EVOLUTION OF DLR'S MULTI-MISSION GROUND STATION AS A RECEPTION FACILITY IN THE MIDDLE OF EUROPE (СЕКЦИЯ 2)

H. Damerow[1], J. Richter[1], K.-D. Missling[1], H. Maass[1]

[1] Earth Observation Centre (EOC, DLR), Neustrelitz, Germany;

Introduction

The Earth Observation Center (EOC) is a cluster institute of the German Aerospace Center (DLR). The EOC comprises the German Remote Sensing Data Center (DFD) and the Remote Sensing Technology Institute (IMF), at work in Oberpfaffenhofen, Neustrelitz, Berlin-Adlershof and Bremen. With its national and international receiving stations, DFD offers direct access to data from earth observation missions, derives information products from the raw data, disseminates these products to users, and safeguards all data in the National Remote Sensing Data Library for long-term use.

The EOC operates the National Ground Station Neustrelitz (NSG), which is used as main ground station for the payload data reception of high rate data stream (X-Band, Ka-Band). In the beginning of the 90th, after finishing the INTERKOSMOS program, the station development has started into a new era. First projects have been OKEAN, the solar mission CORONAS-I/F, and the joint project MOMS/PRIRODA. Nowadays, the ground station is involved operationally for remote sensing missions like TerraSAR-X, TanDEM-X, Landsat-8, Landsat-7, KOMPSAT, Sentinel-1A/B, OCEANSAT-2, AQUA, TERRA, and for several small explorer missions. A number of Indian and international projects have been successfully supported. On behalf of ESA, the EOC, especially NGS with specific front end processing systems, has developed and operates the Sentinel-5P Ground System inclusive the operations of ground station elements at Svalbard and Inuvik.

The paper describes the evolution process over two decades with respect to the station site and infrastructure, and the main hardware and software design. It focuses on the automation system of the station, which is either today station specific.

From the beginning, the development goal was full integration in a highly automated multi-mission system. Relevant working areas are reception planning, reception automation, and quality control. Starting from long-term experience in data reception a software system supporting operations planner and operators has been developed. This system realizes a fast and reliable adopting of changing operation scenarios, a stable station monitoring and control and an objective collection of reception quality data. Furthermore, the paper gives a detailed view on the main integration and production component: the Front-End Processing system (FEP). In this role, the FEP is capable to be easily integrated in local and external facilities and provides a rich bundle of functions beside an excellent expandability and maintainability having limited resources.

Historical Review

In 1994, three year after the reunification of East and West Germany, a large reorganization of the scientific landscape in the former GDR was ongoing. In this context, a project with Russian and German scientific institutes, based in the Munich, Bonn and Neustrelitz was setup to take advantages and changes in this new freedom. The joint project called “MOMS PRIRODA“, was driven by with RKK Energia, DARA, and DLR.

In the beginning of 1996, a widely visual signal was the erecting complete and the start of operations of the first 7.3 m S/X-Band System (DATRON). In the beginning, the core antenna system was supplemented by DATRON demodulators, L3 bit synchronizer, mission-specific frame synchronization hardware and AMPEX tape recorder. The supported missions have been ERS-1/2, and the IRS-P3 mission in a context of Indian-German cooperation. The used hardware was fairly specific for the mentioned missions. The adoptions to other missions have not been supported. Either the automation was only available for the antenna core system; all other equipment was controlled manually by an operator. Furthermore, the technic room was in short distance to the antenna because the length criteria of RF cables. Small software application for a few automatization functions have been developed, e.g., to control digital tape recorder devices. Nevertheless, this was the starting point for the Neustrelitz Ground Station. At that time there was no station in Germany geared to receive payload data via X-band in the remote sensing sector. There was the station in Weilheim, which provided mission support in particular, as well as the international stations of the German Remote Sensing Data Center. Hence a real and prospective niche was found for Neustrelitz.

Until 2000, a second antenna system was planned because the number of supported contacts increases and so fare the risk of conflicts between mission contacts. The installation of a second antenna causes a number of consequences:

- Multiple contacts at same time can’t be supported by one operator.
- The technics room must be centralized and provide more capacity for third party equipment.
- Some equipment must be shared between the antennas, because they have been a limited resource.
- As a side effect, more and more modern reception equipment needed to be integrated.

Consequently, the second antenna provides now more capacity but drives the engineering team to follow a strong multi-mission approach to cope with the mentioned. At this time CORONAS-F, a Russian sun explorer mission built by the IZMIRAN institute, the now mature MOMS/PRIRODA project, and a number of further Indian missions become important for the ground station.

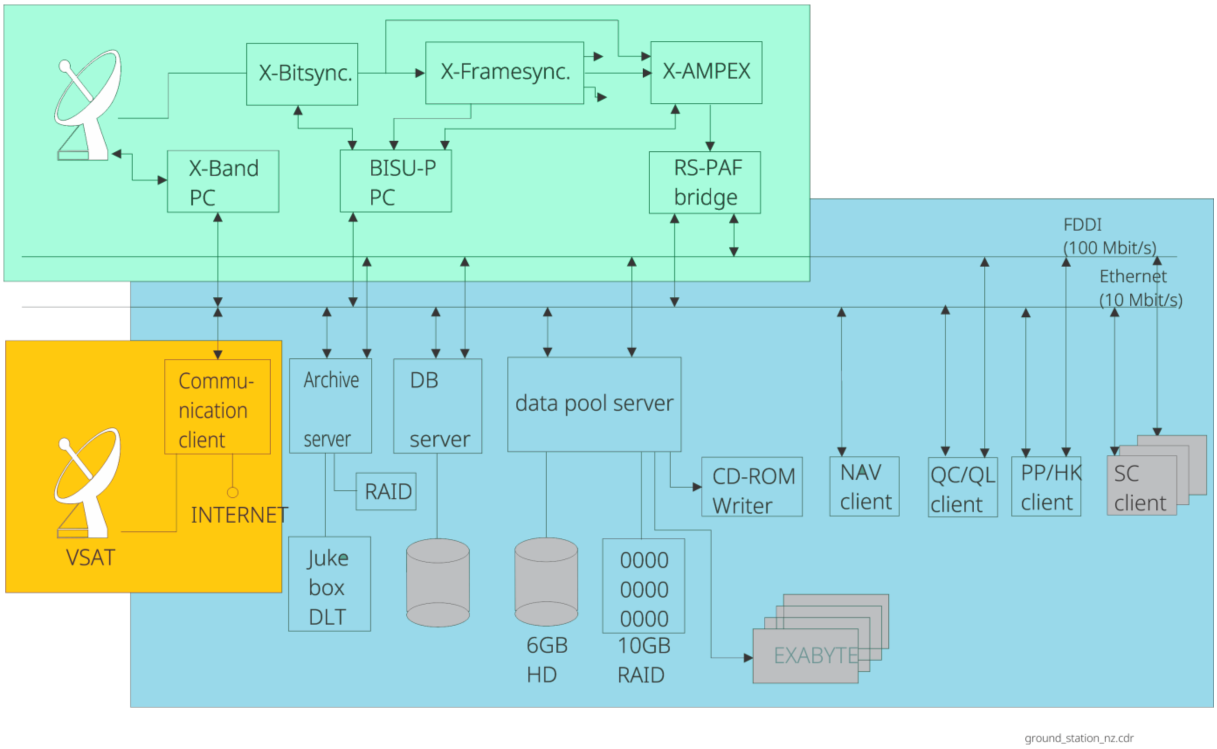

Figure 1. Block graph of the Neustrelitz Ground System in 1998

Figure 1 gives an overview of the MOMS/PRIRODE mission specific station design. Obviously, this breakout was embedded in a larger system, which will be shown in figure 2. The reference list below provides papers and conference contributions with respect to the MOMS/PRIRODA project. They are mostly technology and system engineering oriented.

Current Ground Station Situation

Since approximately 2000, the ground station has established here profile as a multi-mission ground station with focus to payload data reception and real-time applications. This profile can be concluded as follows:

- Supporting Earth Observation Center and DLR application departments and thematic projects to develop NRT services and processors.
- Supporting national and international scientific missions with payload data and real-time streams.
- Supporting German Space Operations Center (GSOC) with TT&C services.
- Supporting on site data or service provider, e.g. GAF for Indian missions.
- System Engineering Support for national projects, e.g., TerraSAR-X, EnMAP, TanDEM-X.
- Supporting international scientific partners (USGS, NOAA, KARI).

The cooperation takes place on several levels and styles. That can be a project, a high level Memorandum of Understanding (MoU) to support each other on institutional level or a contract with a company. For these functions, it was decided to follow some station design goals for efficiency, reliability, and costs. As mentioned above, the engineering was strictly focused on a multi-mission approach trough all system components to support the following aspects:

– Single operator for planning and process observation in 7/24 shifts on demand.
– Detailed data quality monitoring for all data streams and products.
– Cost sharing and delta funding over multiple projects.
– Moderate dependence from industry.
– High flexibility to cope with new requirements to gain unique selling points.
– System and process ownership according the EOC institutional baseline.

According this approach, the engineers has started from the beginning to develop an own station software for automatization, planning, reporting and near real-time product generation and dissemination. Also the site infrastructure and redundancy has been developed for the main goal. This includes power network independency through uninterrupted power supply (UPS) and diesel generator, a redundant WAN connection of 1 GBit/s for the Neustrelitz site, and a redundant WAN connection for TT&C purposes. Furthermore, the receiving station part of the ground station can rely on a distributed robot archive systems (1st and 2nd copy) und fiber channel and 1GBit/s LAN network interconnects. This connects to comprehensive processing infrastructure with data processing and archive systems, which is partly complementary to the EOC site in Oberpfaffenhofen.

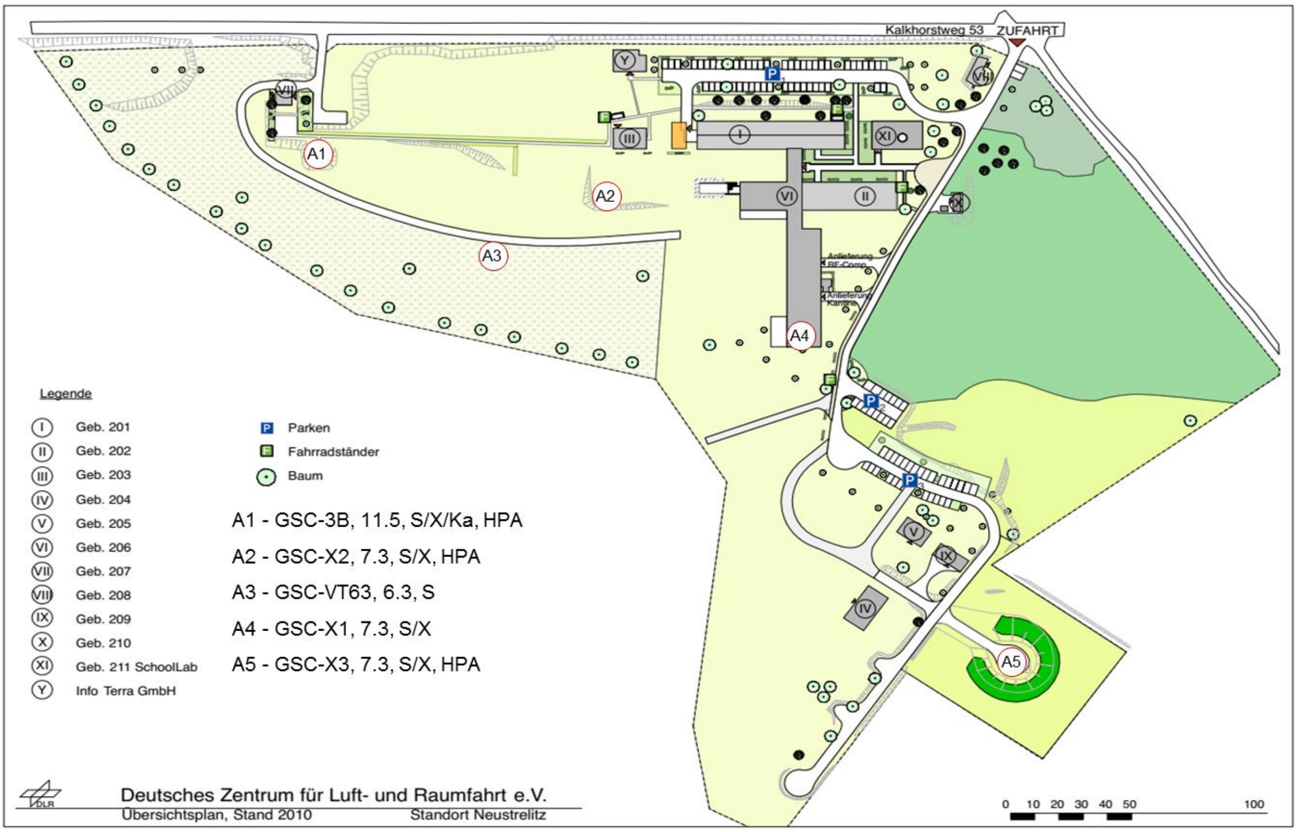

Figure 2. Block Graph of the Ground Station System

In 2012, a modern technics building was erected, see the south wing of the building complex in figure 2. This building provides new opportunities and excellent infrastructure with respect to operator control room, water cooled rack system. Furthermore an additional antenna place was gained on the roof of the new building. At this place, the first S/X-Band antenna was moved on top, which provide now an excellent horizon mask of 2 degree elevation all around.

The Reception Part of the Ground Station

The core ground station breakdown is given by figure 3 below. Nowadays, the system consists of three 7.3 m and one 11.5 m antennas with service capabilities for X-band downlink, S-band TT&C support, and Ka-band downlink. Furthermore, a 6.3 m antenna (S-band) for the NOAA sun explorer mission DSCOVR has been integrated into the reception system. Also, a historical 4 m S-band antenna supports ACE sun explorer mission as well, either for NOAA ground station network. Specifically the roof antenna (X-band) provides an extended European coverage through a low horizon mask.

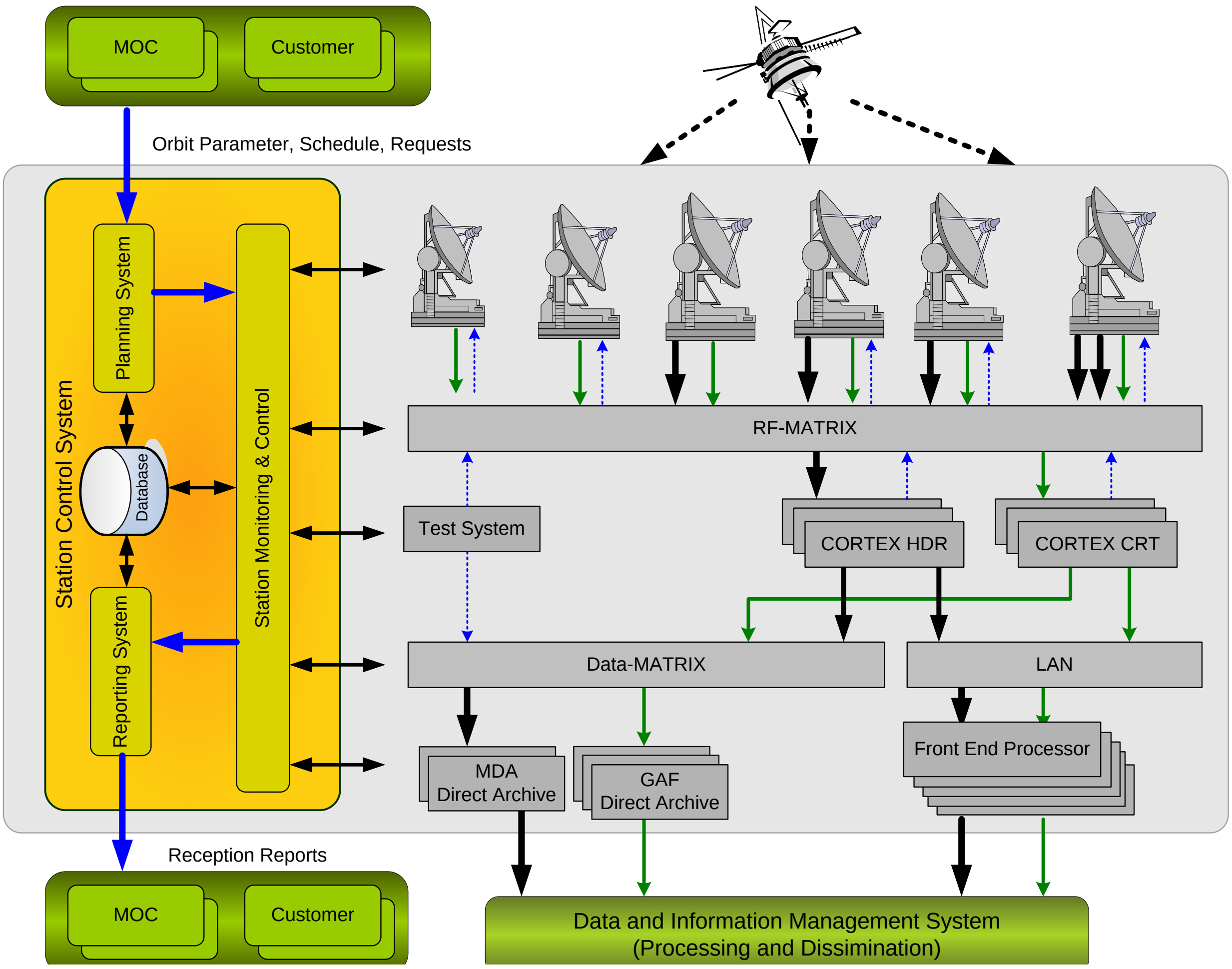

Figure 3. Block Graph of the Ground Station System

All antenna systems connected to the central control room with fiber optic links for intermediate frequencies to all CORTEX HDRs and CRTs using a RF switch matrix. The high data rate recorders have been grouped in a pool to enable dynamic device allocation, hot redundancies, or in-situ integration and validation tasks. The CRT devices are allocated to a concrete antenna since there are integrated in a space link extension infrastructure which itself is not switchable. According the specific mission, the so-called baseband devices provide a data signal as bit-serial ECL signal or a real-time CADU stream via independent LAN interconnects. The latter one is the standard for most of the missions.

Station Automation

It is obvious and state of the art, that a modern ground station has a station control system. For the Neustrelitz ground station, a distributed Station Monitoring and Control (MMSC) system has been designed and developed by the station engineers, see figure 4. It consists of a number of so-called Antenna Stations (antenna control and a Front End Processor), a central monitoring and control system, and a planning system. All of these components are running on PC systems and DELL servers and are complemented by a file server and file distribution infrastructure.

The station automation, namely the three main integration tools, has been designed to use a common frame work and specific software infrastructure components. This approach shall enable code reusability. The introduction of abstraction layers, also the use of object oriented design shall reduce complexity and support maintainability if the software must be evolved. At the other hand, the software was also constructed to meet the following requirements:

– Fully interoperability through Matrix and LAN interconnects controlled by a central station automation component.
– Unified user interface for planning, subsystem scheduling, configuration, monitoring, interconnect, reporting interfaces to establish an operator assisted system.
– Establishing a distributed software system focus on so-called antenna stations.
– Establishing of abstraction layers (driver model) to integrate various level and style of communication interfaces and automation capabilities.

The integration approach does foresee the Front End Processor as a control system for a so called antenna station. This exonerates the central monitoring and control system and supports the concept of distributed control of the station. Furthermore, this antenna station controller concept allows to operate the station in parallel by specialist for different station tasks, e.g. for the mission (uplink) support and station planning. Consequently, the design considers the following aspects:

– Distributed control system along with distributed configuration databases together with loose coupling of monitoring and control instances.
– Reception of a number of missions with minimal operational effort through unified workflow (planning, scheduling, data reception, reporting).

– Creation of a simplified human-machine interface, which provides efficient supervising, configuration and control capabilities for the whole ground station without information overload.
– Configuration and functional support of automated tests to ensure proper function after device replacements, configurations tasks, and signal problems.
– Provision of multiple problem-handling functions.

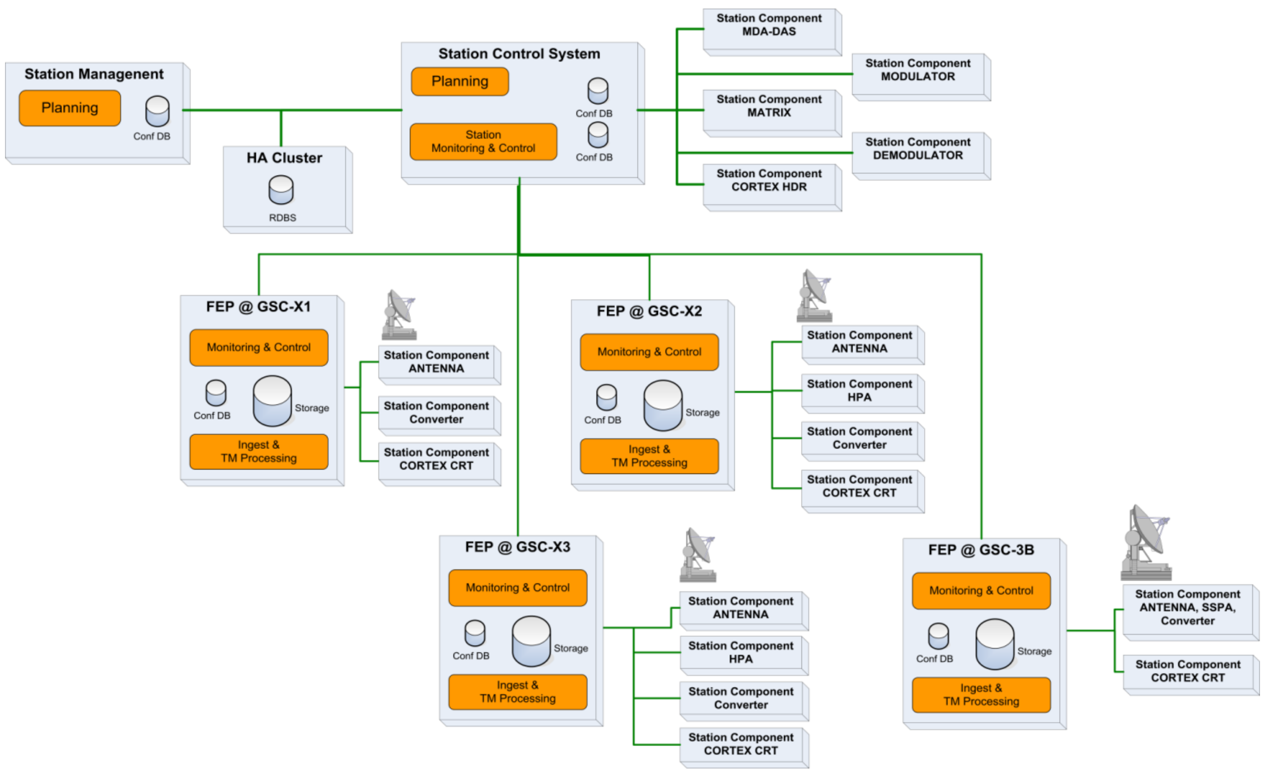

Figure 4. The Distributed Automation System

It has been make valuable that smaller problems, e.g. during the setup of the station, shall not lead to the abort of any activity. Also with support of the operator, the last process step, e.g. setup of a certain device can be repeated. Furthermore, if the signal reception works, the operator has functions available to proceed with the operations to overcome secondary problems.

The Front End Processor

This chapter explains the Front End Processing component more in detail. Although all design principle and significant parts of the code are applicable to the other components of the station automation software. An overview for this system is given by figure 5 below. The applied design aspects and rules can be listed this way:
– Multi-threaded design for device drivers, scheduler, and activity control elements
– Displaying of low number high level information for the operator by graphical user interface

- Automatically generated reception reports with few, selected quality parameters for each accomplished contact.
- Automatically generated technical reports with extensive information.
- Automated measurements capabilities for the station. Routine tests can be accomplished by simply initiating of measurements by the operator

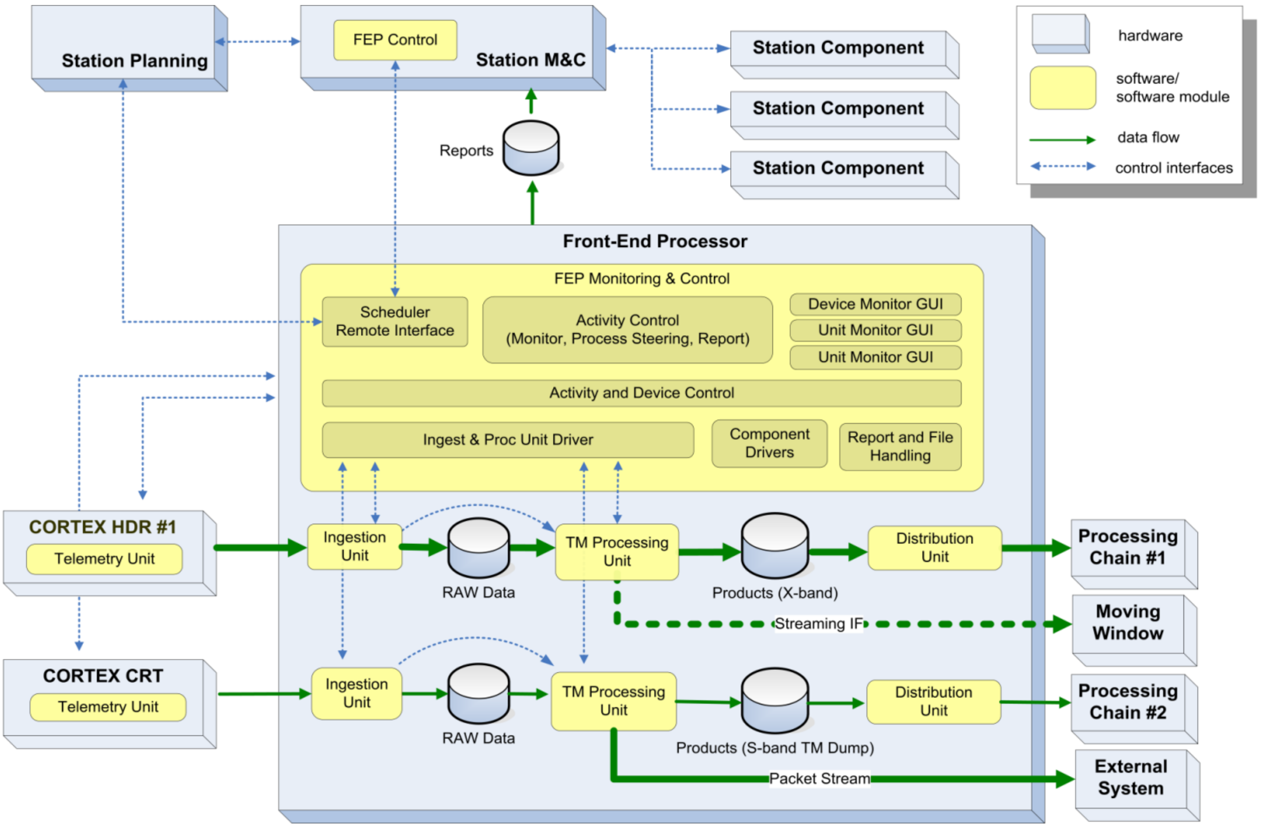

Figure 5. The Front End Processor Telemetry and Automation System

The yellow units represent separate executables, which can be maintained independently with respect to test and run-time environment. The following chapter explains the key component for the telemetry processing function of the FEP.

FEP Telemetry Processing Unit

Each FEP system controls multiple telemetry storage and processing drivers (Pair of Ingest and TmProc Unit) to handle CADU (Channel Access Data Unit) streams from CRT and HDR CORTEX systems in real-time. The embedding of the telemetry storage and processing drivers in the FEP system is shown in figure 5.

The design of the drivers considers separated processes for safe storage of incoming streams (Ingest Unit) and processing of data (TmProc Unit) to several levels of CADU or ISP (Instrument Source Packets) products. Another design aspect is the gapless observation of frame and packet streams and visualization of corrupt or missing parts of the CADU stream. The visualization is shown in figure 6.

This view allows an operator notification in case of potential risk for processing failures during the contact and an uncompromising reporting of data quality. This high level information and a comprehensive number of metadata are compiled in so-called Station Report, which can be used as a source for customer reporting. Furthermore, the TmProc unit supports various scenarios for immediate product dissemination in (near) real-time, e.g., ISP segments during the contact. For this purpose a so-called Distribution Unit has been established as well on the FEP system.

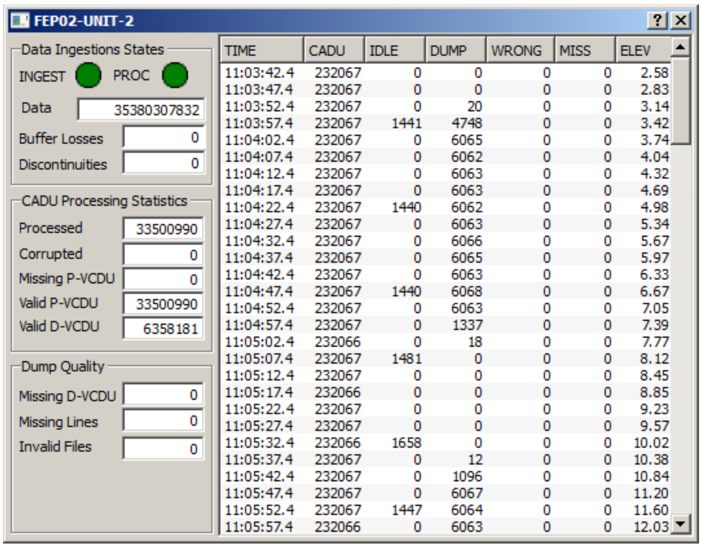

Figure 6. The FEP Telemetry Statistic Monitor View

The Distribution Unit provides an automation layer over a FDT (Fast Data Transfer) application. This application is originated the MonALISA project supported through CalTech. Regularly for specific missions, the FEP system is able to make all data products available fairly soon as the contacts finishes.

Software Life Cycle and Development Environment

Due to the high number of different requirements and installations at the one hand and the limited resources on developer power at the other hand, the software life cycle must be lean and very effective. Over the years, beside others agile concepts have been adopted to the software process which can be outlined with the following elements:

– Requirements handling based on project documentation and station story cards, mission baselines (local interfaces, quality statement, responsibilities, and engineering procedures).
– Basic principles for coding avoiding double development through domain framework, a common code base, no single ownership, and a sharing culture.
– Planning and resource allocation over several projects and station funding.
– Ticket system, e.g., MANTIS, and operations feedback handling (pass oriented reporting by operator using the station mail system.
– Repository and configuration management (Confluence, SmartGit, SVN).

- Testing support through extensive report generation, so fare delta tests provides an uncompromised and fairly complete coverage.
- Tool chain (Visual Studio 2017, C++ 0x17), Framework Qt Library 5.12, and static code analysis tool ReSharper.
- Design, concepts, infrastructure, and implementation
- Communicated rollout after operational testing and configuration management

Absolutely, it is required for that process a consequent deviation of 2-3 developer roles. The breakdown is done into roles for architecture, central functions, frame work, device driver, and very important the functional testing and rollout as well as the configuration control.

Conclusion

The present work status is accomplished in the context of the EnMAP, GRACE-FO and Sentinel-5P project. Future missions future missions like Tandem-L or Landsat-9 will take advantage of the achieved station concept concerning hardware and software.

The automated ground station is designed to provide payload operators or mission operation centers (MOC) with cost-effective services. All missions can be served on a time and cost-sharing basis with basic equipment of the station like antennas, demodulators, standardized baseband acquisition systems and dedicated equipment. This approach allows flexible operation at reduced operational costs. It was shown that with the selected design of the software all requirements can be fulfilled to the control of data receipts for most different missions. Especially the balanced combination of commercial systems and station specific automatization, M&C and telemetry processing software solutions allows the Station to maintain quickly customized solutions for operational concerns.

References

1. *Damerow H., Richter J., Schwarz J., Maass H.* Integrated Real-Time Processing of X-band Telemetry // Conference Proceedings ETC, 2010.
2. *Damerow H., Pannowitsch H.-J., Richter, J., Schwarz, J., Maass, H.* Ausbau der Multimission Bodenstation Neustrelitz für TerraSAR-X // DGLR e.V. Jahrbuch der WGLR/DGLR 2006, Band I+II; Deutscher Luft- und Raumfahrtkongress, Braunschweig, ISSN 0700-4083, 2006.
3. *Damerow H., Schwarz J.* Satellite Data Reception System at Multi-mission Ground Station // Selected Proceedings of 3rd IAA Symposium on Small Satellites for Earth Observation, Berlin (IAA-B3-0502), 2001.
4. *Damerow H., Richter J.* The Software Scope between Operators and Complex Ground Station Equipment in a Multi Mission Scenario // Conference Proceedings ETC 2000, Garmisch-Partenkirchen, 2000.

5. *Bettac H.-D., Missling K.-D., Panchenko V., Tyan T., Voroncov V.* The Project MOMS/ PRIRODA Main Results in 1996-1999 // ISPRS-Workshop Sensors and Mapping from Space, Hanover, Germany, 1999.
6. *Ebner H., Kornus W., Ohlhof T., Putz, E.* Orientation of MOMS-02/D2 and MOMS-2P/PRIRODA Imagery // ISPRS Journal of Photogrammetry and Remote Sensing (No. 54), 1999.
7. *Schneider T., Manakos I., Reinartz P., Müller R.* Anisotropy information from MOMS-02/PRIRODA stereo datasets - an additional physical parameter for land surface characterization // Joint ISPRS/EARSel Workshop "Fusion of Sensor Data, Knowledge Sources and Algorithms for Extraction and Classification of Topographic Objects", P. 97-105, Valladolid, Spain, 1999.
8. *Bettac H.-D., Mißling K.-D., Tyan T., Voroncov V.* The Ground Segment of the MOMS-2P/PRIRODA Mission. The Experience of Development, Implementation and Exploitation // 48th International Astronautical Congress, Turin, Italia. 1997.
9. *Bettac H.-D., Mißling K.-D., Maass H.* German centre for receiving and processing of PRIRODA module information // International Scientific Council Meeting for PRIRODA-mission, Russian Academy of Sciences, IRE-Moscow, 1993.