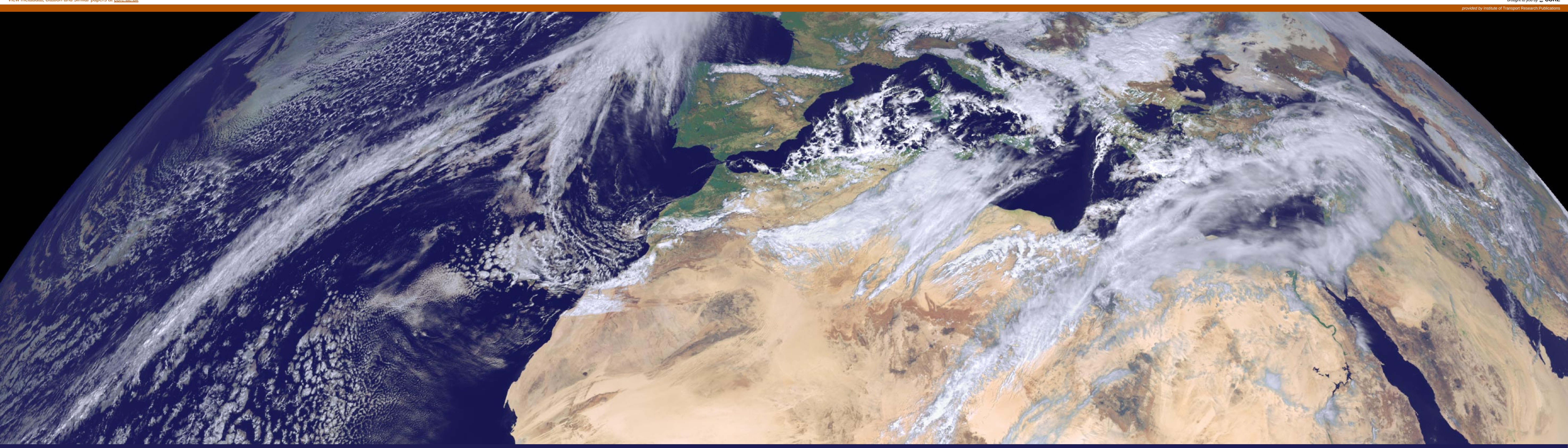

Remote Sensing Technology Institute
Experimental Methods

EnMAP related Cal/Val Activities of the User Service OpAiRS

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The User Service OpAiRS

The user service Optical Airborne Remote Sensing & Calibration Home Base (OpAiRS) is an ISO 9001 certified entity within the DLR Remote Sensing Technology Institute (IMF). Together with the German Remote Sensing Data Center (DFD), the IMF forms the DLR Earth Observation Center (EOC). In close cooperation with the DLR Flight Experiments Facility, OpAiRS provides comprehensive hyperspectral remote sensing expertise covering a wide range of services from sensor operation to the generation of various thematic products (figure 3). Thereby OpAiRS builds on the expertise and infrastructure of various EOC departments. OpAiRS focuses its activities on the development of innovative remote sensing methods through the provision of high quality sample data. Furthermore we support the validation of current and upcoming satellite missions (EnMAP, Sentinel-2) with airborne & ground based campaigns. Our services are available to third-party institutions through cooperative research projects.

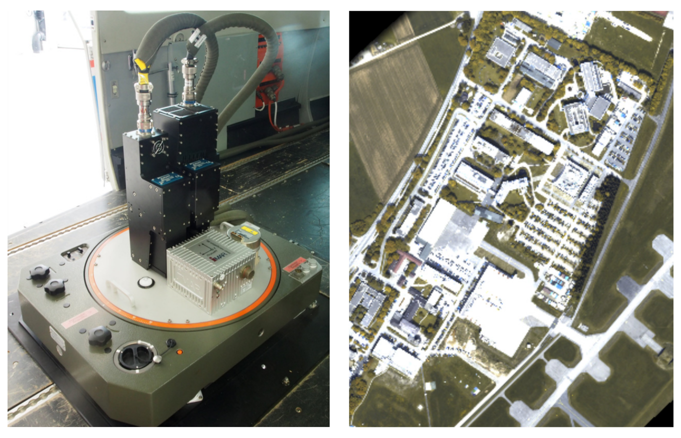

Figure 1: Photo of the HySpex sensor system (left) with an RGB image created from data acquired over DLR's Oberpfaffenhofen site (right).

The HySpex Sensor System

OpAiRS operates a combination of two imaging HySpex spectrometers manufactured by the Norwegian company Norsk Elektro Optikk (NEO) [1]. The push broom sensors (see figure 2) of type *VNIR 1600* and *SWIR 320m-e* (figure 1) are used for the airborne acquisition of spectrally and spatially highly resolved hyperspectral data. Due to a similar spectral resolution and the almost identical spectral range, the system is perfectly suited for the simulation and later validation of data recorded by the German EnMAP [3] satellite. This is the reason why the system is also referred to as *DLR EnMAP simulator*. HySpex can optionally be operated in combination with a very high resolution stereo camera system for experimental data fusion applications. The HySpex system is available for Transnational Access (TNA) through EUFAR.

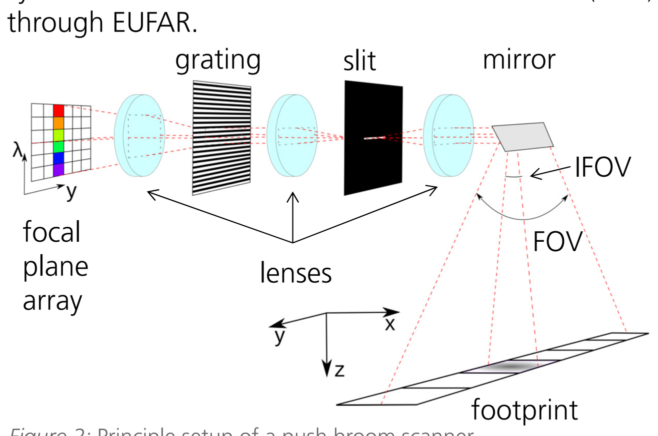

Figure 2: Principle setup of a push broom scanner

The OpAiRS Calibration Facility (CHB)

Within the scope of OpAiRS the IMF maintains a laboratory specially dedicated to the characterization of push broom sensors (figure 2). This so-called *Calibration Home Base for APEX* (CHB, [2]) has been designed for the airborne imaging spectrometer APEX funded by ESA. One distinct feature of the laboratory is its high level of automation, which enables the encompassing characterization of the OpAiRS sensor suite on a regular basis including their spectral, geometric and radiometric properties. The CHB is also used for the development of novel calibration techniques. Based on the experience gained with the CHB and HySpex, OpAiRS supports the preflight calibration of EnMAP in close cooperation with the EnMAP prime contractor OHB.

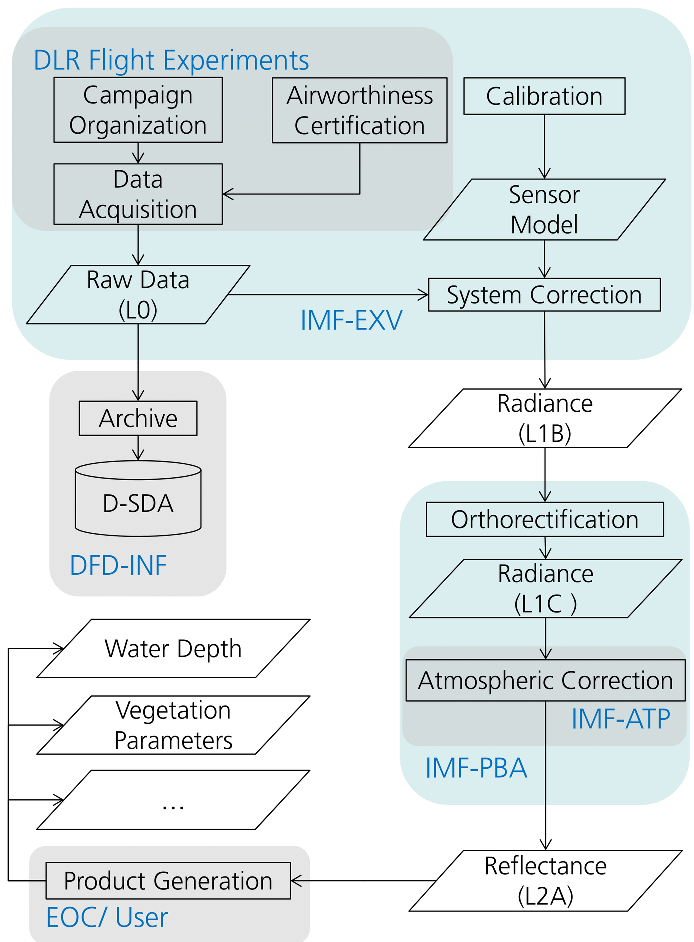

Figure 3: Flowchart of OpAiRS core services (blue background) with contributions of various EOC departments (gray background).

Ground Based and UAV borne Instruments

Apart from HySpex, OpAiRS operates various field spectrometers and a UAV borne snapshot imager (figure 4). Handheld spectrometers such as the SVC 1024i have proven to be useful tools for reference measurements at the surface. They facilitate the in-situ identification of distinct spectral properties for various materials, which form the basis of most remote sensing applications. Recently OpAiRS also acquired a Cubert *UHD-185 Firefly* snapshot spectrometer, which can be mounted on one of several Unmanned Aerial Vehicles (UAVs) available at IMF. The light weight Firefly imager can be flown in configurations, where the maximum take-off weight of the UAV is below 10 kg, thus minimizing legal constraints on airborne operations. UAVs are expected to play a crucial role in bridging the gap between ground based measurements and aircraft observations. However, a reliable calibration is a prerequisite for a meaningful comparison of measurements acquired by different instruments from different platforms. We are currently investigating, in how far commercially available instruments such as the Firefly are capable of delivering the required data quality. Table 1 shows selected key properties, which were determined in the CHB for Cubert Firefly and NEO HySpex. As the snapshot imaging technology allows to acquire entire hyperspectral scenes without scanning, we are also examining the potential regarding hyperspectral remote sensing of highly dynamic scenes, where common push broom scanners deliver unsatisfactory results.

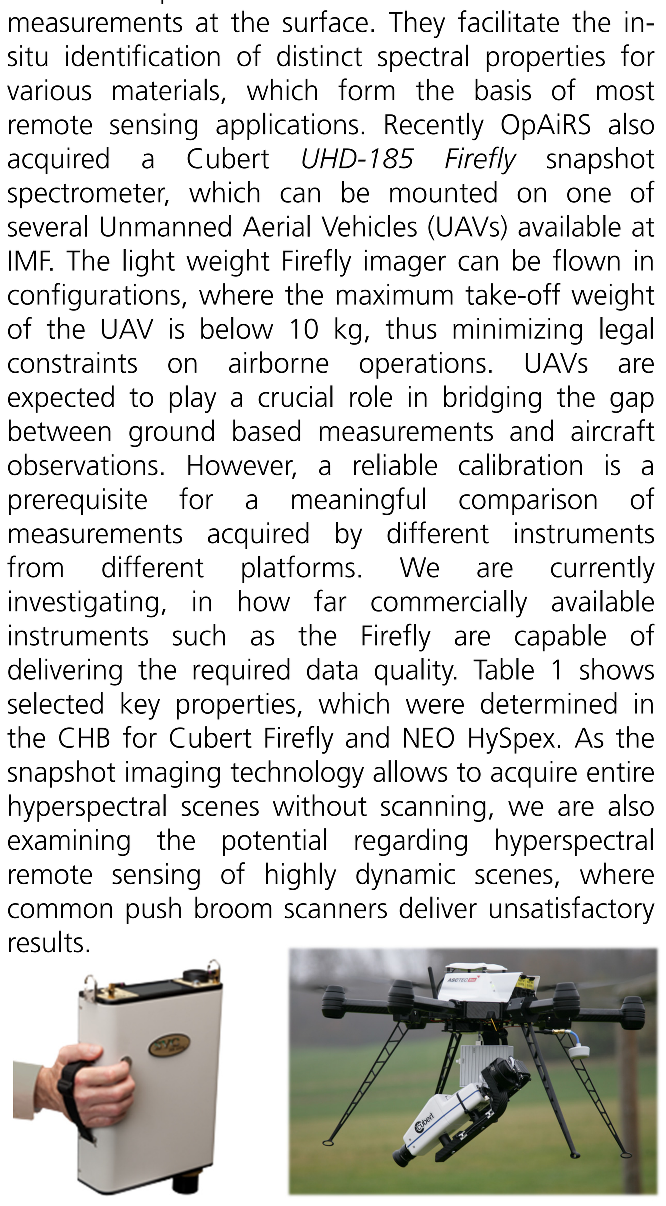

Figure 4: SVC 1024i field spectrometer (left) and Cubert Firefly snapshot spectrometer mounted beneath an ASCTEC UAV (right).

	VNIR-1600	SWIR-320me	UHD-185 Firefly
Spectral range [µm]	0.41–1	0.97–2.5	0.45–0.95
Spectral res. [nm]	3.5–6	5.6–7	5–30
Num. of channels	160	256	125
Num. of pixels	1600	320	50x50
Min. spatial res. [m]	0.3/0.6*	0.6/1.2*	0.1

Table 1: Characteristic properties of the HySpex VNIR & SWIR sensors compared to those of the UAV-borne Firefly snapshot camera. The asterisk (*) indicates usage of an expander lens, which approximately doubles the HySpex field of view.

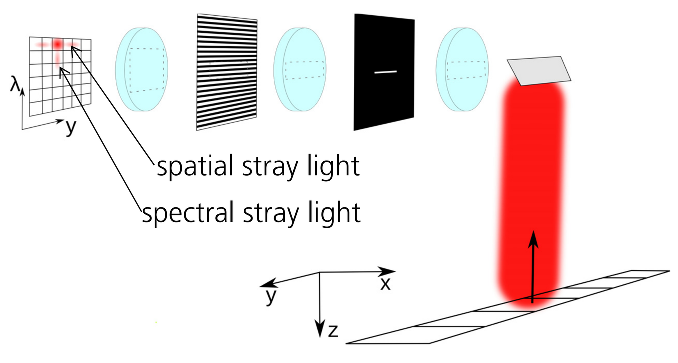

Figure 5: Schematic depiction of a stray light measurement of the central pixel of the "redmost" channel.

EnMAP Calibration Support

Based on the expertise gathered with multiple airborne instruments over the last 25 years, OpAiRS supports the calibration of the EnMAP satellite instrument in a joint OHB-DLR project. Apart from consulting OHB regarding the measurement of the geometric and spectral instrument properties, OpAiRS develops a method for the experimental determination (figure 5) and subsequent algorithmic correction of stray light (figure 6). Stray light is defined as radiation detected under a wrong wavelength and/or a wrong angle of incidence due to imperfect optical imaging inside the instrument. Stray light can cause significant problems if strong gradients occur inside a single frame. These gradients can be caused by scenes with large intensity variations (e.g. white sand close to dark water bodies) or by scenes containing strong spectral variations (consider red light with high intensity scattered into a blue channel with faint illumination). The experimental challenge consists in the exposure of a small detector region to radiation with an intensity sufficient to cause measurable stray light on the remaining detector pixels while avoiding unpredictable behavior of the detector due to overexposure . Additional challenges arise due to the large number of measurements required to completely characterize the stray light properties of an optical system.

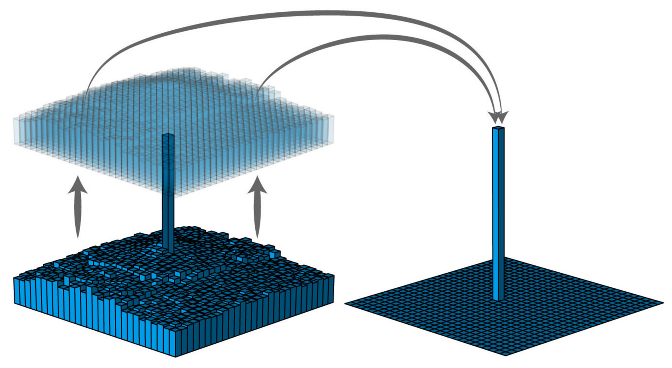

Figure 6: Stray light correction for the idealized case of mono-chromatic illumination of a single geometric pixel: Contributions erroneously detected by other channels/pixels have to be reattributed to the correct channel & pixel. The plot uses a logarithmic intensity scale.

Towards Improved Remote Sensing Products

Our ultimate goal at OpAiRS is to support the development of innovative remote sensing methods. Current and upcoming instruments designed for optical earth observation offer a combination of high spatial resolution and fine spectral resolution. The information content of the measured data allows to combine retrieval techniques typically applied to atmospheric remote sensing with those developed for traditional earth observation applications. In combination with an accurate and reliable instrument calibration recent developments may lead to significantly improved remote sensing products, especially in challenging applications such as remote sensing of inland waters or the determination of atmospheric aerosols and trace gases.

References

[1] DLR Remote Sensing Technology Institute (IMF) (2016). Airborne Imaging Spectrometer HySpex. *J. large-scale res. fac., 2*(A93)

[2] DLR Remote Sensing Technology Institute (IMF) (2016). The Calibration Home Base for Imaging Spectrometers. *J. large-scale res. fac., 2*(A82)

[3] http://www.enmap.org

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