PROCESSING, VALIDATION AND QUALITY CONTROL OF SPACEBORNE IMAGING SPECTROSCOPY DATA FROM DESIS MISSION ON THE ISS

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ABSTRACT

The German Aerospace Center (DLR) and Teledyne Brown Engineering (TBE), located in Huntsville, Alabama, USA, cooperate to develop and operate the new space-based hyperspectral sensor DLR Earth Sensing Imaging Spectrometer (DESIS). While TBE provides the Multi-User platform MUSES and infrastructure for operation of the DESIS instrument on the ISS, DLR is responsible for providing the instrument and the processing software as well as instrument in-flight calibration and product quality operations. MUSES has been already launched and installed on the International Space Station ISS in early 2017 and DESIS will follow mid of 2018. We present here an overview of the DESIS instrument, the on-ground data processing, the in-flight calibration and product quality investigations.

Index Terms— Hyperspectral, DESIS, Validation

1. INTRODUCTION

The DESIS instrument is realized as a pushbroom imaging spectrometer sensitive in the Visible Near Infrared (VNIR) spectral range (from 400 to 1000 nm) and with a spectral sampling distance of 2.55 nm employing a 2-dimensional back illuminated Complementary Metal Oxide Semiconductor (CMOS) detector array from BAE Systems (CIS2001). Larger spectral sampling distances are configurable by means of an onboard binning of up to four spectral bands. The Ground Sampling Distance (GSD) depends on the flight altitude and is about 30 m at nadir. This results in a swath width of about 30 km. The data acquisition is based on an electronic shutter mechanism realized as a rolling shutter collecting for each channel light during the same period of time, but the time light collection starts and ends is slightly different for each channel. As a result, each spectral channel integrates light over slightly different surface areas on ground.

The DESIS instrument is equipped with a pointing mirror to acquire scenes at different observation geometries during one orbit, a colored LED bank for spectral and radiometric in-flight calibration [1]. The specifications of the DESIS instrument are given in Table 1. A comparison of DESIS with the upcoming Environmental Mapping and Analysis Program EnMAP can be found in [2] and [3].

Mission **Instrument**	**ISS/MUSES** **DESIS**
Space agency	DLR, Germany & Teledyne, USA
Target lifetime	2018-2023
Orbit (type, local time at equator, inclination, hight, period)	not Sun-synchronous, various, 51.6°, 320 km to 430 km, 93 min (no repeat cycle)
Off-nadir pointing (across-track, along-track)	-45° (backboard) to +5° (starboard), -40° to +40° (by MUSES and DESIS)
Max. Frame rate	232 Hz
Pixel Size	24 µm x 24 µm
Pointing Knowledge	< 30 m (with GCPs extracted from references e.g. Sentinel-2 global mosaick and Aster GDEM)
Coverage	55° N to 52° S
Revisit frequency	3 to 5 days (average)
Instrument (mass)	93.2 kg
BRDF (bidirectional reflectance distribution function)	BRDF mode: 11 measurement positions ±15° (every 3°) with 20 arcmin accuracy FMC mode: Rotation speed 0.6°/sec and 1.5°/sec with 0.06° accuracy (11 measurements between -15° and +15° in steps of 3°)
Spatial resolution	30 m (@ 400 km)
Swath	30 km (@ 400 km)
Spectral range	420 nm to 1000 nm
Spectral sampling	2.55 nm @ no binning
Spectral bands	235 @ no binning 117 @ 2 band binning

	78 @ 3 band binning 58 @ 4 band binning
SNR (signal-to-noise-ratio)	205 (no bin.) / 406 (4 bin.) @ 550 nm
Smile & Keystone	Smile <1.7 pixel Keystone <0.3 pixel
Radiometric resolution	12 bit plus 1 bit (low gain/high gain)
On-board calibration	dark signal (before/after acq.), detector LEDs (white and colored)
Capacity (per day, storage, downlink)	2360 km per day, 225 GBit, Ku-band
Processing levels	L1A (archived), L1B, L1C, L2A (deliverable)

Table 1 Design parameters of the DESIS instrument

2. PRODUCT GENERATION

The DESIS products are derived from tiled data takes of size 1024x1024 pixels (~30x30 km²), which are generated within an automatic processing chain. Identical processing chains are implemented at DLR and TBE Ground Segment. At TBE the processors are running in a cloud based system (© Amazon Cloud). For the user the following DESIS products are available [4]:

L1B Products (systematic and radiometric correction)
Top-of-Atmosphere (TOA) radiance data cubes with quality layers for each band (encoded as number of bands *x* 8-bit mask of size 1024*x*1024 pixel and indicating abnormal pixels, band-to-band correlations, bad line and bad column, pixel values outside linear behavior of the instrument) and metadata (e.g. orbit and attitude measurements, geometric calibration values, spectral channel information). Rolling shutter, smile and keystone correction is performed by the L1B processor [5]. The L1B product comprises all information for further processing.

L1C Product (geometric correction)
Orthorectification is performed using the on-board orbit and attitude measurements. The platform is equipped with a star tracker (sampling rate 10 Hz) and a Miniature Inertial Measurement Unit (sampling rate 50 Hz) providing a 10 Hz attitude measurement after filtering. ISS GPS data provide position and velocity vectors and time tags (sampling rate 1 Hz) serving as a master time for the DESIS instrument with an accuracy of ±250 µs. Image matching techniques to extract Ground Control Points (GCP) from reference data and to enhance the sensor model for improved relative geo-location accuracy are employed [6]. A global Sentinel-2 cloud-free mosaic with an accuracy of ~12m at 2 sigma confidence level is foreseen as geometric reference. The user is able to select the re-sampling method (Nearest-Neighbour, Bilinear, Cubic Convolution) and map projection (UTM or Geographic)

L2A Products (atmospheric correction)
The L2A processor performs the atmospheric correction of the DESIS data employing a python-based code of the IDl-program ATCOR [7]. L2A processor is applied on a L1C DESIS input product and uses MODTRAN-5.4.0 to model properties of the solar reflective spectrum in the 350 nm to 1050 nm range. The code includes a rigorous treatment of the coupled scattering and absorption processes, and supports a sufficiently high accuracy for the absorption simulation. The L2A processor also offers representative aerosol models to be used during the correction (rural, urban, maritime and desert) over land. Internally, the processor uses a MODTRAN generated database of atmospheric correction look-up tables (LUTs) with a spectral resolution of 0.4 nm, to enable the processing of the different band widths of DESIS. This fine spectral resolution database is re-sampled with the updated spectral channel response functions enabling the processing of all the applied binning (from 2.55 to 10.21 nm) of DESIS. The atmospheric correction is able to take into account the surface temperature to apply summer/winter LUTs. The DESIS atmospheric correction accounts for flat and rugged terrain and includes haze detection algorithms. The output products will consist on a ground reflectance data cube and a set of image masks indicating: water, land, haze, cloud, shadow and snow. Aerosol optical thickness and atmospheric water vapour maps will be produced for land pixels [8][9].

3. VALIDATION AND QUALITY CONTROL

Vicarious validation activities will be performed at regular interval – or after processing chain updates – to ensure that a suitable data quality is met. For the radiometric and spectral validation, three main tasks will be performed:

- Validation over well-known Calibration Sites like CEOS Landnet sites or CEOS Pseudo-Invariant-Calibrations-Sites, which allows an absolute assessment and comparison with existing sensor systems (e.g. MODIS).
- Cross-Comparison, where simultaneous data acquisitions of DESIS and a reference sensor (e.g. airborne survey along with ground truth data) are used to compare simulated TOA from the reference data with the derived DESIS products. It is foreseen to perform these activities over the DLR's validation test-site of DEMMIN.
- Finally, analysis of local homogenous areas on the imagery will made in order to get estimates of the signal to noise ratio over the complete radiometric range of the sensor. Locally homogeneous surfaces are identified by analysing imagery's texture for each spectral channel [10].

Some further collaborations are also under discussion (e.g. with Teledyne or HISUI [11]) and will involve further data validation activities.
Additionally, in-flight geometric validation will periodically assess the possible changes of geometric parameters during sensors life time for the available L1C Earth Products. This will be achieved by carrying automatic image matching methods between L1C Earth Products and orthoimages from flat and mountainous areas of superior quality (e.g. about 10 m absolute accuracy), for example the LandSat-8 panchromatic imagery [12].

4. CONCLUSION

From 2018 onward the DESIS sensor on board the ISS will provide hyperspectral data for commercial and scientific applications. DLR is developing a processing chain in order to generate well-calibrated data products up to orthorectified and atmospheric corrected data that include as well metadata and quality control information.

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