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Editorial

Department of Optical Information Systems (OS) – Sensors and Instruments for Space- and Airborne Applications

Preface: This PFG-issue focuses on the work of the Department of Optical Information Systems (OS) at the Institute of Robotics and Mechatronics of the German Aerospace Center (DLR). DLR is Germany's national research centre for aeronautics and space. Its extensive research and development work in aeronautics, space, transportation and energy is integrated into national and international cooperative ventures. As Germany's Space Agency, the German federal government has given DLR responsibility for the forward planning and implementation of the German space programme. Presently, the DLR is composed of about 100 departments and 31 institutes. However, the department of OS is the only one specialized on airborne and space borne optical sensors.

In combination with engineering research the latest generations of spaceborne sensor systems are able to achieve the highest spatial and spectral resolutions to meet the requirements of Earth and planetary observation systems. The combination of large line and / or matrix detectors with intelligent synchronization control, fast read-out chains and new focal plane concepts open the door to new remote-sensing and smart deep space instrumentation.

The Department of Optical Information Systems was founded in 2003. Its predecessor was founded in 1981 as the Institute of Space Research of the Academy of Sciences of the GDR with the focus of Earth observation hardware and real time information processing. After the German reunification parts of the institute were integrated in the DLR. Thus, Berlin-Adlershof has been a centre for optical remote sensing sensors for 40 years.

In the past 20 years many widely known air- and space sensors had their origin in the department of OS. This editorial highlights the scientific results of DLR and OS in Berlin-Adlershof over the last two decades in the field of leading edge instrumentation and focal plane designs for space- and airborne applications. The paper includes instruments and sensors developed by DLR-OS which have influenced photogrammetry, planetary research and remote sensing. The articles that follow provide an insight in the present scientific work of the department.

Vorwort: Das vorliegende PFG-Heft widmet sich schwerpunktmäßig der Abteilung Optische Informationssysteme (OS) am Institut für Robotik und Mechatronik des Deutschen Zentrums für Luft- und Raumfahrt (DLR). Das DLR ist Deutschlands nationales Forschungszentrum für Luft- und Raumfahrt. Seine umfangreichen Forschungs- und Entwicklungsarbeiten in Luftfahrt, Raumfahrt, Verkehr und Energie sind in nationale und internationale Kooperationen eingebunden. Als Deutschlands Raumfahrt-Agentur hat die Bundesregierung dem DLR die Planung und Umsetzung der deutschen Raumfahrtaktivitäten übertragen.

Zum DLR gehören derzeit etwa 100 Abteilungen, die in 31 Instituten zusammengefasst sind. Allerdings ist OS die einzige Abteilung, die auf flugzeug- und satellitengestützte optische Sensoren spezialisiert ist.

Mit Hilfe der Ingenieurswissenschaften und der neusten Generation dieser Raumfahrttechnologien erreichen diese Produkte eine Qualität, die für höchste geometrische und spektrale Auflösung genutzt werden kann. Die Kombination von großen Zeilen- und / oder Matrix-Detektoren mit intelligenter Synchronisation, schnellen Verarbeitungsketten, und neuen Fokalebenenkonzepten öffnet die Tür für neue Erdbeobachtungs- und Tiefrauminstrumente.

Die Ursprünge der Abteilung gehen auf das 1981 gegründete Institut für Kosmosfor-

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schung der Akademie der Wissenschaften der DDR zurück. Nach der Wende wurden Teile des Instituts vom DLR übernommen. Die Abteilung OS wurde 2003 gegründet. Damit ist seit 40 Jahren der Standort Berlin Adlershof ein Zentrum der optischen Sensorik für die Fernerkundung.

In den letzten 20 Jahren sind viele bekannte Sensoren am OS entwickelt worden. Das Editorial ist eine Darstellung der technologischen und wissenschaftlichen Resultate der letzten zwanzig Jahre, in denen die Abteilung OS eine führende Rolle in der Sensor- und Instrumententenentwicklung für die Luft- und Raumfahrt gespielt hat. OS hat und wird neue Detektorentwicklungen betreiben und neue höchstgenaue Verarbeitungstechnologien entwickeln, die es ermöglichen, den immer weiter steigenden Anforderungen der Nutzer gerecht zu werden. Die weiteren Artikel des PFG-Heftes gewähren einen Einblick in die aktuellen Forschungsarbeiten der Abteilung.

1 Introduction

The preceding institute of Optical Information Systems (OS) at the Robotics and Mechatronics Center of the German Aerospace Center (DLR) was founded 1992 at January 1. OS has been formed from parts of the former Institute of Space Research of the Academy of Sciences of the GDR. Here the members of the institute were working on a variety of technical and scientific challenges. Some highlights are change detection methods in real time for space- and airborne applications, in parallel on-chip analog processing and digital real time data processing. The following technological results reflect different steps of the digital processing chain.

Main topics are the development of sensors with high spatial and / or spectral resolution. The first on-board real time classification was demonstrated with the BIRD (Bi-Spectral Infrared Detection) satellite which provided fire maps and high temperature events in real time. For high spatial resolution the data processing is much more complex because of the need of generating the DTM first or of using an actual DTM to be able to compare the data independent of the satellite manoeuvres and scaling factors. The following parts show instruments and FPAs (focal plane assemblies) which are developed to fulfil the particular performances criteria and in parallel opens the door to the digital instrument design. For most of the shown applications, a data compression capability (lossy or lossless) as part of the digital data processing has been implemented in order to reduce the whole data rate. The Institute for Robotics and Mechatronics has also been working on 3D automatic data processing to use the technology for sensor orientation and remote sensing. In combination with the hardware technology OS is working on the next generation of remote sensing satellites, which can be used for information extraction based on change detection methods.

In the following the most significant developments are described.

2 WAOSS (Wide Angle Optoelectronic Stereo Scanner) (1996)

DLR OS was responsible for the CCD Line Scanner WAOSS for the Mars 96 Mission. The design is shown in the Fig. 1. The Wide-Angle Optoelectronic Stereo Scanner WAOSS was one of the important payload components for

Tab. 1: WAOSS Specification.

Focal Length	21.7 mm
Field of View (across track)	80 °
Convergence Angle	25 °
Number of CCD-Lines	3
Elements per CCD-Line	5184
Elements Spacing	7 µm
Spectral Channel – Nadir – Forward, Backward	 470...670 nm 580...770 nm
Data Compression Method	DCT (discrete cosine transform) - JPEG

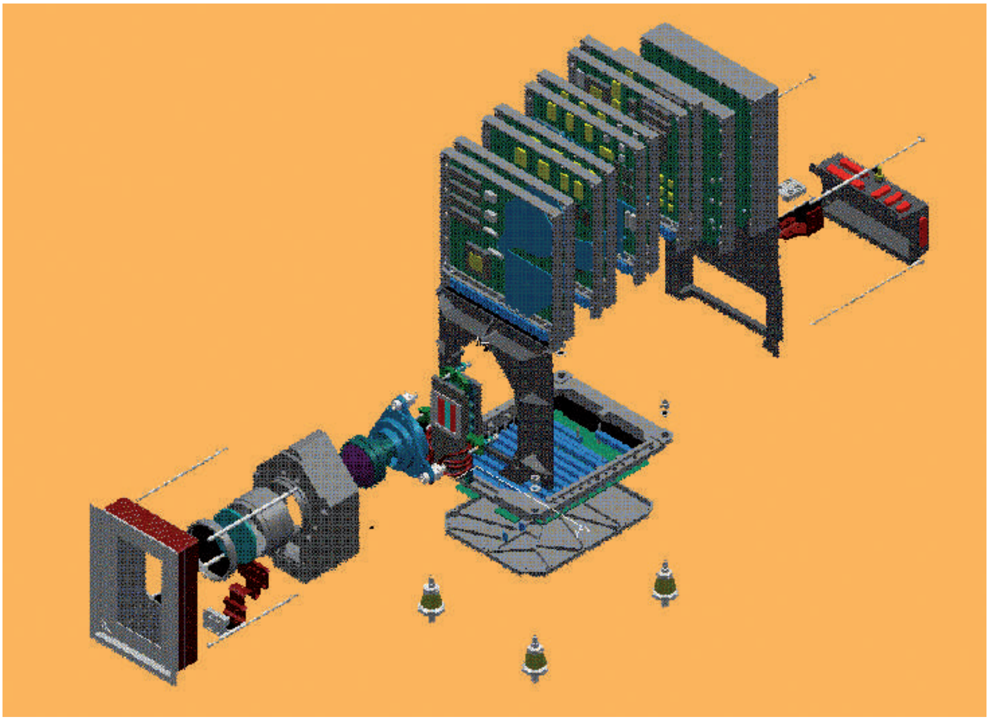


Fig. 1: Structure of the WAOSS camera (Wide-Angle Optoelectronic Stereo Scanner). Source: WAOSS, a synoptic stereo camera for the Mars-96 mission, and WAAC, the camera for terrestrial applications. From left to right: baffle (reduces straylight), optical path, focal plane (three CCD-lines), front end electronics (redundant layout with four pairs of circuit boards), digital electronic part, compression board. CD ROM, DLR, Institut für Weltraumsensorik, Berlin, 1996.

the Mars 96 mission. WAOSS is a three line stereo scanner working in the push-broom mode. The Tab. 1 shows the most significant specifications of WAOSS. The WAOSS components and algorithms have been tested with the airborne version WAAC. The Wide Angle Airborne Camera WAAC was derived from the modular WAOSS design concept allowing flexible imaging conditions including high data rate and high data volume applications.

3 Airborne Digital Sensor (ADS40) Design (2000)

The company LH Systems and DLR OS have developed the commercial airborne digital sensor ADS40. This high-resolution imaging system is able to fulfil both photogrammetric and remote sensing requirements. The new sensor was introduced in mid-2000 and was designed to complete the digital chain for airborne photogrammetric data processing. The following Figs. 2 and 3 show that the focal

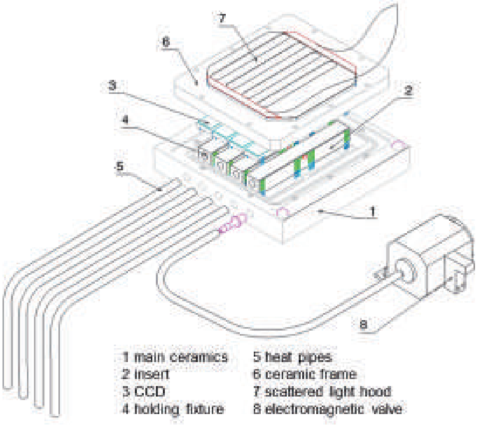


Fig. 2: ADS40 focal plane concept.

Fig. 3: ADS40 focal plane.

plane design for airborne applications is much more complicated than the one for space applications due to the fact that environmental conditions can change dramatically.

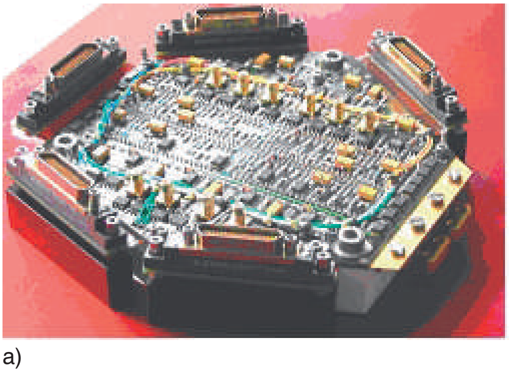
The FPA including the analog conversion and the optics define the performances of the instrument. In the case of ADS40 the flatness of 20 µm allows the small f-Number of the optics and the black detector shielding reduces the stray light effects. In order to compensate for the pressure differences an air filter and drying system was installed to avoid the optical distortion of the cover glass of the FPA. The thermal stabilisation via heatpipes is required to ensure the excellent image quality of the ADS40. The system works as a measurement device independent of the environmental conditions. The optics and the FPA were in focus to obtain the best reproducible imaging performances.

4 RapidEye: Focal Plane Assembly and Front End Electronics (2005)

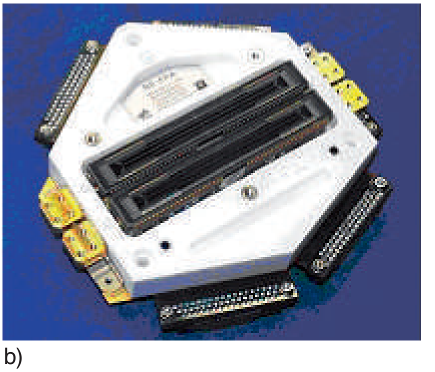
This FPA has been optimised for a medium geometric and high radiometric resolution of the instrument based on the focal plane development for the airborne digital sensor ADS40. The advanced focal plane for ADS40 was modified for space in order to meet the RapidEye requirements. This focal plane is the main component of the Multi Spectral Imager (MSI) of the RapidEye payload (Fig. 4). DLR OS was the subcontractor of Jena Optronik GmbH, Jena, Germany, for the MSI development. The RapidEye satellite constellation consists of five identical small satellites. These satellites are each equipped with the powerful MSI to record imagery of the Earth in five spectral bands and with a GSD of 6.5 m. The FPA of the MSI contains five colour 12k CCD lines and the focal plane electronics. The FPA receives bias and clock signals from the front end electronic which is located in a separate box. The focal plane electronics includes the output buffering and the clock driver of the CCD. The amplified analog high speed data channel is part of the front end electronics.

5 Hot Spot Recognition System (HSRS) (2001 and 2010)

HSRS is a two-channel pushbroom scanner with spectral bands in the mid-wave infrared (MWIR) and thermal infrared (LWIR)



a)



b)

Fig. 4: RapidEye: a) Focal Plane with transport cover, b) without transport cover.

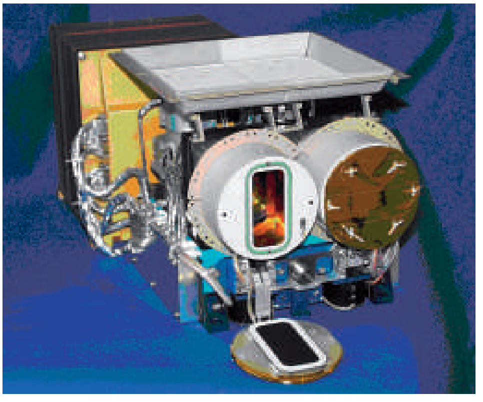


Fig. 5: Flight model HSRS 2001.

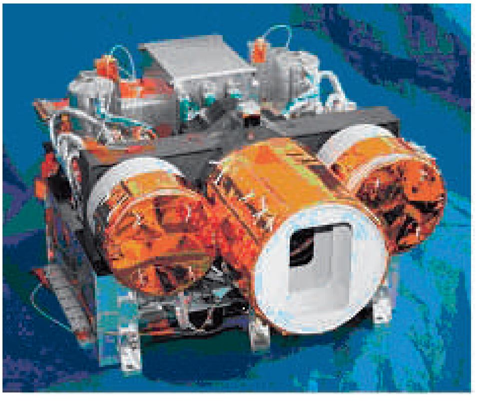


Fig. 6: Flight model HSRS 2010.

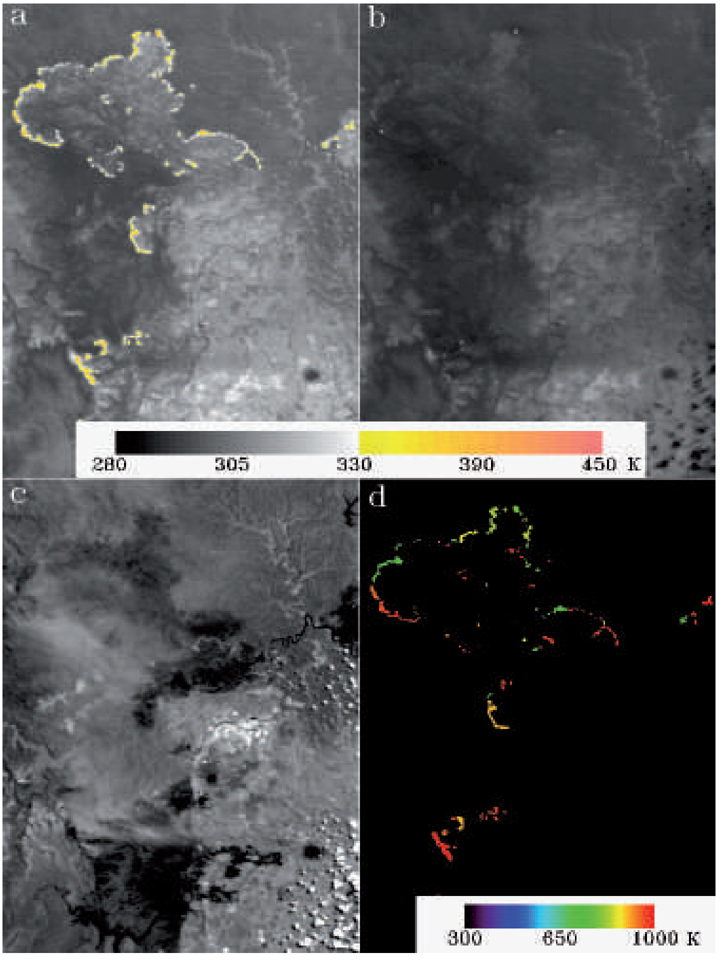


Fig. 7: BIRD image fragment of the Sydney bush fire scene observed on January 5, 2002, taken with the HSRS:
a – MWIR image
b – LWIR image
c – NIR image
d – detected hot clusters
The black-and-white and colour coding of the MWIR and LWIR images represents their pixel brightness temperature; the colour coding of the hot clusters represents their equivalent fire temperature.

Tab. 2: Modular Optical Scanner MOS IRS-P3, performance data (altitude 817 km).

Parameter	MOS-A	MOS-B	MOS-C
Spectral range [nm]	755 – 768	408 – 1010	SWIR
No. of channels	4	13	1
Wavelengths [nm]	756.7; 760.6; 763.5; 766.4	408; 443; 485; 520; 570; 615; 650; 685; 750; 870; 1010	1600
	O2A-band	815; 945 (H_2O-vapour)	
Spectral half width [nm]	1.4	10	93
FOV along track x [deg]	0.344	0.094	0.052
across track y [deg]	12.9	13.8	13.5
Swath width [km]	187	200	192
No. of pixels	420	384	299
Ground Sample Distance x*y [km²]	4.9*0.45	1.34*0.52	0.74*0.74
Measuring range Lmin ... Lmax [W/m²/nm/sr]	0.001 … 0.4	0.002 … 0.48	0.005 … 0.08
$\Delta L/L$ at L_{min} [%]	0.3	1.0	2.0

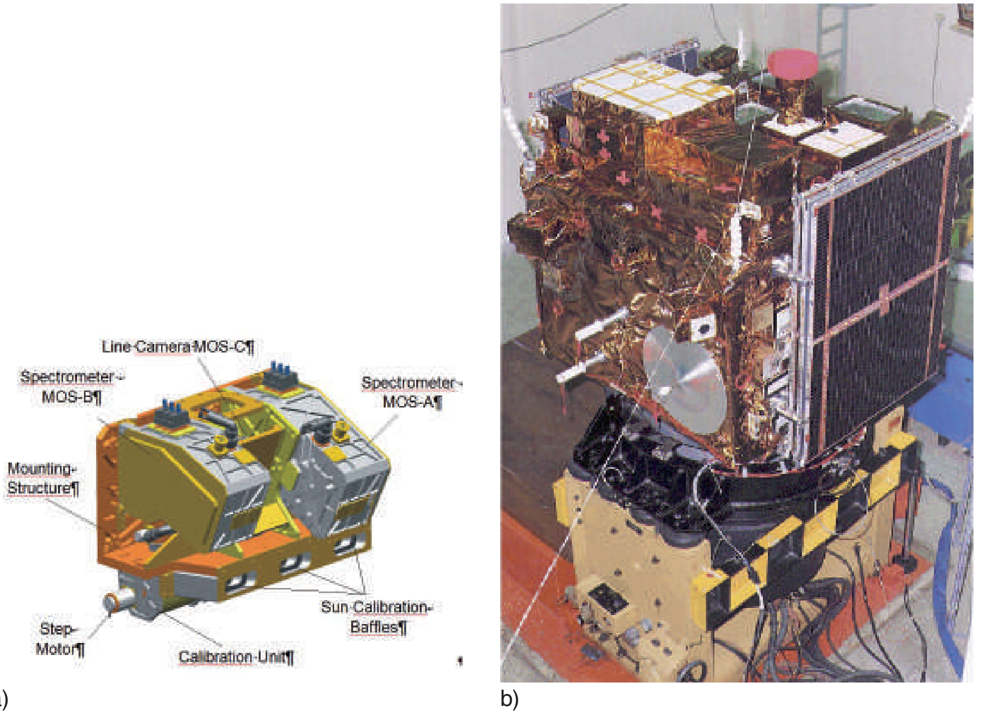


Fig. 8: MOS-instrument and Indian Remote Sensing Satellite IRS-P3 during pre-launch tests at Indian Space Research Organisation / Space Application Centre (ISRO/SAC).

spectral ranges. The detectors are two Cadmium Mercury Telluride (CdHgTe) linear photodiode arrays. The lines – with identical layout in the MWIR and LWIR – are comprised of 2 x 512 elements each in a staggered structure where two linear detector arrays are arranged in parallel to each other with an along-line shift of a half pixel size. The HSRS sensor head components of both spectral channels are based on identical technologies to provide accurate pixel co-alignment. Both spectral channels have the same optical layout but differ in the wavelength-adapted lens coatings. Figs. 5 and 6 show the HSRS flight model. The HSRS sensor was the key device of the BIRD (Bi-Spectral Infrared Detection) satellite.

6 DLR Sensor MOS IRS-P3 (1997)

The Modular Optoelectronic Scanner MOS was developed and built at DLR OS. This imaging spectrometer worked in the visible and near infrared spectral region and was especially designed for observations of relatively large scaled effects of the oceans, the atmosphere and land surface areas. MOS was launched on 21 March 1996 on board the Indian Remote Sensing Satellite IRS-P3 with the Indian Wide Field Scanner WIFS. During its operation time the MOS sensor provided spectral radiance data of the atmosphere-surface system in 18 spectral channels and up to 420 pixels in a 200 km swath from an 817 km sun synchronous polar orbit.

The international science community received a huge amount of important data for scientific use. MOS worked successfully for more than eight years in orbit.

7 KompSat3 CEU (2011-12)

KompSat3 (K3) is a project under the leadership of the Korean Space Agency KARI. The FPA has been developed by the joint teams of EADS-Astrium, BAE Systems and DLR OS. DLR OS is responsible for the FPA, front end electronics (FEE) and power design of the camera electronics unit (CEU).

The development challenge was to meet the high performances requirements of the system which has direct links to the focal plane assembly. In order to enable the design to meet

Tab. 3: K3 CEU Specification.

Key Parameters	Value
No. of Pixels PAN	24160
PAN-Sensor	2 x 12 080- plus max 64 TDI levels
Line Rate PAN	≤14 kHz
CCD Output Rate	16 x 25 MPixel/s
Data Rate	≤5.4 Gbit/s
MS-Sensor	8 x 6 040, plus max. 64 TDI levels
Line Rate MS	≤ 3.625 kHz
CCD Output Rate/ Colour	2 x 12.5 MPixel/s
Data Rate	4 x 338 Mbit/s
Pitch PAN	8.75 µm x 8.75 µm
Pitch MS	2 x 17.5 µm [binned 35 µm]
Anti Blooming	Yes
Image Plane dx, dy	220 mm, 97 mm
Dynamic Range	14 Bit
PRNU correction (photo-response non-uniformity)	Yes
DSNU correction (dark signal non-uniformity)	Yes
FPA-Flatness [z]	+/- 15 µm
SNR PAN	>100 [TDI64], 20 % albedo, 30° sun, 10:30 Seoul, SSO
SNR MS	>200 [TDI32], 20 % albedo, 30° sun, 10:30 Seoul, SSO
TDI Steps	1, 8, 32, 64
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

Tab. 4: K3CEU operation conditions.

Parameter	Value	Remarks
Power Interfaces	unregulated (26 … 30 VDC)	satellite power bus
Power consumption	<350 W	
Power module efficiency	>80 %	
Reliability	0.94	
Operation duty cycle	10 % / Orbit	Depends on thermal buffer
EMC	MIL-Std. 461 applicable	
FPA Mass	11 005 kg	2 x PAN + 4 x MS
Dimensions	See Figs. 9 and 10	
Operational Temperature Range	15 °C to 25 °C	Performances guaranteed
Non-Operational in-flight Temperature Range: Storage Temperature Range	0 °C to 40 °C −20 °C to 55 °C	
Radiation (total dose)	15 krad	
In-orbit lifetime	7 years	

the requirement of KARI, the design philosophy of ADS40 and RapidEye had been completely changed. Instead of using CCD line technology, TDI (time delay integration) technology was introduced. The FPA of K3 is equipped with six sensor modules (two PAN and four MS) which are completely independent. The key parameters of the K3 CEU are shown in the Tab. 3.

The FPA is able to operate under the following conditions shown in Tab. 4.

The mechanical configuration is based on a three-box philosophy. The first box contains the first stage of the power supply (CEUP). This box is used for the DC to DC converting of all different voltages and active/passive filtering of input and output voltages and the output can be controlled by the camera controller. The second box (CC-Box) includes the different switching options driven by the redundancy philosophy, the camera controllers, the clock generators and the focus mechanism control (FMC). The third box contains the modular stack of all CCD line modules of the FPA.

The focal plane assembly for the KompSat3 satellite is specified as the part of the camera electronics unit which is integrated into the telescope structure, and provides the focal plane interface. The functionality of the FPA is the integration of the combined sensor system with the panchromatic and multi-spectral detectors, which includes the related electron-

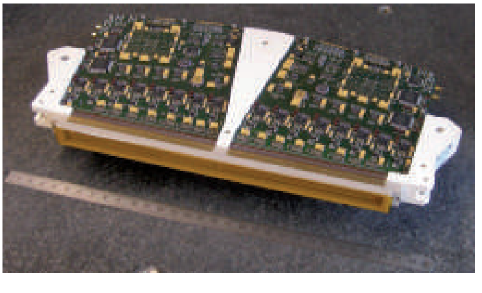


Fig. 9: K3CEU subunit Module.

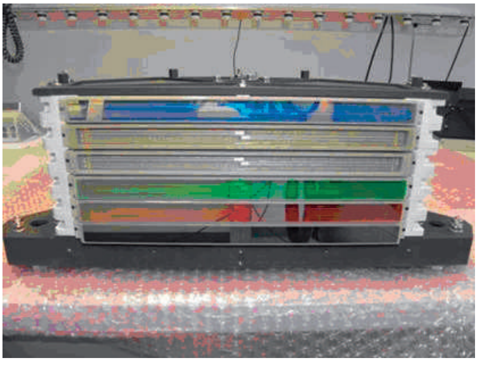


Fig. 10: K3CEU modular subunit Stack.

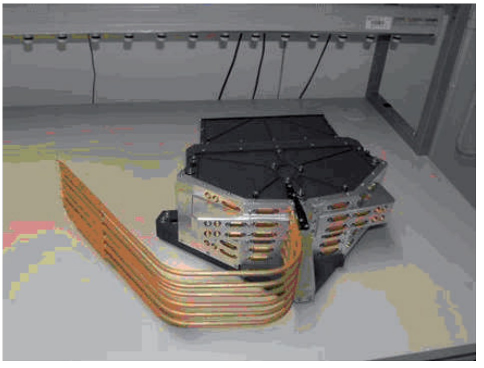


Fig. 11: Mechanical Interface of the K3CEU.

ics together with the structure for thermal management housekeeping and the mechanical interface to the telescope. To reduce the complexity of the arrangement a modular approach has been taken which is based on individual sub-units for each of the spectral channels in two forms:

(1) the 2x 12k panchromatic FPA TDI module and
(2) the 2x 6k multi spectral FPA TDI module.

The design is shown in the Figs. 9 and 10.

When the CEU FPA was integrated into the telescope as a complete assembly the structure was to hold and handle the interfaces which are shown below. Here the optical interface is oriented to the Z-direction. Assuming the overall payload concept the opposite direction is oriented to the S/C outer wall where the thermal control system is located. FPA heat pipes are installed to this well defined thermal contact point, and provide a specified temperature and heat dissipation capability.

The key advantage of the current design are the free programmable line rates which are necessary to control the different scaling factors in order to realise the mission requirements and the key performances as shown in the key parameter table.

8 FPA Design Phase B1 for GMES Sentinel-4 (S4, 2010)

GMES Sentinel is a large European satellite mission. Requirements have to comply with spatial-geometrical, mechanical and thermal constraints by dedicated constructive and technological approaches designing a suitable concept for FPA assembly. Existing heritage in FPA design from ADS40, BIRD, RapidEye, TET, KompSat 3, EnMAP and MERTIS play a major role and influences the present FPA concept.

Main FPA design driving requirements can be summarized in the Tab. 5.

The appearance of high temperature gradients in optical interface can be suppressed by thermal isolation. That means existing heat flows should be reduced. Since the module of thermal conductivity and geometrical parameter as cross-section and length define the heat flow (HF) the concept must consider all of them. HF can be calculated as $HF = \lambda \times A/L$ where, λ is the thermal conductivity (material parameter), A is the cross-section (geom-

Tab. 5: S4 FPA Mechanical Specification.

Parameter	Value	Remark
Envelope	$\leq 70 \times 70 \times 80$ mm³	
Mass	≤ 0.7 kg	
Mechanical stability	≤ 1 µm	from Alignment on ground up to operation on orbit
Detector temperature	−43 °C	
Detector window temperature	+21 °C	
Telescope interface temperature	+21 °C	
Alignment	6 axes	
Alignment accuracy	axial ≤ 1 µm; lateral ≤ 5 µm	
Protection of sensor	against contamination	

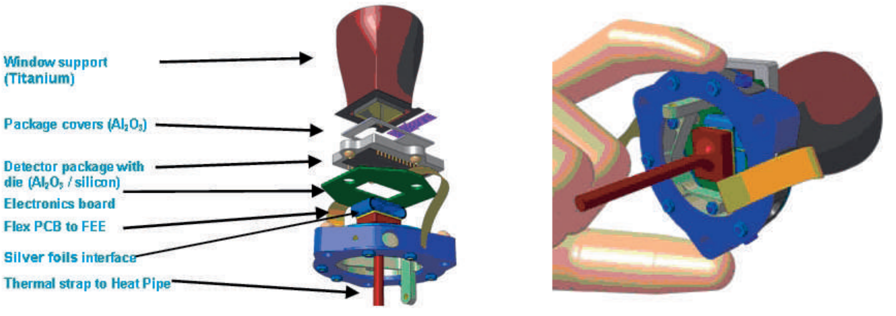


Fig. 12: Sentinel-4 FPA designexploded diagram (left) and sizes of the focal plane relative to a hand (right).

etry parameter) and L is the length (geometry parameter). The main focus of the design phase was on the mechanical design because the electronics design is well known and the pixel rate is low. But the thermal mechanical interface to the spectrometer is challenging. In order to realise this interface the optical glass and the baffle is sealed on ground and the detector is thermal controlled via a passive heatpipe system. Before launch the ventilation line system will be opened to avoid any optical distortion. Any condensation from the FPA on the launch side will be prevented by heating the system up.

9 EnMAP-VNIR-FPA (2012)

EnMAP (Environmental Mapping and Analysis Program) is a German satellite for simultaneous acquisition of high resolution hyperspectral images at visible to near infrared (420 nm – 1000 nm, VNIR) and short wave infrared (900 nm – 2450 nm, SWIR) wavelength.

DLR OS is developing the VNIR camera focal plane assembly VNIR-FPA as a subcontractor of Kayser-Threde. The key technology of the VNIR-FPA is an extremely low noise and sensitive sCMOS (scientific CMOS) detector device in back-side illumination configuration. This device is built by the OS subcon-

Tab. 6: EnMAP Key Parameters for the VNIR FPA.

Parameter	Value	Remark
Spectral channels	108	in the range from 420 nm to 1000 nm
Pixel per channel	1024	
Average band width of channel	6.5 nm	
Image rate	230 Hz	
Exposure time	4.4 ms	
Full Well Capacity (FWC)	> 1 000 000 e-/Pixel	
Read-out noise	< 200 e-/Pixel (low gain), < 70 e-/Pixel (high gain)	
Linearity error (10% - 100% FWC)	< 2 %	
Linearity error after digital correction	< 0,2 %	
Mass of sensor assembly	< 1 Kg	
Temperature stabilization	< 50 mK	
Power consumption	< 2 W	
Detector clock	252 MHz	

tractor BAE Systems. The highly integrated detector device has more than 2000 analog to digital converter and releases 13 bit high and low gain value per pixel in parallel.

The EnMAP VNIR-FPA is comprised of two mechanical units. The sensor assembly integrated into the Kayser-Threde optical unit carries the detector, the proximity electronics and a thermal control. A front end electronics box mounted outside the optics compartment provides power supply and camera control. For improved image quality a detector active thermal stabilization base on peltier element has been realized.

Key parameters of the VNIR-FPA detector are shown in Tab. 6.

The sensor assembly is built on a stiff Macor ceramics frame with a three point mounting interface to the optical unit. This provides the needed pixel registration stability for the narrow band hyperspectral mapping during space operation, and also a reliable interface for multiple mounting cycles during ground calibration and qualification procedures. The detector package has built in baffles to support stray light suppression and a tilted cover glass to prevent ghosting. Sensitive detector voltages are programmable to allow adjustment during life time if required.

The instrument power supply located in the FEE box is custom made by the company Apcon GmbH and optimized with respect to noise and stability to support the hyperspectral imager operation. The camera is controlled by a radiation tolerant re-programmable FPGA (field-programmable gate array). The main tasks of the controller are the detector control and image acquisition, telecommand and telemetry handling, peltier control for detector temperature stabilization, digital image correlated double sampling, housekeeping data acquisition and radiation protection support (detector and FPGA scrubbing). It is possible to upload new FPGA controller designs in space via a telecommand interface.

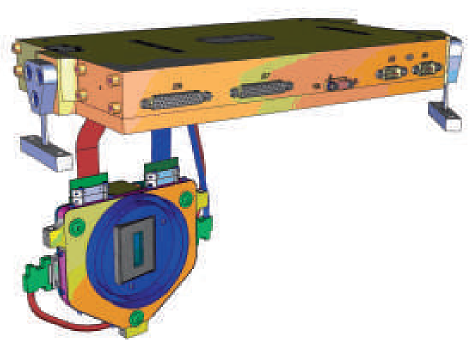


Fig. 13: EnMAP VNIR-FPA modules sensor assembly and front end electronics box.

The controller is designed by coupled state machines and provides automatic parameter checking for self-protection and error insulation. The envisaged launch of the EnMAP satellite is 2015.

10 MERTIS Imaging Spectrometer (2012)

MERTIS (MErcury Radiometer and Thermal Infrared Spectrometer) is one of the scientific payloads of the ESA deep space mission BepiColombo to Mercury. BepiColombo will be launched in 2014 to Mercury to observe the planet from 2020 on.

The MERTIS instrument design is based on a highly integrated and miniaturized concept, featuring low mass of approximately 3 kg and a sophisticated design developed by DLR OS. The specification is shown in Tab. 7.

MERTIS is an imaging spectrometer obtaining hyperspectral data in the thermal IR wavelength range with a medium spatial resolution to determine the mineralogical composition of the Mercury's surface. An un-cooled micro-bolometer array provides spectral sepa-

Tab. 7: MERTIS Key Parameters.

Parameter	Value
Spectral range	7 – 14 µm (Spectrometer)
	7 – 40 µm (Radiometer)
Spectral resolution	80 spectral channels, 90 nm (<200 nm)
Spatial resolution	> 280 m
Swath width	> 28 km; Field of View: 4°
Mass	3,3 kg
Power	8 – 13 (19) W
Dimensions	180 x 180 x 130 mm³ (excl. Baffles)

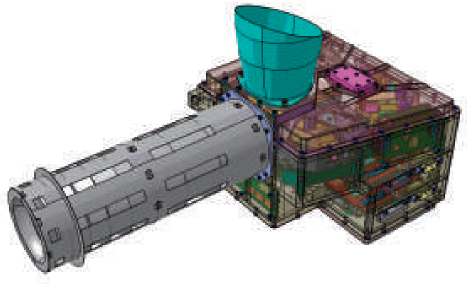


Fig. 14: MERTIS Instrument.

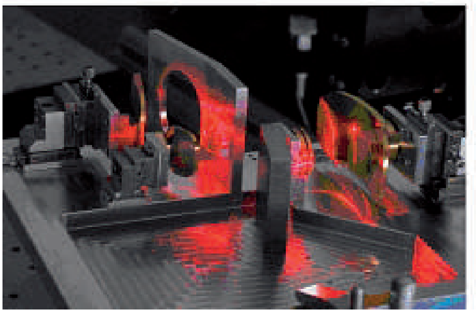


Fig. 16: MERTIS optical breadboard.

ration and spatial resolution according to its 2-dimensional shape and operates close to room temperature. Sharing the same optical path a pushbroom micro-radiometer is integrated allowing measurements of the Mercury surface temperature and obtaining the thermal inertia of the regolith.

The operation concept principle is characterized by intermediate scanning of the planet surface and 3 different calibration targets – deep space and two on-board black body sources.

The general instrument architecture is comprised of two separate parts – the Sensor Head including optics, detectors, shutter and proximity sensor electronics and the electronics unit containing the instrument control unit, power supply as well as calibration sources. This highly integrated measurement system is complemented by a pointing/scanning device

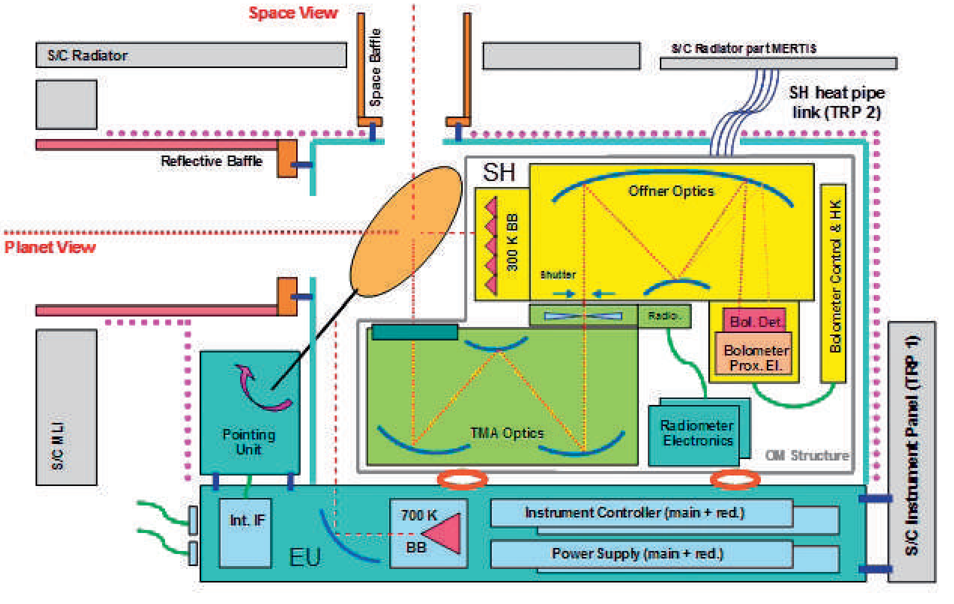


Fig. 15: MERTIS Block Diagram. S/C Radiator – space craft radiator, BB – black body, TMA – three mirror assembly, Int. IF – internal interface, EU – electronics unit, Bol. Det. – bolometer (thermal infrared) detector, Prox. El. – proximity (neighbouring) electronics, Offner Optics serving spectral decomposition.

which orients the optical path to the planet view and the calibration targets.

DLR OS develops the system design, integrates the instrument sub-units and verifies the overall performance based on laboratory investigations including instrument calibrations. The MERTIS development is done in close cooperation with scientific and industrial institutions, the Principle Investigator of the University Münster, the DLR Institute of Planetary Research in Berlin, Kayser Threde in Munich, Astrofeinwerktechnik in Berlin, the Polish Space Research Center in Warsaw and the Ingenieurbüro Ulmer in Frankfurt/Oder.

11 Summary and Outlook

The scientific objectives and the user requirements drive the performances of the whole system in particular of the focal plane. The improvement of the radiometry and the signal-to-noise ratio (SNR), the increase of the number of spectral channels and the spatial resolution (GSD), they define the technology edges of the design. In any case, the whole system shall be optimised to maintain the data product quality. The availability of new sensor technologies, e. g. CMOS back-thinning, allows the enhancement of the quantum efficiency mainly in the blue channels of the VNIR. The SNR and MTF achievable values can be met and related much more easily to the users' and scientists' performances requirements.

A software modelling system for the complete imaging chain of the digital cameras is used and continuously upgraded for design optimisation. The model incorporates the radiometry, the complete camera processing and the environmental conditions.

The next generation of detectors, new data processing capabilities and automatic data product algorithms are definitely of great interest to the work of DLR OS, and the application of on-board change detection capability will be one of our key topic focuses. The goal of applying this technology is data reduction and increase of information. This technology can be available for high resolution satellites in the next 15 years and will change the complete architecture of the ground and operation centres.

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