IMPLEMENTATION OF THE AUTOMATIC PROCESSING CHAIN FOR ARES

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ABSTRACT

DLR and GFZ are procuring the airborne hyperspectral scanner ARES (Airborne Reflective and Emissive Spectrometer) to be operating from autumn 2005. In order to ensure the first fully automatic processing environment for hyperspectral airborne scanner data working without any user interaction, a complete processing chain for hyperspectral data is designed. It includes an automatic invocation of system correction, parametric geocoding and atmospheric correction, as well as the archiving and filing of the resulting data products. This task is performed relying on an operational processing and archiving environment, installed at DLR, where the whole processing chain is embedded. It empowers the provider and the user of hyperspectral data to utilize a web interface making the data stock and status transparent. It further grants the operator access to a professional processing and archiving environment. This ensures an automated generation of standardized data products, allowing a reproducibility of the data at any time.

INTRODUCTION

DLR (Deutsches Zentrum für Luft- und Raumfahrt) and GFZ (Geo-Forschungszentrum Potsdam) are acquiring the airborne hyperspectral scanner ARES to be operating from autumn 2005, being available for the scientific community from 2006.

In order to ensure the first fully automatic processing environment for hyperspectral airborne scanner data working without any user interaction, the whole processing chain is embedded into the 'Data Information and Management System' (DIMS) (Mikusch et al., 2000 (i)), an operational processing and archiving environment installed at DLR. The following objectives were pursued: automation and standardization of the processing environment and the resulting data products, ensuring a high quality data standard, utilization of a professional web interface making the data stock and status transparent to the user, plus offering access to a professional archiving environment.

DIMS provides an archiving subsystem as well as a generic processing environment and a searchable database including a public access via the WWW.

The processing steps embedded into DIMS include system correction, orthographic rectification and atmospheric correction, which all rely on well-established software packages operating for several years. A product model for the automatic processing of airborne optical scanner data at Level 0 and 1 (raw data and system corrected data) has been presented in by Strobl and Habermeyer, 2001 (ii) and Habermeyer et al., 2001 (iii). It is used in this context and allows the fully automatic ingestion of the data in the processing and archiving system. In the course of the orthographic rectification by ORTHO (see Müller et al., 2002 (iv)) the attitude and position data recorded during datatake are synchronized with the scanner data and geo-referenced by the use of a Digital Terrain Model. This can be provided by the customer. In case no DEM is available the processing

system relies on a digital elevation database operated at DLR and called W42 (Roth et al., 2002 (v)). The task of the atmospheric correction is the calibration of each pixel to ground reflectance. This is done by the implementation of the software package ATCOR (Richter & Schläpfer, 2002 (vi)), which is based on the radiative transfer model MODTRAN (Berk et al., 1998 (vii)), and integrates the digital terrain model and meteorologic data. Each processing step is followed by a quality control giving evidence if the quality standards are met.

A data model for geometric and atmospheric correction is described, including the components available at each processing level plus a set of parameters describing the dataset. This description of parameters on the one hand facilitates the traceability of the processing steps, while on the other hand enables the user to view all relevant parameters, when inspecting the data catalogue.

The work is structured as follows: Based upon the data model the design (previously shown in (viii)) is revisited and the implementation of the processing system is explained, where the interaction of the individual processing components between each other and with the generic processing environment are shown.

In this context an overview of DIMS is given, with a stress on those components actually employed for our purposes. In the following the organisation of the processing system is outlined in combination with an explanation of the work to be done to employ the capabilities of DIMS for the processing system for ARES. An introduction of the sub-systems for system correction, geocoding, the digital elevation database and atmospheric correction follows. An outlook of the work to be done concludes this paper.

COMPONENTS OF THE DATA INFORMATION AND MANAGEMENT SYSTEM

DIMS (Data Information and Management System) (for an overview see e.g. Mikusch et al., 2000 (i)) is a generic processing and archiving environment for the purpose of providing services within the framework of Earth observation product generation, storage, ordering, and delivery. It consists of several components providing a global product catalogue, storage media transparence and scalability with respect to storage capacity and data modelling. The parts of DIMS employed for our purposes are: the Product Library, the Processing System Management and the Operating Tool. Their interaction is shown in Figure 1.

The Product Library (PL) is responsible for the long-term storage and availability of Earth observation products. It consists of an extensible product inventory with optimized geo-spatial search capabilities and a product archive using a robot media library. In DIMS the PL handles input and output of processing systems, input for user information systems, and is the source for product delivery to end users. For a more detailed description of the PL see Kiemle et al., 2001 (ix).

The Processing System Management (PSM) provides an interface between the sensor-specific processing algorithms and the processing and archiving facility (x). Its main functions can be identified as enabling input product retrieval from and output product transfer to the PL, and production request handling.
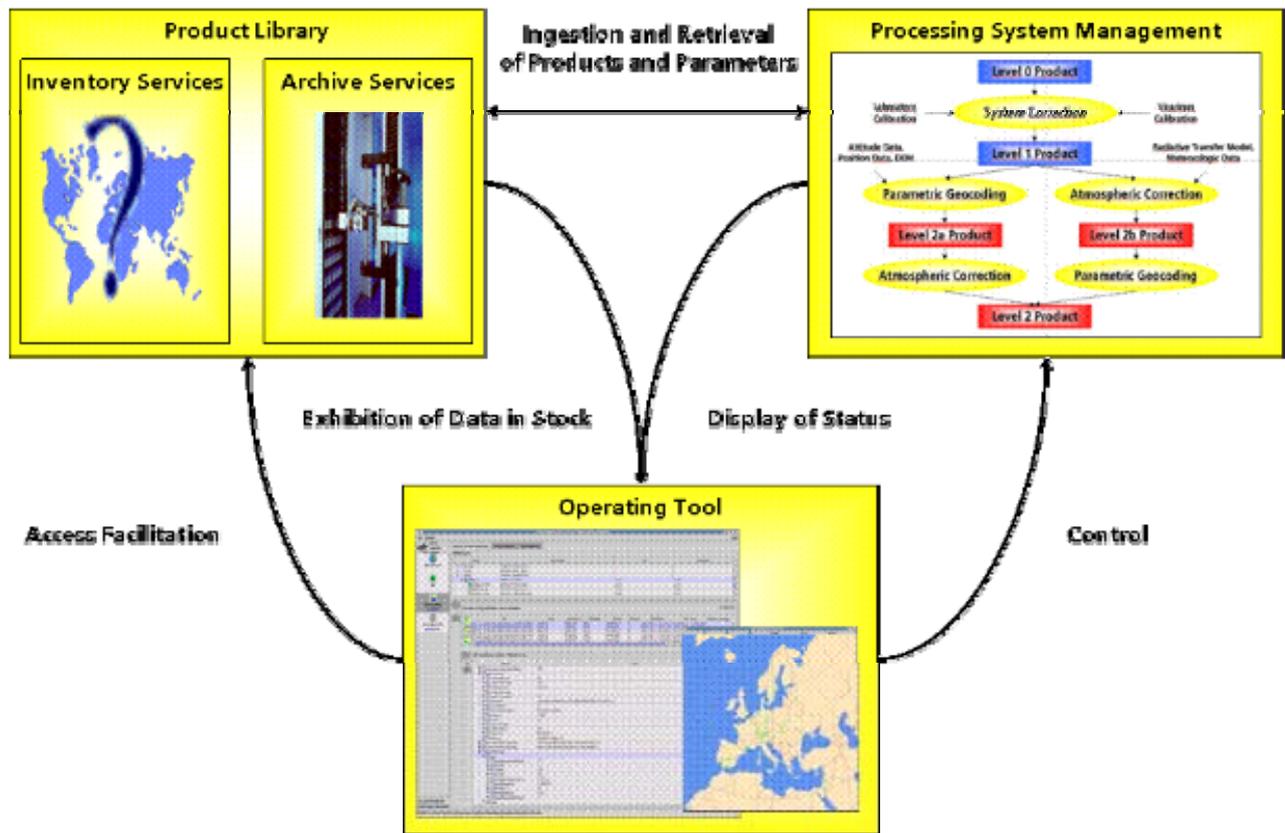
Figure 1: Overview of the Data Information and Management System.

The Operating Tool (OT) is a graphical user interface allowing control of the processing system and serves as a visualization tool for the data in stock. It is capable of displaying the status of the processes requested. Access is further facilitated to the PL, in order to provide an interface for searching as well as exhibiting the data in stock.

Essential for the integration of a processing system into DIMS is a valid data model that allows the identification of specific datasets, and thus the administration of the dataset in terms of processing and archiving. The data model for atmospheric and geometric correction is discussed in a subsequent section.

OVERVIEW OF THE PROCESSING SYSTEM

The specific processing steps necessary for ARES include system correction, geocoding, and atmospheric correction. During system correction artefacts due to the sensor's characteristics are removed and the data is calibrated to at-sensor-radiance based on calibration coefficients attained during laboratory calibration. In the course of georeferencing the attitude and position data of the aircraft and the sensor recorded during datatake are synchronized with the scanner data. Furthermore the hyperspectral dataset is rectified by application using a Digital Elevation Model and the synchronized data. During atmospheric correction atmospheric and topographic effects are removed and the radiance values are converted to ground reflectance for the reflective bands and surface emissivity and temperature for the thermal bands. Figure 2 gives an overview of the processing system.

The order of the processing steps depends on the nature of the terrain of the recorded scene: in case of rugged terrain, geocoding has to precede atmospheric correction, for flat terrain atmospheric correction can be performed prior to geocoding. This difference in the application flow has to be taken into account when modelling the processing system.

The development of a data model for each processing level, containing the components available plus a set of parameters describing the dataset, is a fundamental step towards the integration of

the processing system into DIMS. For the interaction of the processing subsystems between each other and with DIMS the PSM-Library is used. The tasks to be performed are ingesting the products into DIMS, and triggering the processing subsystem dependent on the availability of their product components.
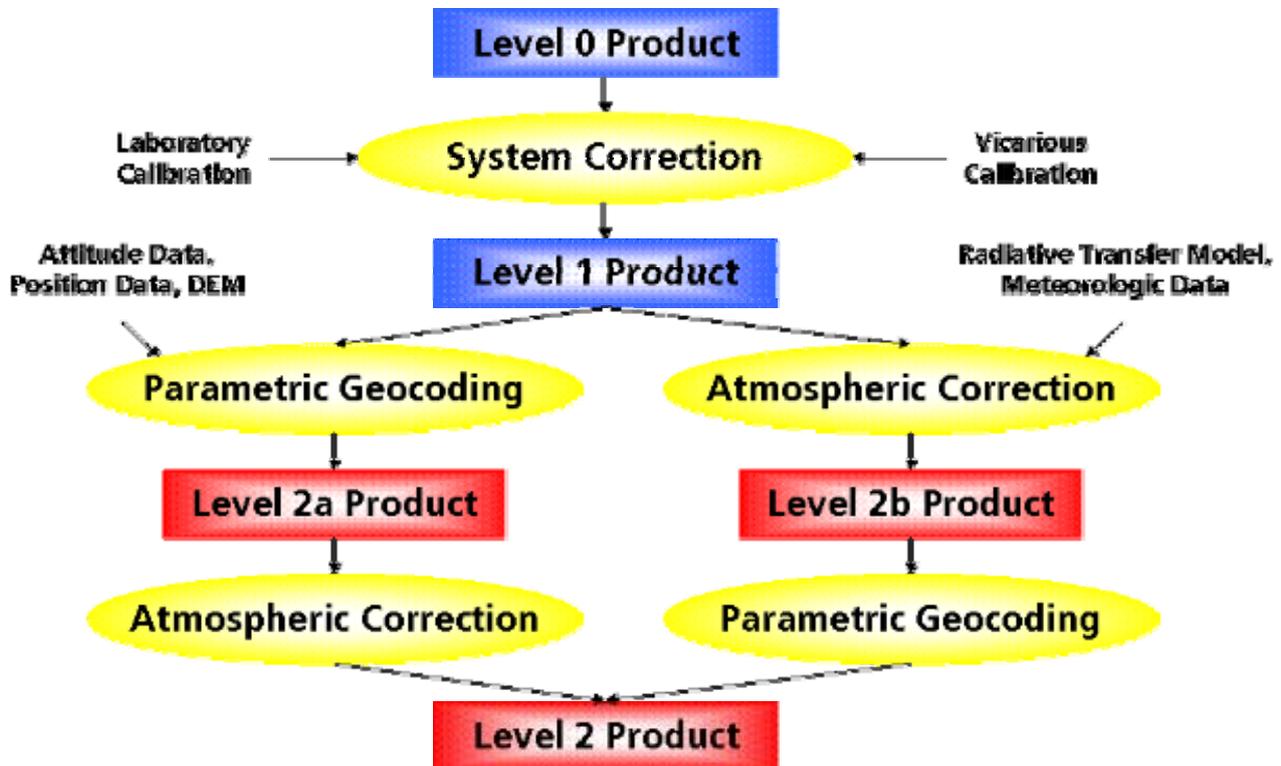

Figure 2: Overview of the Processing System.

Ingestion and System correction

The first step after the data has been recorded onto hard-disk aboard the aircraft is an ingestion of the dataset into the processing system including the generation of metadata. This can be derived from various sources: the logging information recorded during data acquisition is read, as well as parameters intrinsic in the data are extracted or calculated. Some of the information required is not inherent in the data acquired during recording. This information has to be passed to the processing system by a human operator or using the results from the flight planning data acquired prior to the overflight.

After ingesting the product into the processing system, system correction is performed, which comprises correction of the dark current, removal of system artefacts and finally the radiometric calibration of the data to at-sensor-radiance by application of the calibration coefficients attained during laboratory calibration prior to the overflight.

The components of the incoming Level-0 product and the resulting Level-1 product are the hyperspectral imagery data, a herefrom generated quicklook, additonal meta-data describing the dataset and data essential for geometric correction. Valid data for the hyperspectral imagery dataset are BIL-, BIP-, and BSQ-format. Raw data (Level-0) data in the ARES case is presented in BIL-format and the system corrected dataset ordered in BSQ-format. The additional metadata describes the dataset and can be devided into administration-, sensor-, scene-, and software-specific parameters. Those parameters describe the circumstances, under which the scene has been recorded, provide information needed in subsequent processing steps, hold information concerning quality control aspects and allow the administration of the product stored by the Product Library. The quicklook is generated as a first instrument for quality-control, and for a quick provision of the scene content. Data concerning the external and internal orientation of the sensor is provided for the purpose of a following geometric correction.

The data models for Level-0 and Level-1 data have already shown their adequacy during the incorporation of DAIS7915 and HyMap data into the DIMS (Strobl and Habermeyer, 2001 (ii), Habermeyer et al., 2001 (iii)).

Geocoding

In the process of geometric correction the geometric distortions due the movement of the aircraft and the scanner during data acquisition are removed. In case of the ARES processing chain, we rely on direct georeferencing software (documented in Müller et al., 2002 (iv)) for an automatic ortho-rectification of the imagery, as the system is supposed to work without user interaction. This is done by reconstructing the scanning geometry for each pixel in the image using the scanner's interior orientation, the position and attitude data of the scanner, recorded during data acquisition as well as a Digital Elevation Model (DEM).

In detail the following product components can be identified: the external orientation file represents attitude and position data of the scanner and is recorded during data acquisition using DGPS (Differential Global Positioning System) and INS (Inertial Navigation System) measurements. The sensor's internal orientation is stored within another file. By acquisition of the time at the end of each scan line and the recording of the positional data together with GPS time it becomes possible to synchronize the positional and attitude data with the scanner data. The actual geo-rectification algorithm is performed using the internal orientation, known position and attitude data, and the corresponding digital elevation model.

Application of the georectification algorithm yields an ortho-rectified imagery, and a file representing the viewing geometry of the sensor for the particular scene processed which can be used as an input for the subsequent atmospheric correction.

Atmospheric correction

In the course of the atmospheric correction of airborne optical imagery, the influence of the atmosphere, solar illumination, sensor viewing geometry and terrain information are calculated to attain radiometrically corrected data. For our purposes the latest version of ATCOR4 is employed to correct the data for ground reflectance. The algorithm is discussed in detail in Richter and Schläpfer, 2002 (vi), at this point the input and output products contributing to a Level-2 product model are identified and described.

From the overview of the interaction of the described components (Figure 4) the following input components can be identified: the airborne imagery dataset itself, the scan angle file, the sensor characteristics, a digital elevation model, and additional data describing temporal and positional information for the dataset. Those product components have to be made available from prior steps and should be considered in the models of earlier processing steps, namely system correction and georectification.

Digital Elevation Database

For both procedures, the geo-rectification and the atmospheric correction the use of a Digital Elevation Model is obligatory. It can be provided by the customer. In case no DEM is available, the data can be extracted from a Digital Elevation Database with world wide coverage, named W42 (Roth et al., 2002 (v)). Its roots stem from data from Radar Shuttle and Satellite missions. Further incorporation of other data sources is possible to improve the accuracies of those regions of the earth, where the information provided is insufficient. On the one hand there are utilities providing basic database functionality, as import, export, and removal of tiles. On the other hand a whole suite of routines is implemented to allow the application of the data stored throughout various projects, e.g. mosaicking and transformation routines. An overview is given in Figure 3.
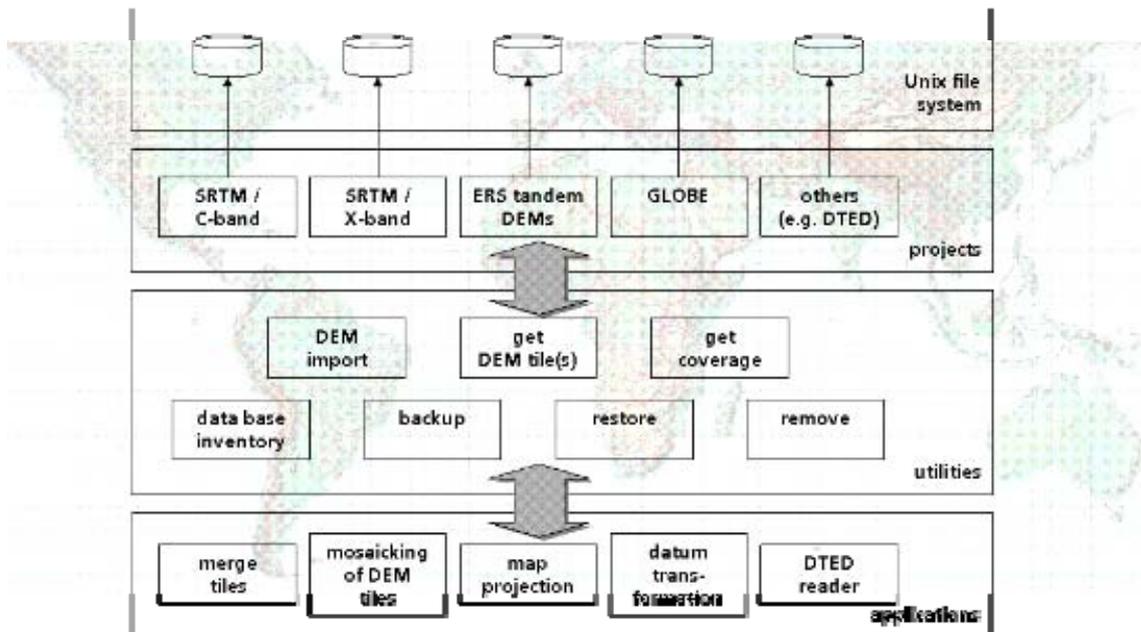
Figure 3: W42 – The Digital Elevation Database.

IMPLEMENTATION OF THE SYSTEM

The Product Model consists of data and meta-data describing the dataset, making it possible for the data provider to stock all data necessary for engineering purposes as well as enabling the user to check for scene-specific information. Therefore the organization of the data consists of product components, i.e. single files that can be binary and ASCII data, providing various kinds of information, in our case e.g. the data cube, header in various formats plus different kinds of auxiliary data. These product components are stored in a specific format previously defined, and identical to all products in that product level. This organisation is together with the meta-information described in a so called item information file (IIF), which is specified in XML format. The information provided by the IIF is shown by the Operating Tool. The IIF represents the link of DIMS with the processor.
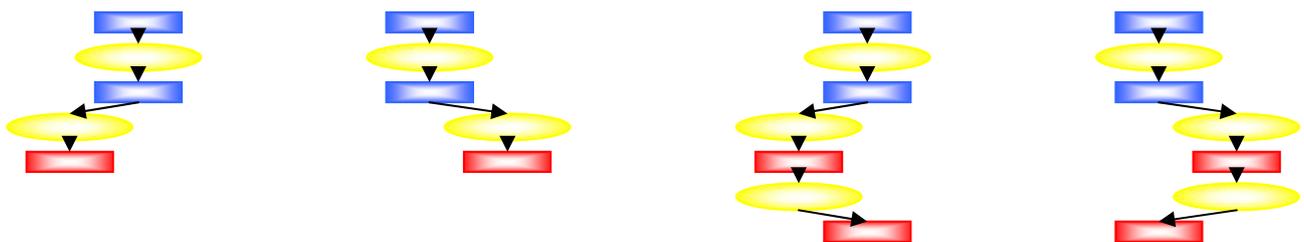

Figure 4: Foreseen Processing Mechanisms: a)apply geocoding and stop, b) apply atmospheric correction and stop, c) apply geocoding before atmospheric correction (default), d) apply atmospheric correction before geocoding.

The Processing System has been introduced before. When it comes to an implementation, it is important to point out again, that there are different sequences, geocoding and atmospheric corrections are passed through: atmospheric correction can be performed prior and subsequent to geocoding. In case the scene has been acquired over flat terrain and a Digital Elevation model is not available, it is more appropriate to conduct atmospheric correction right after system correction. The cases taken into account, are shown in Figure 4 and become understandable when revisiting Figure 2. From left to right the following situations are addressed: a) apply geocoding and stop, b) apply atmospheric correction and stop, c) apply geocoding before atmospheric correction (the default) and d) apply atmospheric correction before geocoding. The different processing mechanisms have an impact for the processing system as well as for the resulting data models: two types of

processors have to be foreseen: a type of processor that just feeds the data into in the archive, i.e. sets up the available data according to the organization of the product model, plus generating the IIF. This type is called Ingestion Processor. The other type of processor allows processing on demand: the dataset only is processed to a certain level, e.g. stopping at Level 1, Level 2a, after the geocoding (case 4a) or Level 2b, after the atmospheric correction (case 4b). When additional data becomes available, the subsequent steps are attempted, based on the information provided by the Product Model describing the preceding steps. As a consequence, every product has to contain all parameters and products necessary for subsequent processing.

The resulting data model for a completely processed Level-2 product is shown in Figure 5. The Level-2a product (after parametric geocoding without the application of atmospheric correction), and the Level-2b product (after atmospheric correction without the application of geocoding) are both subsets of the Level-2 product. The single components can be described briefly (Figure 5, left to right):

- The LOG product component contains all the logging accomplished during processing, i.e. the logging files of ATCOR and ORTHO, as well as their configuration files plus the navigation file, where attitude and position information for every flight line are stored.

- The QL compontent contains quicklooks in different image formats for a quick visualization on the screen.

- The PRIM component contains the data cube itself plus a number of value adding products, e.g. a water vapor, emissivity, heat flux, and visibility maps.

- The HAZE component holds the information about the haze content in the scene, provided as haze levels and haze removed DN image.

- In the DEM component various files derived from the digital elevation model and the sun angles are stored.

- In the CSHD component information concerning the cloud shadow in the scene is stored, provided as shadow removed DN image and fractional solar illumination image.
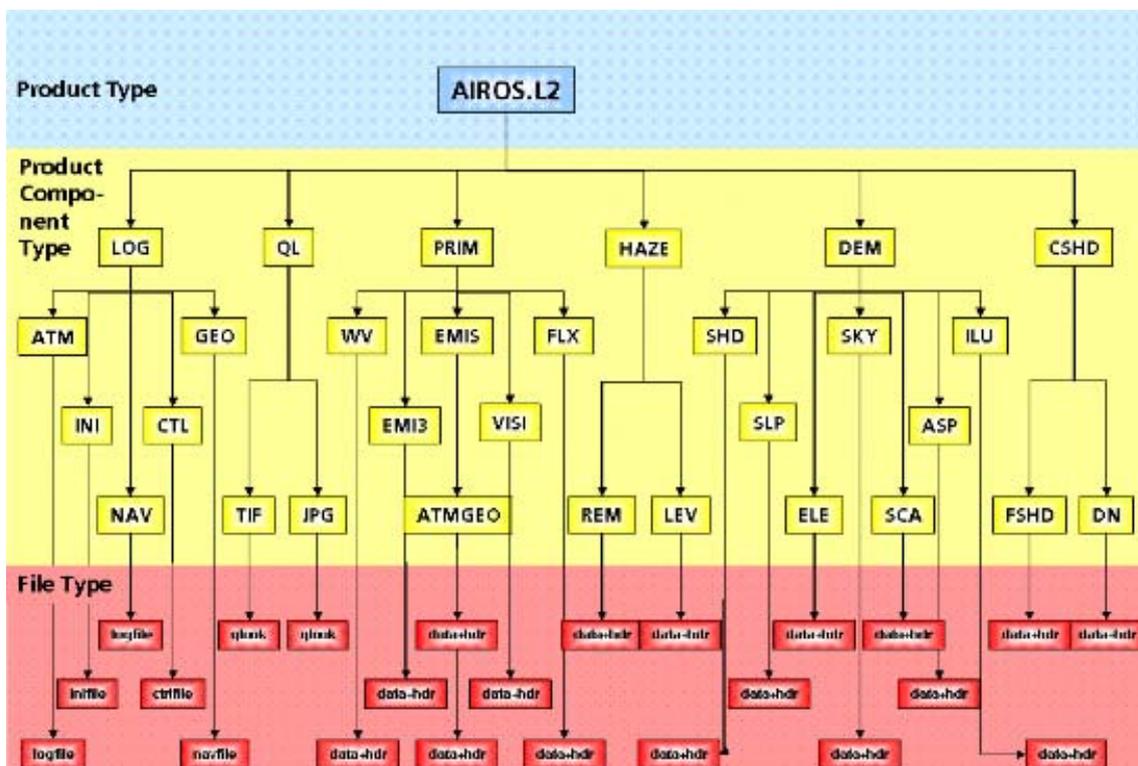

Figure 5: The Level 2 Product Model

At all levels a high flexibility in the choice of parameter values is mandatory. In every processing step there are four types of parameters: those constant for a scene, the ones inherent in the scene, others that have to be provided from some other source, and the ones that can be calculated or rearranged from the other types. To take all those possibilities into account, a system-immanent database is created, with the flexibility to override the default values. This database is organised in a specific directory structure with an own directory for every parameter block. It is read before the invocation of the geocoding and atmospheric correction processes.

CONCLUSIONS AND OUTLOOK

The design and implementation of a fully automated processing chain for the upcoming hyperspectral sensor ARES has been displayed. The modules of a generic processing and archiving environment necessary for the construction of such a processing chain have been introduced. Based on the terminology for this introduction the relevant modules of a processing system for hyperspectral scanners have been identified. It has been pointed out, which parameters provide the meta-information necessary for a unique and adequate description of the data, plus which products serve as input for the processor's components as well as which output is produced by each component.

As the described data model is generic, the incorporation of other sensors remains to be shown.

References

i   MIKUSCH E, E DIEDRICH, M GÖHMANN, S KIEMLE, R REIßIG, K SCHMIDT, W WILDEGGER & M WOLFMÖLLER, 2000. Data Information and Management System for the Production, Archiving and Distribution of Earth Observation Products. In: Proceedings of DASIA – Data Systems in Aerospace, Montreal, Canada, 22-26 May 2000

ii STROBL P & M HABERMEYER, 2001. A generic archiving and processing structure for airborne optical scanner data. In: Proceedings of the 5th International Airborne Remote Sensing Conference, San Francisco, USA, September 17-20, 2001.

iii HABERMEYER M, P STROBL & A MÜLLER, 2001. Interfacing Airborne Scanner Data to a Generic Archiving and Processing Environment: a Case Study for the DAIS7915. In: Proceedings of the 5th International Airborne Remote Sensing Conference, San Francisco, USA, September 17-20, 2001.

iv MÜLLER R, M LEHNER, R MÜLLER, P REINARTZ, M SCHROEDER & B VOLLMER, 2002. A program for direct georeferencing of airborne and spaceborne line scanner images. In: Mid-term symposium of ISPRS Commission I, WG 1/5 Intergrating Remote Sensing at the Global, Regional and Local Scale. Colorado, USA, Nov 10-15, 2002.

v   ROTH A, W KNÖPFLE, G STRUNZ, M LEHNER & P. REINARTZ, 2002. Towards a Global Elevation Product: Combination of multi-source digital elevation models. In: Proceedings of the Joint International Symposium on Geospatial Theory, Processing and Applications. Ottawa, Canada, July 9-12, 2002.

vi RICHTER R & D SCHLÄPFER, 2002. Geo-atmospheric processing of airborne imaging spectrometer data. Part 2: atmospheric/topographic correction. International Journal of Remote Sensing 23, no. 13, pp. 2631-2649.

vii Berk A, L S Bernstein, G P Anderson, P K Acharya, D Robertson, J H Chetwynd & S M Adler-Golden, 1998. MODTRAN cloud and multiple scattering upgrades with application to AVIRIS. Remote Sensing of Environment 65, pp. 367-375.

viii HABERMEYER M, A MÜLLER, S HOLZWARTH, R RICHTER, R MÜLLER, K-H SEITZ, P SEIFERT & P STROBL, 2003. DEVELOPMENT OF A FULLY AUTOMATIC PROCESSING CHAIN FOR THE UPCOMING HYPERSPECTRAL SCANNER ARES. In: 3rd EARSeL Workshop on Imaging Spectroscopy, Herrsching, Germany, 13-16 May 2003, edited by M Habermeyer, A Müller & S Holzwarth (EARSeL, Paris), 82-87.

ix KIEMLE S, E MIKUSCH & M GÖHMANN, 2001. The Product Library: A Scalable Long-Term Storage Repisitory for Earth Observation Products. In: Proceedings of DASIA – Data Systems in Aerospace, Nice, France, 2001.

x BÖTTCHER M, R REIßIG, E MIKUSCH & C RECK, 2001. Processing Management Tools for Earth Observation Products at DLR-DFD. In: Proceedings of DASIA – Data Systems in Aerospace, Nice, France, 2001.