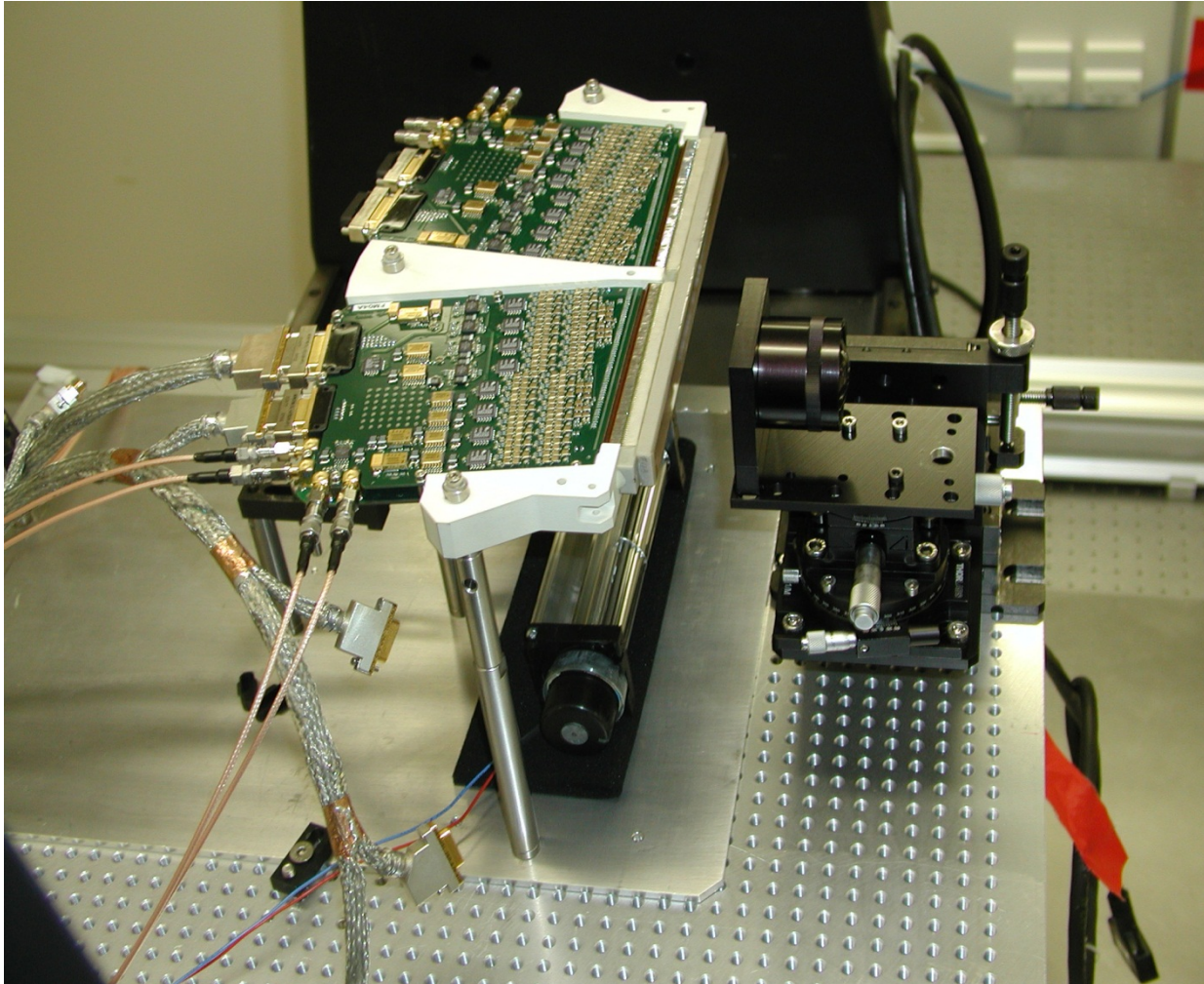
* SSO:10:30 Berlin, 30° viewing Angle, Albedo 20%, Model lambert radiator



FPA Module



FPA Test Set-up at DLR Optical Ground Support Equipment



Technological Challenges

Satellite Ground speed : 7000 m/s

Spatial High Resolution

0.5 m GSD / 30000 Pixel

→ $14000 * 30000 * 16 = \mathbf{6.7 \text{ Gbit/s}}$

0.25 m GSD / 60000 Pixel

→ $28000 * 60000 * 16 = \mathbf{26.9 \text{ Gbit/s}}$

0.1 m GSD / 150000 Pixel

→ $70000 * 150000 * 16 = \mathbf{168 \text{ Gbit/s}}$

Spatial and Spectral High Resolution

10 m GSD / 1 M Pixel

→ $700 * 1000000 * 16 = \mathbf{11.2 \text{ Gbit/s}}$

5 m GSD / 2 M Pixel

→ $1400 * 2000000 * 16 = \mathbf{44.8 \text{ Gbit/s}}$

1 m GSD / 10 M Pixel

→ $7000 * 10000000 * 16 = \mathbf{1.12 \text{ Tbit/s}}$

→ New Detector Designs NG

→ On Board Data Processing

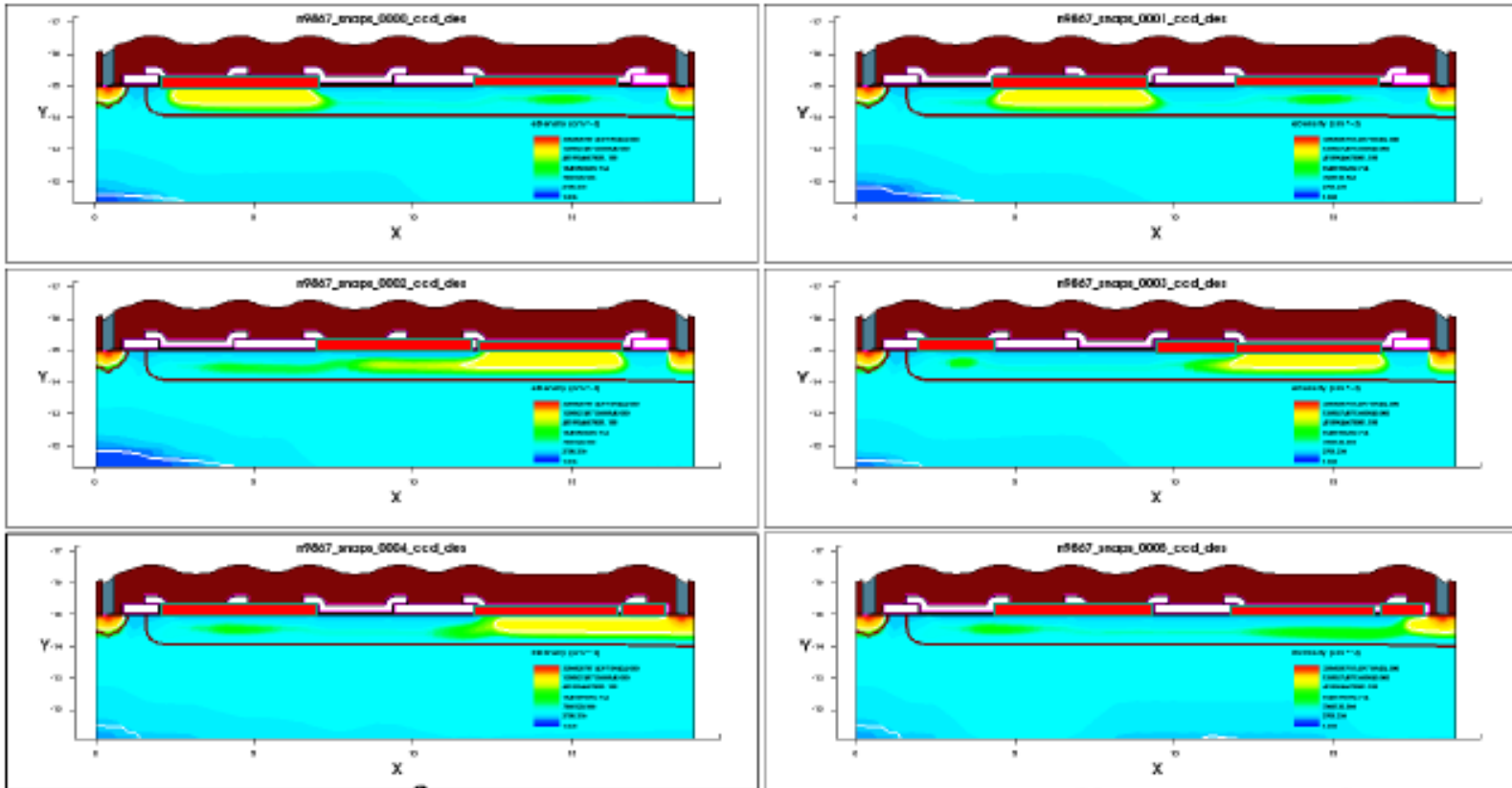


Status CMOS TDI Development

Charge Transfer – Electron Density

$$N_{electron} = 150000$$

$$V_{Gate} = 5V, V_{SW} = 8V, V_{TG} = 8V$$



$$D = 4 * 1e11 cm^{-2}, E1 = 250keV, E2 = 400keV$$

$$N_{electron-lag} = 0$$

$$\rightarrow CTE > 99.9994 \% = 100\% - 1/150000$$



Berlin 3D



Conclusion

Spectral high Resolution

The new Detector Technologies will change spectrograph Capability

The challenge is now the grating technology of the one detector designs

The new sCMOS Technology opens also door for UV-VIS-NIR Spectrograph

Spatial high Resolution

Based on the US technology are more than 10 Systems in Orbit

The advantage as System of System tool has a lot of advantages

The new Technologies degrees the investment $1/5 \dots 1/10$

Real time data processing on board become possible

Necessary Investigations

CMOS TDI Technology

On Orbit Change Detection



Thank you for attention



any question is welcome

