APEX – A new Pushbroom Imaging Spectrometer for Imaging Spectroscopy Applications: Current Design and Status

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ABSTRACT

Within the framework of the European Space Agency's funding scheme PRODEX, an airborne imaging spectrometer named APEX (Airborne PRISM Experiment) is developed.

APEX is designed to be a pushbroom imager with 300 spectral channels in the 400 – 2500 nm wavelength region, and with 1000 pixels across track. The mission objectives of APEX are mainly being a simulator, calibrator and validation experiment and fostering the application development for hyperspectral imaging.

The APEX hardware consists of an airborne imaging spectrometer with an optimized hyperspectral sensor design for the detection of land surface processes, a flexible aircraft integration scheme, a laboratory calibration home base, and a Processing and Archiving Facility (PAF) for the generation of Level 1 through 3 data.

INTRODUCTION

APEX will be an airborne imaging spectrometer with the following unique capabilities:

- pushbroom imager with ≤ 1000 pixels across track and a swath width of 2.5 – 5 km,
- spectral wavelength range covering 400 – 2500 nm,
- up to 300 spectral bands, continuously and contiguously recorded,
- a spectral sampling interval < 10 nm at a spectral sampling width < 1.5 times the sampling interval in most of the bands, and
- the ability to provide calibrated data and a suite of user oriented products up to fully geocoded and calibrated data.

APEX is currently built by a joint endeavor of Swiss and Belgian institutes and industries and is funded by the European Space Agency (ESA).

Based on the outcome of a feasibility study [1] and the subsequent modeling of the instruments radiometric performance, the specifications for APEX have been derived as listed in Table 1.

Table 1: APEX System Specifications

Parameter	**Specification**
Field of View (FOV)	± 14 … ± 20 deg
Instantaneous Field of View (IFOV)	0.48 … 0.70 mrad
Flight altitude	4’000 - 10'000 m.a.s.l. 7’500 m nominal
Spectral channels	VNIR: approx. 140 SWIR: approx. 145
Spectral range	400 – 2500 nm
Spectral sampling interval	400 – 1050 nm: < 5 nm 1050 – 2500 nm: < 10 nm
Spectral sampling width	< 1.5 * Spectral sampling interval
Center wavelength accuracy	< 0.2 nm
Spectral sampling width accuracy	< 0.02 * Spectral sampling width
PSF (Point Spread Function)	≤ 1.75 * Sampling interval
Smile	< 0.1 pixel
Frown	< 0.1 pixel
Bad pixels	None (requirement after electronics)
Scanning mechanism	Pushbroom
Absolute radiometric calibration accuracy	≤ 2%
Storage capacity on board (online / offline)	> 50 GByte / > 200 GByte
Dynamic Range	12 … 16 bit
Positional knowledge	20% of the ground sampling distance
Attitude knowledge	20% of IFOV
Navigation system, flight line repeatability	± 5% of FOV
Positional and attitude data	Recording of data onto a housekeeping channel.

Table 1: APEX System Specifications

Parameter	Specification
Reliability	99% successful data acquisitions for all flights
Vibration	Anti vibration means
Optical head dimensions	Must fit in standard mount

SIMULATION APPROACH

A consistent software based simulation of imaging spectrometers is not possible without appropriate information on its operating environment, the observed scene and the related geometry between sun, observer and object. A dedicated software model has therefore been built for APEX in order to complete the following tasks:

- Evaluation of sensor specifications and their possible changes,
- Optimization of sensor parameters and observation conditions for a certain task (e.g. cost, development risk, etc.),
- Evaluation and adaptation of existing processing algorithms (e.g. calibration, etc.),
- Efficiency and robustness testing of dedicated processing chains,
- Error and uncertainty estimation, and
- Cost-versus-quality considerations.

All these above mentioned tasks are modeled using SENSOR (Software ENvironment for the Simulation of Optical Remote sensing systems) [2]. The basic concept behind SENSOR is to concentrate all relevant knowledge of hardware of the remote sensing system (e.g. optical distortions, stray light, dark signal, pixel response non-uniformity, etc.), the source of radiance (e.g. the sun), the atmosphere, and the observed object (e.g. landuse class, slope, aspect) into one model. SENSOR pursues a similar philosophy as other end-to-end simulation approaches.

After finalizing the specifications and the modelling, the Processing and Archiving Facility (PAF) is defined.

PROCESSING AND ARCHIVING FACILITY (PAF)

Processing systems in Earth remote sensing can be characterized in general as distributed, platform–inhomogeneous, complex and cost intensive information systems. In order to manage the complexity and performance requirements, different application scenarios must be evaluated to assess the required modularity and interoperability.

The PAF for the APEX system is mainly based on standard hardware and software items. Special emphasis has been put on automatization of the individual processes.

The hardware setup includes a 4 processor SUN SPARC architecture, operated with SUN Solaris. The standard UNIX file system has been replaced by a journaling file system (Veritas), supporting dynamic table size allocation with the database (Oracle). The backup of the machine is based on DLT tapes, which may also be used to transfer data from the PAF to the user. The major software components include IDL/ENVI for processing, and time critical procedures are rewritten in C. The connectivity of the modules is based on different Internet based applications and scripting languages (e.g. Apache web server, TCL/TK, websh, Java Script, IDL on the Net (ION)).

The software approach of the PAF is based on the Spiral model using evolutionary prototyping. The basic processing of the acquired data into different processing levels is handled by the PAF. The Level 0 data processing scheme is depicted in Fig. 2.

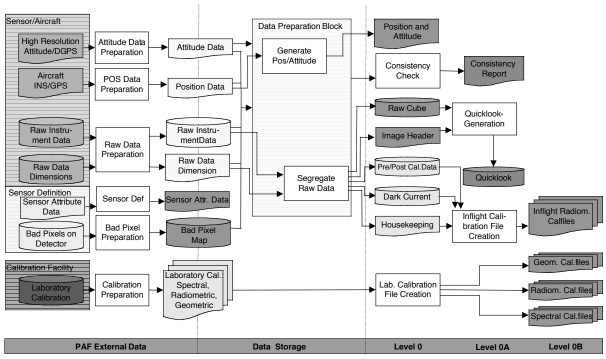

Fig. 2. Level 0 data processing scheme of the APEX PAF.

The final precessing result will be quicklook data as well as radiometrically calibrated data. Atmospheric corrected data as well as geolocation is available upon special request.

OPTICAL SUBSYSTEM

The optical subsystem of the APEX consists of two channels, one covering the VNIR range between 400–980 nm and a SWIR range covering the 950–2500 nm range. The system is optimized for high SNR and spectral uniformity. The full system is integrated in a sealed environment and can be mounted on a stabilized platform. The integration concept foresees an easy transition between a laboratory calibration environment and different specified, APEX compatible, aircrafts. Over 18 APEX compliant carriers are available within Europe. The choice of aircraft will be finalized upon completion of the APEX system in 2002.

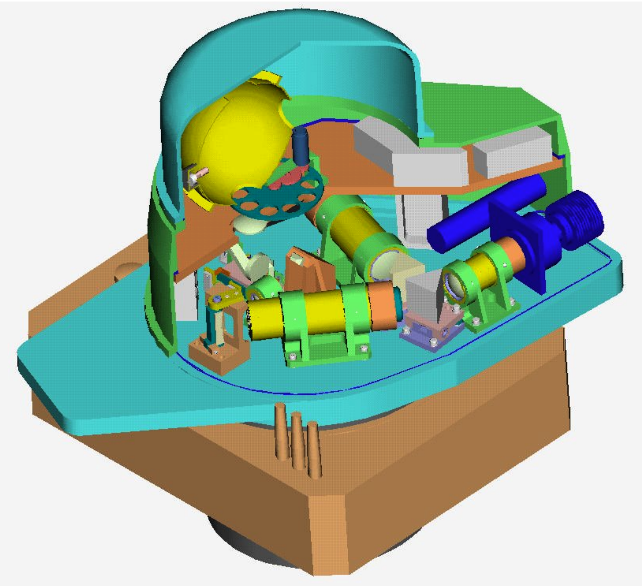

Fig. 3. APEX instrument design mounted on a stabilized platform.

CALIBRATION

A detailed calibration concept exists for APEX [3], including on–board calibration means (e.g., integrating sphere with spectral and radiometric standards), laboratory calibration, and reflectance based vicarious calibration approaches.

The on–board calibration will support pre– and post data acquisition calibration, since pushbroom based imagers cannot be calibrated during the actual data takes. The on–board calibration means are depicted in Fig. 3., where in the upper part of the instrument the filter wheel for different radiance and spectral standards can be identified.

CONCLUSIONS

The APEX system as presented will be able to serve as a radiometric transfer standard to close the gap between ground based point measurements and spaceborne imaging spectrometer data acquisition. In addition to this, the system will be able to significantly improve the application development in imaging spectroscopy. The presented complete system approach, including calibration, data processing and operational concept, will allow for an ongoing operation starting in 2002.

ACKNOWLEDGMENTS

This work has been carried out under contract–no. 13115/98/NL/VJ(IC) of the European Space Agency (ESA). The support of B. Zufferey, M. Rast, R. Meynart, and U. Del Bello (ESA/ESTEC) is greatly appreciated.

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