The Generalized Processing Chain for BIRD and FireBIRD Mission

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Abstract The FireBIRD mission has been designed to detect and monitor dynamic high temperature events, such as wild fires or volcano eruptions. In order to provide calibrated and geo-referenced data in near real time to users, a ground processing system is going to be established and deployed in the downstream chain in the national ground segment in Neustrelitz. The ground processing system consists of the Payload System Management (PSM) and one or more Instrument Processing Facility (IPFs). Due to the experimental nature of small satellite missions the components of the ground system have been often specific solutions. The design of the FireBIRD ground segment uses a modular design with separate control and payload data interfaces. For data interfaces abstract data descriptions are used in order to achieve a mission independent design to a large extend. A design constraint is to separate processing control components from data processing components as far as possible. The goal is to achieve extendibility and reusability of the processing components as well as portability of the IPF to other systems and migration for future missions.

Keywords: Automatic data processor, abstract data model, ground station

1 Mission FireBIRD

The mission FireBIRD [1] is based on a two satellites constellation - TET-1 (already successful launched on July 22, 2012) [2], as part of the German Program "On-Orbit-Verification of new technologies“ and BIROS (Berlin Infrared Optical System). This second satellite will be launched in 2014. The satellites are designed to detect and monitor dynamic high temperature events, such as wild fires or volcano eruptions.

The mission inherits concepts of the small satellite mission BIRD (Bi-Spectral Infra-Red Detection, operational from 2001 to 2006) [3]. The heritage relates to the basic design and components of the satellite and will be extended by using a constellation of satellites and takes into account new technical developments. So it is possible to achieve a high reliability, while minimizing the costs.

The ground segment for the mission (see Figure 1) consists of two main components, the mission operation segment, carried out by German Space Operations Center and the payload ground segment, executed by the German Remote Sensing Data Center with the ground station and the Payload Data Center (PDC) in Neustrelitz. The ground segment is completed by a processor and Cal/Val Segment.

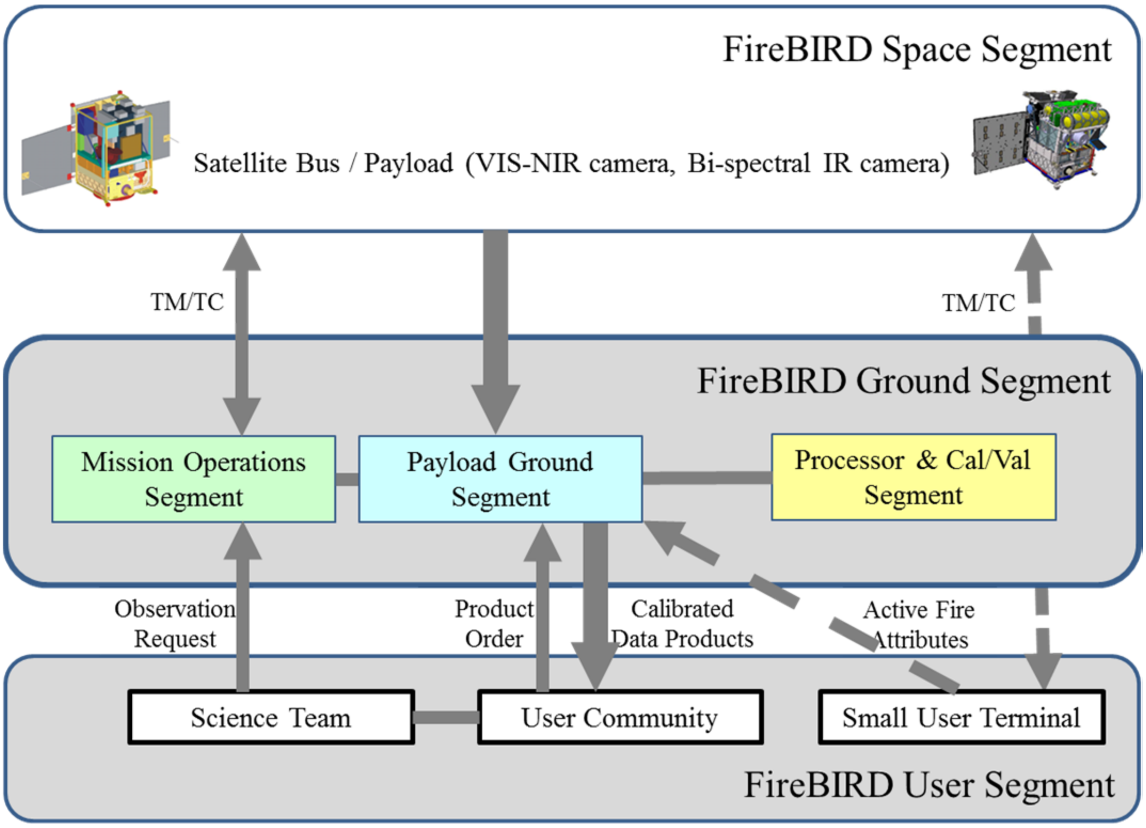

Figure 1 FireBIRD Components and data flow in the ground segment

The ground station of the DFD in Neustrelitz receives data from the camera payload. In the Payload Data Center, this data is then combined with additional data, e. g. attitude data, processed, cataloged, archived and made available to the scientific user community using the Data Information Management System (DIMS). With the DIMS it is possible to have the data processed immediately upon receipt automatically by the scientific processors managed by the Process System Management. Figure 2 shows the components of the ground station and the Payload Data Center in Neustrelitz. Data will be processed immediately after the downlink, and in case one scene (datatake) requires several downlinks, a second time after completion. The first processing step is used to provide near real time (NRT) products. The final processing takes part after instrument source packages (ISPs) have been received, including AOCS, calibration and housekeeping data in order to achieve a good product quality. Via the user interface reprocessing of selected data can be performed, possibly with upgraded calibration data.

2 The Generic Processor

2.1 Payload Data Center

In the past typically all ground segment facilities and services incl. its processors were a specific development to a mission. In the last decade a multitude of services was established which work independent from a special mission. DLRs Data and Information Management System (DIMS) is such an example. During the last years this

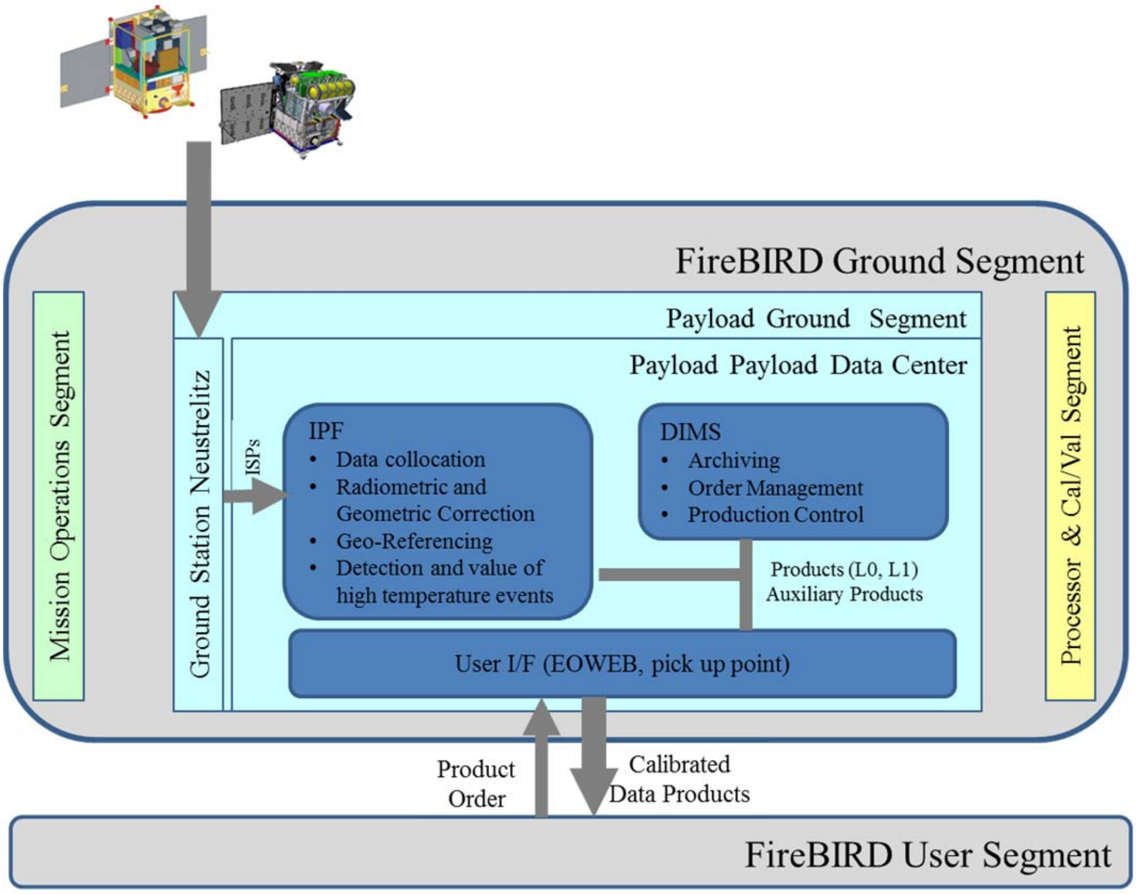

Figure 2 The Payload Data Center

services were complemented by two parallel developments. On the one hand generalized work flow management systems were established to combine in an automated or semi-automated way a selection of processors to compute special products from a variety of data sources. DLRs project CATENA ([4], [5]) is such an example. On the other hand, processors were developed which are able to process a special product from a broad class of input data. However these processors are mainly dedicated to higher level products, such as calibrated and geo-referenced image data.

Still Instrument Processing Facilities (IPF) used for the very first processing steps from level 0 to level 1b remain unique solutions, dedicated to a specific mission and instrument. The reason is that each instrument and mission has its own specific characteristics in terms of data content and physical properties derived from physical properties of the sensor and data structures designed for data downlink. In addition, the control interface of the data processor needs to fit to a given tool environment provided along with data reception or data archiving facilities, e. g. handling of input and output products. The effort to adapt a given processor to a new mission or a different ground station can be therefore very high.

ESA has made some effort to standardize the control segment within the ground processing facility [6]. The Processing System Management (PSM) represents such a system. It consists of the control layer used by the operator to retrieve data from data reception and data archive and to start the instrument processor as the second major part of the PSM (Figure 3).

Since the interface between the control layer and the instrument processor is provided via shell and files, a processor fitted to the PSM can be used also without the PSM control layer. Due to the standardized description of the interfaces, it is possible to design the control elements of the instrument processor itself in form of a library. Such a library can be utilized for other data processors as well, independently from the algorithmic processing.

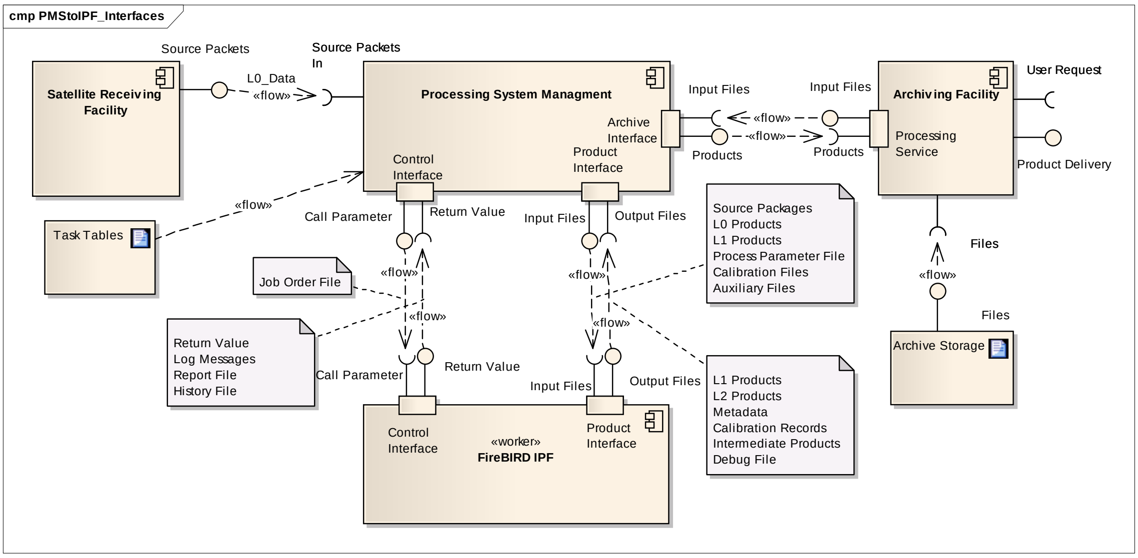

Figure 3 Ground Data Processing Facility Interfaces

The basic structure of the Payload System Management is presented in Figure 3. A task table provided to the PSM lists all the input needed and output generated for a specific working step. From this the list of products to be requested from the archive and provided to the processor is derived and after processing which products will be send to the archive. Calibration records will be kept in the archive as well, which allows to reprocess data according to the best knowledge of the instrument state.

2.2 FireBIRD Data Processor

The development goal for a processor should be framework which allows to handle data from different sources and to allow a variety of different processing steps depending on the input data source and output product as well as a specific configuration. This means that the internal structure with respect to control, data flow and algorithmic functions needs to be as much as possible independent from instrument specific structures, but still allow access to all data and functionalities needed.

The FireBIRD Data Processor has a modular design with separate modules for control interfaces, data interfaces, processing components and services. The central part is a based on a generic data storage model in which instrument specific structures can be incorporated. Instrument specific processing tasks, such as level 0 extraction will be isolated in separate modules.

Since we deal with image data, the structure and format can be kept throughout the processing. This allows applying algorithmic functions also in variable order, to leave steps out or to add additional steps. Especially in the early mission phase flexibility with respect to the algorithm is needed.

Figure 4 shows the basic data flow of the FireBIRD level 1 instrument data processor. In case of FireBIRD we deal with 2 different types of cameras with together 5 spectral channels, where each channel might be considered as an individual imager. Channels can be processed individually or in chunks for all channels together.

In order to make a data processor generic, we need to separate clearly between level 0 data source packages and data structures used in the level 1 processing chain and higher data processing levels. This can be achieved by organizing the data in form of an abstract data model, which provides storage and interface capabilities. Data processing is organized with the buffer point of view.

A minimal processing chain as such can be strictly spoken restricted to source package extraction and product generation (level 0 processing). Data processing steps itself start with retrieving data from the buffer, evaluation and/or manipulation of the values and writing the results back to the storage, either replacing original values or in addition to them.

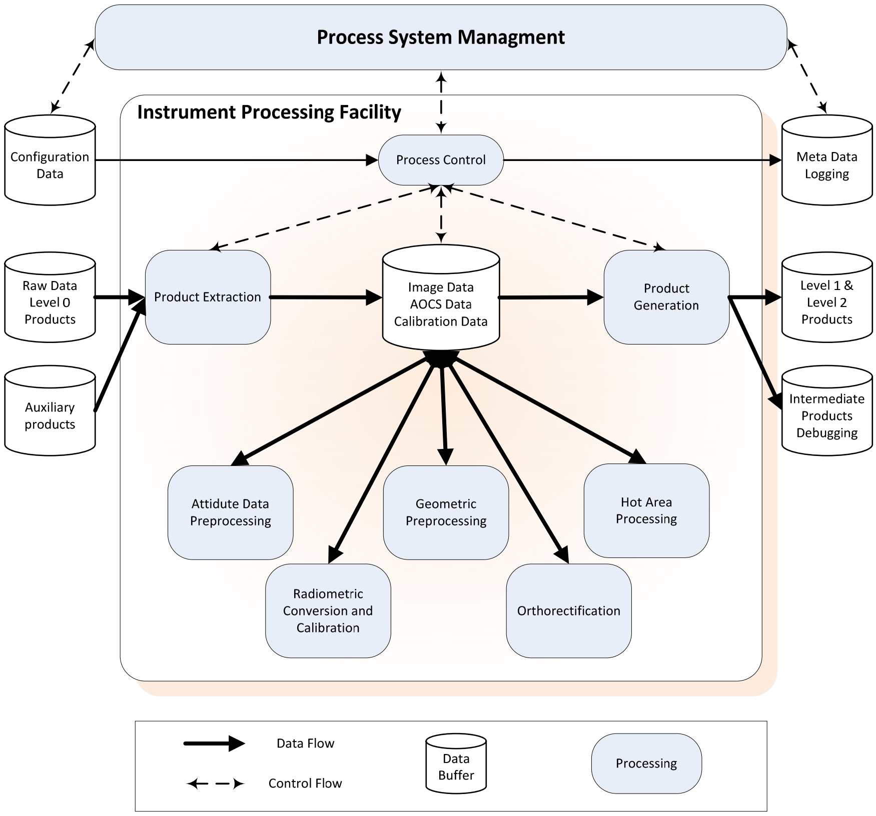

Figure 4 FireBIRD Level 1 Instrument Data Processor

Another aspect is the relationship between spectral channels. Since for higher level processing steps not always all channels are needed, channels should have no direct dependency to each other. This requires reference structures in order to keep temporal and spatial relationships.

2.3 Abstract Data Model

As described, the data buffer used is designed by means of an abstract data model. Basically this is not a new invention, since the design of remote sensing products, such as NetCDF or HDF5-EOS, follows this approach as well. This model however has been extended with respect to information about processing steps, keeping track of steps planned and steps performed.

Data will be stored in objects following an abstract description combining image data and related data, but is still keeping the original image geometry. The image data buffer contains the components:

- Meta data (description of image data and sensor)
- Measurement data including quality parameter
- Auxiliary data, e. g. housekeeping data
- Geolocation data
- Processing data, providing information about processing steps to be performed and have been applied

This data model itself is oriented on the structure of level 1b products, as it is also used in other remote sensing data projects, hence co-referenced images, which are formally independent. Sensor specific parameters are provided in separate subsets of auxiliary data. In addition to these widely used annotations a subset for processing parameter is added. With the help of these parameters the processor can organize the processing steps to be applied and can also keep track of processing steps performed so far. This information is then also utilized in later processing steps, e .g. the detection algorithm needs to adjust whether pixel data are interpolated or not. Such properties can also be added to external data provided, e. g. MODIS Level 1 data.

A key issue is the definition of data containers having a simple and clear design to fulfill the specific needs of individual instruments and to be generic enough, to be described in an abstract layer. A datatake will be considered as a three dimensional set of data. For this the three dimensional structure of a data take needs to be broken down to the pixel level. The top dimension is the spectral dimension, where each spectral channel is handled as one separate set of data, so it can be treated on the control level independent of its origin. Each level or group of data image data is combined with headers describing these data agglomeration and additional auxiliary parameter for individual properties of these data. E. g. camera and satellite specific attributes and methods are implemented in separate modules will be referenced. Following this approach simplifies extension of the data processor towards other instruments hosted on different satellites.

For definition of the data fields itself it is recommended to use internal naming conventions derived from a common ontology, thus it is easy to understand the meaning of individual parameters. Also descriptive parameter, such as units are kept together with parameters throughout the processing steps. In a later stage of development this might be used as a cross check, whether parameters are compatible. As measurement data a combination of pixel value, error margins and confidence parameter is used.

Keeping the structure of the processing parameter static, it is easy to provide methods for search, retrieval of data from the buffer and writing data back to the buffer in form of an API. This simplifies import and export of data for different kind of product formats and for writing intermediate products.

3 Conclusions and Outlook

The paper discusses an example for a modular design of a generic satellite data processing chain, which will be further developed with experience gained from the ongoing mission. The design is based on an abstract data and product definition having the user community in mind.

Data processing steps will be performed in separate processing modules, with abstract data interfaces, to receive data from and send processed data to the data containers sequentially. This allows adding, removing or modifying individual processing steps independently from other tasks, such as file extraction or product generation. Easy modification of the processor is also necessary due to the nature of scientific experiments, requiring permanent maintenance and upgrade of the processor even years beyond the mission life time.

In the long term a model based design strategy will be developed, based on a formal data model and a model of the control interfaces provided. Combined with service libraries for file and product handling, configuration, logging etc. the effort for designing and realization of a new processor should be reduced. Especially for small satellite missions with experimental character, short mission phases, and low budget a generic approach under reuse of given processing and archiving facilities is a need.

4 Acknowledgements

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