Mission Control and Data Systems (MCS)

DLR

Mission Control and Data Systems (MCS)

The Mission Control and Data Systems (MCS) Group designs, develops and supports software and software systems. Before a command can be received by the satellite, it is parameterised, tested and transmitted by our software. Telemetry data sent from the satellite is processed by our software and made available to the engineers.

In order to fulfill our mission to provide customers with innovative and reliable satellite command and data systems, we have excellent experience in advanced systems engineering methods. Since the German Space Operations Center (GSOC, 1968) was founded, the MCS Group has built and maintained more than 30 different command and ground control systems for over 20 different satellite types, including geostationary communications satellites, low-flying Earth observation satellites, scientific prototypes and for human spaceflight. In order to meet our demand for sustainable, innovative and reliable products and services, our daily work includes looking outside the box at conferences and other control centers, as well as participating in standardization boards. Due to our proximity to the operating engineers and our active participation in the operation, we ensure fast response and release times and receive direct feedback from our customers.

These systems consist mainly of software modules, which are developed and maintained by us. The portfolio of the MCS Group currently consists of 20 software tools of different complexity and size. The main tools among others are the following.

Software modules

- GECCOS
- Satmon
- ProToS
- Opsweb
- MOPS
- DORI

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2. MCS in a Box

Fig. 2-1 The accumulated expertise and all software modules in one product - MCS in a Box

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These systems consist mainly of software modules, which are developed and maintained by us. The portfolio of the MCS Group currently consists of 20 software tools of different complexity and size. Every mission requires different versions of a Monitoring and Control System. Especially new, advanced mission types, security-critical missions and prototype satellites require a high degree of expertise and flexibility in the whole process of system design. From design, implementation and acceptance to operations, the Mission Control and Data Systems Group offers all of these in one product: MCS in a Box.

3. Software Modules

3.1 GECCOS

GECCOS – the GSOC Enhanced Command- and Control System for Operating Spacecraft – represents a generic Mission Control System (MCS) for controlling spacecraft missions. It takes a central role within any ground segment to control the communication to the vehicle in space. While the ground stations perform the physical up- and downlinks of communication data – telecommand data (TC) in uplink and telemetry data (TM) in downlink – the MCS GECCOS processes the information inside these data streams: it compiles any spacecraft telecommand into a standard conformal bytecode which is routed to a connected ground station and radiated to the TC receiver of the spacecraft. In turn GECCOS also receives incoming telemetry data recorded at the ground station and processes these data for monitoring the controlled system in space.

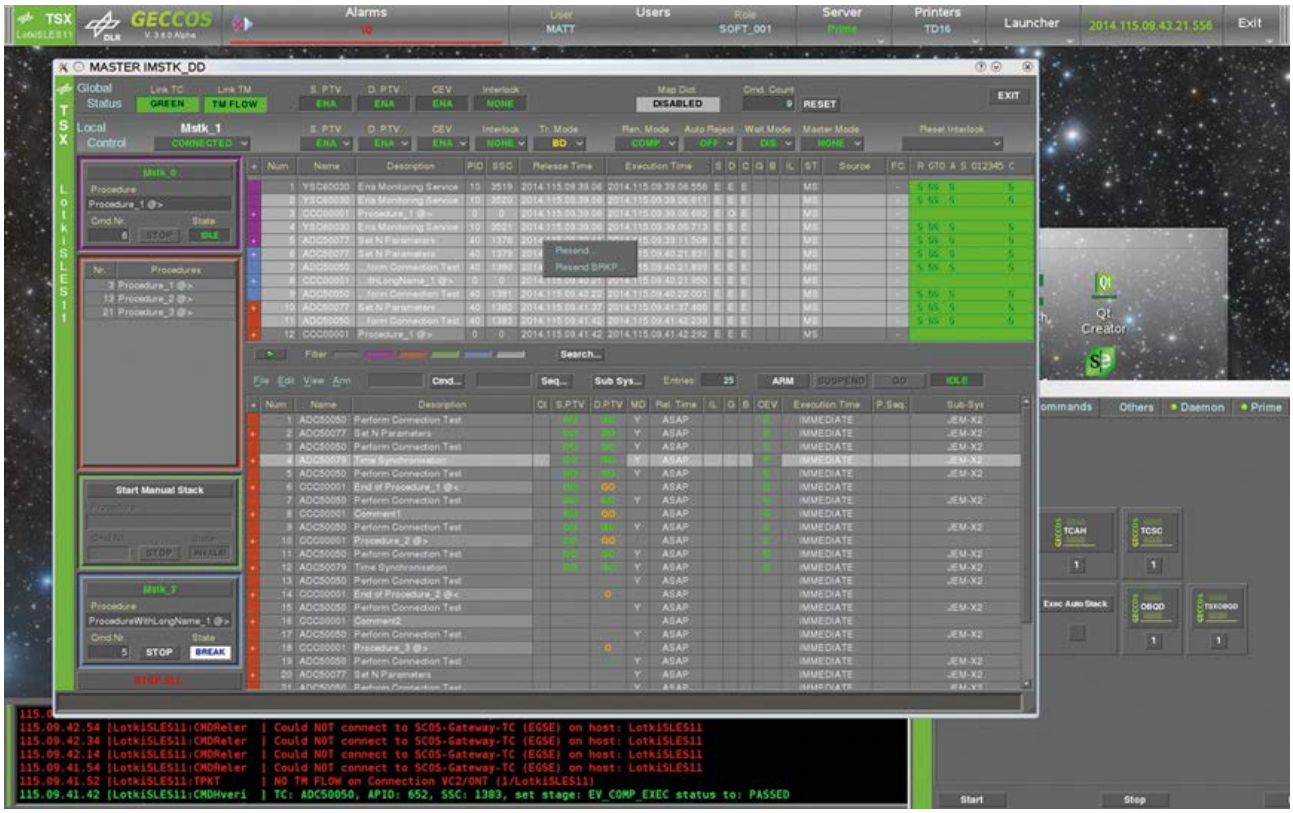

Fig. 3-1 User Interface of GECCOS

GECCOS also performs the archiving of TM and TC data, communication with ground stations, does the calculation, validation and the limit checks on parameter values, verifies and validates outgoing and incoming data and presents these information in an interactive way. GECCOS is also the suitable tool to make all this operational data accessible to other connected or offline tools within a typical mission operations system, e.g. to automation tool "PROTOS", display tool Satmon, or to external GSOC subsystems like Flight Dynamics or to the Mission Planning System. All these processing has to be done in real-time according international standards in a stable and reliable way during 24/7 hours. To fulfill the needs of modern spacecraft control centers GECCOS is continuously enhanced, not only on the user's perspective (modern graphical user interface) but also "under the hood" with a modernised architecture and automated tests.

GECCOS is based on ESA's MCS development SCOS and its story at DLR-GSOC began 1999/2000 to become the leading Multi-Mission Satellite Monitoring and Control System. The goal was to start an own development for replacing various legacy systems with one unique system suitable for current and future missions.
Following this approach, many adaptations for past, present and upcoming missions have been incorporated in addition to further enhancements and modernization approaches. So far it supports as one generic "Multi-Mission MCS" a broad set of scientific and commercial satellite platforms suitable for many missions (CHAMP, GRACE1&2,

Spacebus 3000, TerraSAR-X, TanDEM-X, PAZ, TET-1, BIROS, HAG-1, Eu:CROPIS, EDRS-A, EDRS-C, and scientific studies MICCRO, End2End, RICADOS).

Additionally, GECCOS has the capability to act as MCS as well as Central Check-out System (CCS) to support space mission projects from the beginning on. When the spacecraft manufacturer starts with assembly, integration and test (AIT phase) the spacecraft is typically under control by the Central Check-out System (CCS), similar to the MCS during the operational phase when the vehicle is handed over to the control center. The advantage of combination of CCS and MCS is not only having one system for both tasks. Much more, their combination with respect to their data handling kernels is an important paradigm, demonstrated in the context of the missions TerraSAR-X, TanDEM-X, PAZ, TET-1, BIROS and Eu:CROPIS. The significant benefit is the inherent validation of the upcoming MCS tasks during early mission phases: it ensures the compatibility of the MCS & CCS with the spacecraft database as well as with flight control procedures (FCP), both already validated during early spacecraft AIT and checkout phases and ready to work with the MCS at the control center.

System Requirements:
SIM (=Standalone Machine)

	Minimum	**Recommended (dependent from mission setup)**
Supported Operating System		SUSE LINUX ENTERPRISE SERVER
Cores	2	2
RAM	4GB	4GB
HDD incl. Mission Archive	70GB	70GB

Mission Setup with 1 Chain for 1 spacecraft consisting of
- 1 Core GECCOS TM/TC Server
- And scalable many Client machines. Typically 1 exclusive GECCOS Client exclusively for Command & Control and 1 shared for optional Monitoring User purposes

Needed:
TM/TC Core System

	Minimum	**Recommended (dependent from mission setup)**
Supported Operating System		SUSE LINUX ENTERPRISE SERVER
Cores	4	4
RAM	4GB	8GB
HDD incl. Mission Archive	70GB	120GB

Optional:
Exclusive GECCOS Client, e.g. for CMD Position

	Minimum	**Recommended (dependent from mission setup)**
Supported Operating System		SUSE LINUX ENTERPRISE SERVER
Cores	2	2
RAM	4GB	4GB
HDD	70GB	70GB

Optional:
Generic GECCOS Monitoring Client for up to 20 Users to log in

	Minimum	**Recommended (dependent from mission setup)**
Supported Operating System		SUSE LINUX ENTERPRISE SERVER
Cores	4	8
RAM	4GB	4GB-12GB
HDD	70GB	70GB

3.2 Satmon

Fig. 3-2 Monitoring satellite TM with Satmon

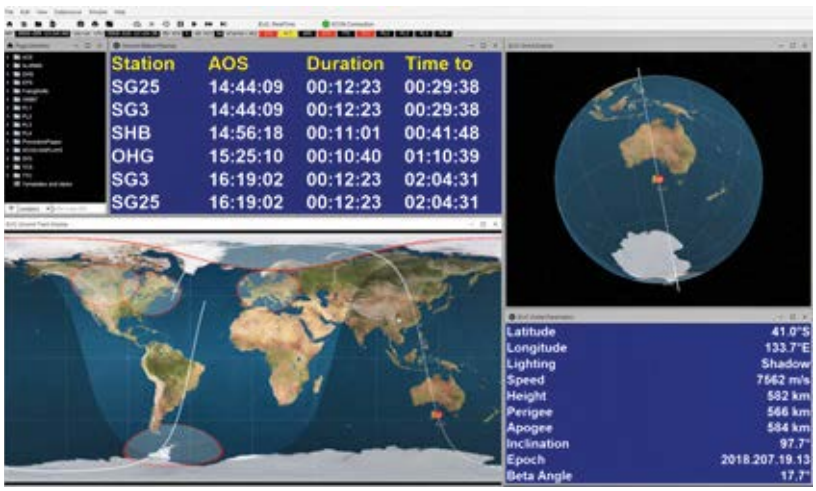

Fig. 3-3 User Interface of Satmon

Satmon is a telemetry visualisation software suite for monitoring satellites (developed by Heavens Above GmbH). Featuring a client server architecture it is able to serve users incoming telemetry in real-time as well as providing fast access to archived and offline data. The client provides many means of displaying telemetry such as lists, aggregated parameter pages, purpose built overview pages, procedure pages, interactive plots as well as reactive flow charts. As it interfaces with the core Monitoring and Control System (MCS), it also allows the visualisation of additional information such as the command history and MCS-Events. An integrated editor allows users to prepare project-specific display pages as well as customise displays for personal needs. The server features user authentication, encrypted connections, data flow control, a highly efficient telemetry database optimised for high storage density and low retrieval latency, and many admin tools for diagnostics and maintenance.

All past, current and upcoming satellite missions within GSOC utilize Satmon for various operational scenarios. During ground station contacts, satellite telemetry is visualised in real-time, enabling operators and subsystem engineers to efficiently monitor the spacecraft's health and quickly validate the successful execution of commands. For analysis of recorded offline telemetry, SatmonOffline is a powerful tool as it hosts a continuous set of comprehensive telemetry, which can be retrieved quickly even for mid and long term data. In case a project requires on call support or needs to provide telemetry to external partners, Satmon@Home is able to provide the before mentioned features and benefits with little delay via a secure internet connection.

System Requirements:
Satmon Client

Minimum Hardware Requirements:	Recommended Hardware Requirements:	Software requirements:
32 bit CPU	64 bit CPU and 64 bit OS	Java 1.8.0 or later
2 GB RAM	4 GB RAM	Inofficially compatible with OpenJDK 8

Satmon Server:

Minimum Hardware Requirements:	Software requirements:
64 bit CPU	Java 1.8.0 only
4 GB RAM	Inofficially compatible with OpenJDK 8

3.3 ProToS

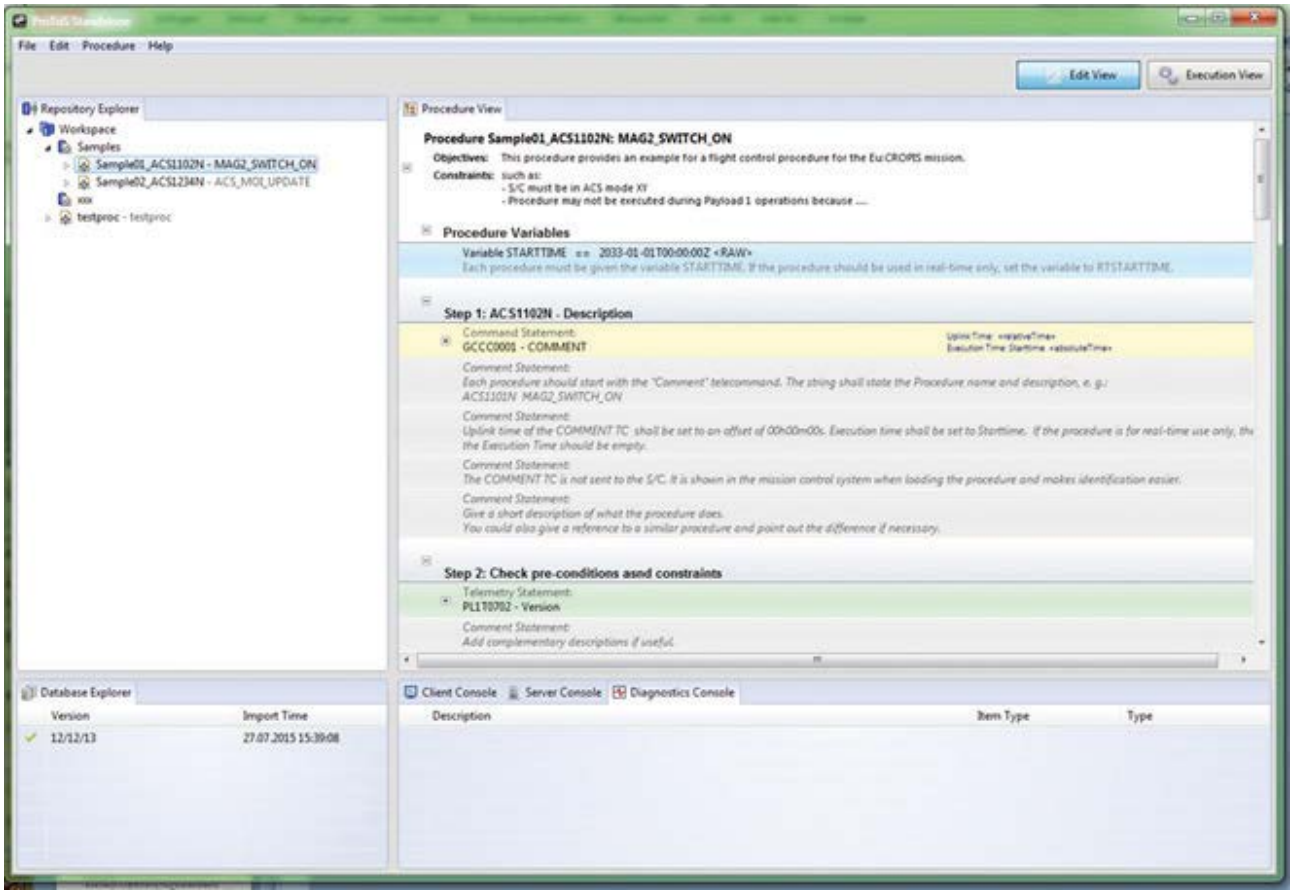

Fig. 3-4 Procedure Editor view of ProToS

ProToS is a multi-mission application package developed at German Space Operations Center (GSOC) to support the creation, instantiation, execution, and management of software-based Satellite Flight Control Procedures (FCPs) by satellite operations engineers. It utilises high-level procedures that encapsulate individual telecommands (TC) and telemetry (TM) checks in order to increase the efficiency of satellite operations in highly complex scenarios. ProToS integrates with GSOC GECCOS or ESA SCOS-2000 mission control systems (MCS) and serves as their command front end for its high-level procedures. It automates the execution of flight procedures and directs their control flow based on incoming TM.
Architecture (tbd)

System Requirements:

Client/Standalone

Operating System:	**CPU:**	**RAM:**	**Software:**
Windows	2x 2GHz	2 GB	Java8 JRE

Client/Standalone

Operating System:	**CPU:**	**RAM:**	**Software:**
Windows or Linux	2x 2GHz	4 GB	Java8 JDK (w/o automation JRE is sufficient)

3.4 OpsWeb

Fig. 3-5 User interface of OpsWeb

OpsWeb is a web-based platform for exchanging information, providing documentations and current data products. It is a main tool in controlling and optimising workflows for the task at hand in GSOCs mission operations for LEO and GEO satellites. One of the main features of OpsWeb is a dedicated issue-tracking system. It provides the framework to control the process flows based on digital signatures supported by our flexible user management. Beside other requirements, this enables us to implement our two-man rule, i.e. two flight directors have to sign any form of ticket or reports. OpsWeb is accessible from the internal network, but also from the internet. The functionality of OpsWeb sites display in the internet can be limited to meet the security requirements of the single satellite projects.

System Requirements:

The following requirements are for physical servers, the OpsWeb servers have been operated and tested in a complete virtualized environment using VMware vSphere ESXi (Version 6.5).

	Minimum	Optimal	Comment
CPU	x86-64 2x2,2GHz	latest Xeon E7, 8 cores or more	
RAM	8GB	16GB or more	
Disk	20GB	depending on number of hosted projects	OpsWeb@GSOC: 200GB
OS	Windows Server 2012	Latest Windows Server Version	
MS .net Version	4.6	Latest Version	Migration to .NET Core planned, making OpsWeb cross-plattform (Win, Linux, BSD, MacOS)
Database	MySQL Server2008R2		Migration to MariaDB planned

3.5 MOPS

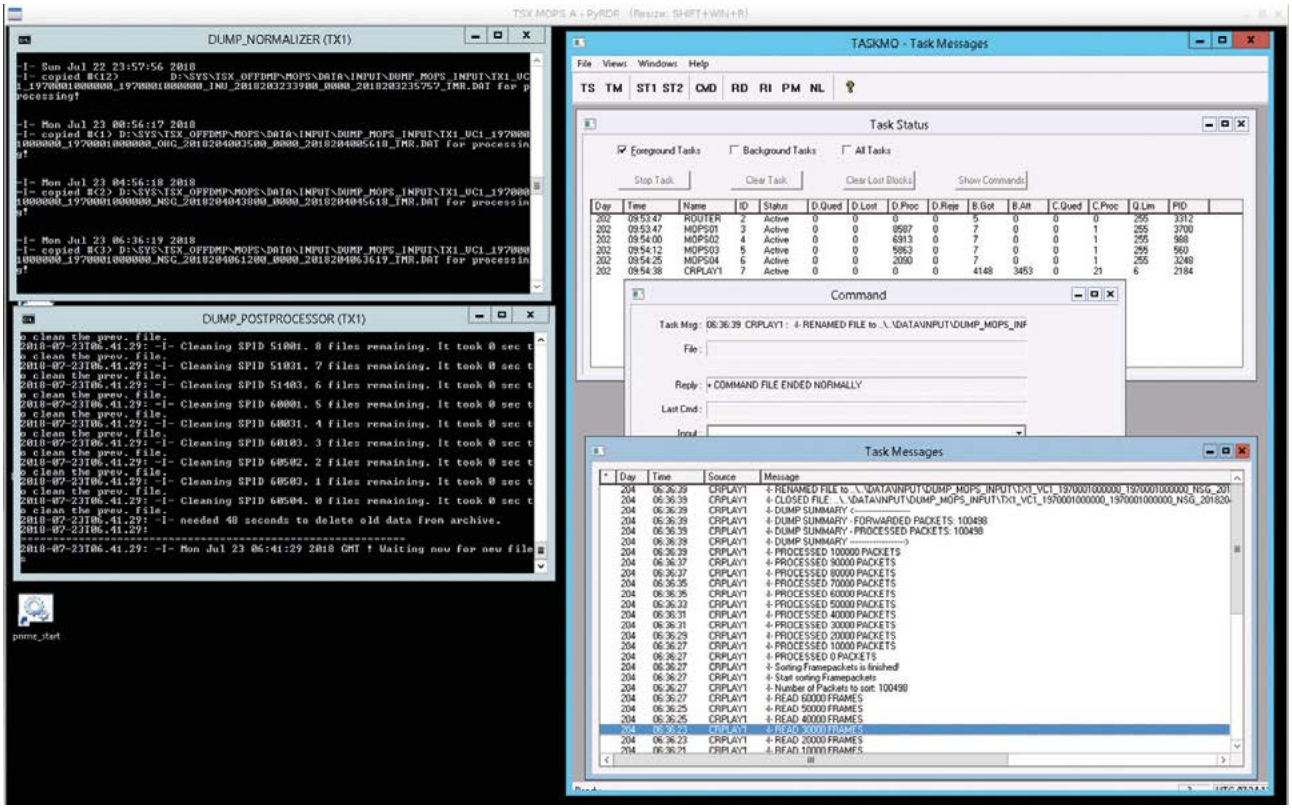

Fig. 3-6 User Interface of MOPS

MOPS is GSOC's Mission Operations Processing System. This software processes telemetry dump files from ground stations into human readable files which contain telemetry values of on-board parameters (physical and/or calculated). This information is essential for on-ground operations of spacecraft.
The processing chain consists of four main parts: a Pre-station script, the Normaliser, the main processing part and the post-processor. The pre-station script routes the incoming dump data files to the appropriate normaliser. The Normaliser converts the ground-station specific format of the dump files into a standardised telemetry file format. These files contain spacecraft telemetry frames which are unpacked by the main processing part and the contained spacecraft packets are processed. The post-processor then generates general and mission-specific output files which are distributed further for display purposes and provision to customers.
There are three kinds of processing modes at GSOC. The real time processing gets its input directly from the command chain. The dump processing computes the dump files from ground stations and distributes the results to the customers. The accumulating processing performs calculation of products which span a time interval of 24 hours.

The MOPS software is used for all LEO missions. It consists of a general multi-mission part which is installed in any case and a mission-specific part which contains the configuration for that mission. Each mission has its own product specification. The mission-specific configuration is developed for every new mission according to the product specification. An import customer is the Flight Dynamics Division of GSOC which receives attitude and position data from the MOPS for planning mission maneuvers. Other products contain extracted telemetry data and are distributed further to internal or external customers. The telemetry dump data products are also ingested into the multi-mission archive for later use.

System Requirements:

Operating System:	**CPU:**	**RAM:**
minimum Windows10 / optimum: Windows Server 2012	minimum 2-core @2GHz / optimum quad- or 8-core @2GHz	minimum 4GB / optimum 8GB

3.6 DORI

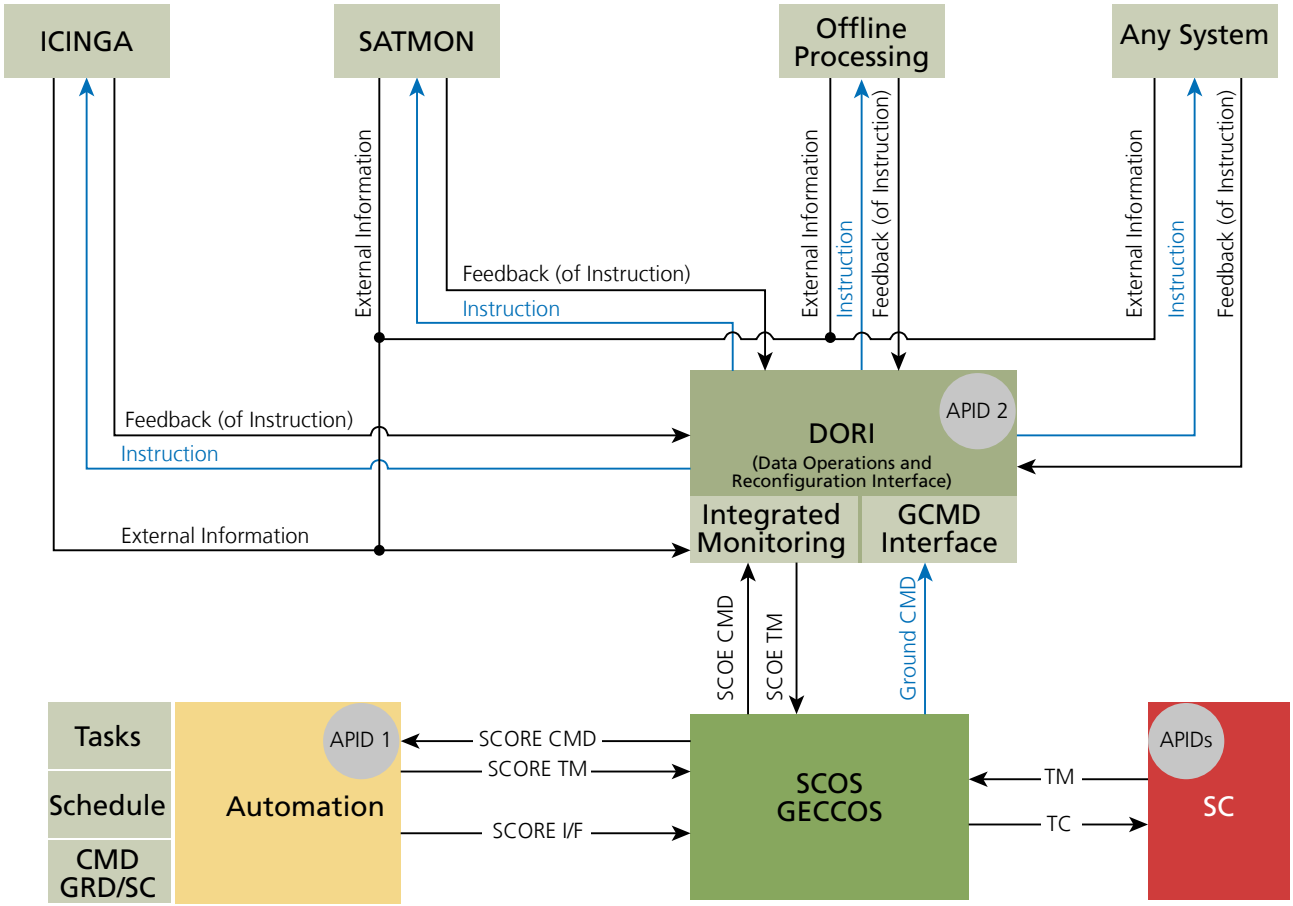

Fig. 3-7 Design of DORI

The Data Operations and Reconfiguration Interface (DORI) is a software framework to integrate monitoring and command capabilities for data systems into the existing spacecraft monitoring and control system (MCS) used at GSOC. By adding an abstraction layer, DORI introduces a homogeneous ground telemetry and telecommand interface utilising the ECSS PUS standard. Defining a "ground subsystem" in the central Mission Information Base, servers and applications can be operated similarly to subsystems onboard a satellite.
In order to support ongoing missions, there is no further change required as DORI is utilising existing GECCOS interfaces. Full compatibility with the GSOC multi-mission environment enables operators and subsystem engineers to utilise familiar tools and existing infrastructure to monitor and control a project's data system. Finally it allows commanding validated ground procedures through the MCS instead of executing many steps through manual labor saves time and reduces the probability of human error.

4. Mission Control and Data Systems Services

In order to fulfil our mission to provide customers with innovative and reliable satellite command and data systems, we have excellent experience in advanced systems engineering methods. Since the German Space Operations Center (GSOC, 1968) was founded, the MCS Group has built and maintained more than 30 different command and ground control systems for over 20 different satellite types, including geostationary communications satellites, low-flying Earth observation satellites, scientific prototypes and for human spaceflight. In order to meet our demand for sustainable, innovative and reliable products and services, our daily work includes looking outside the box at conferences and other control centres, as well as participating in standardization boards.

Our outstanding experience will help you answering all questions regarding the monitoring and control system in order to realize your ideas of a space mission.

4.1 Software Development

A characteristic feature of mission control work is that satellites are highly complex and expensive technical systems which, once in orbit, cannot be accessed directly. Only a thin cord of a radio signal connects the spacecraft with its operators. From abstract data and graphs, those on the ground have to form a picture of the state of a more or less autonomously operating system, foresee and solve problems, and finally maintain the actual "mission" of the satellite. Often only the specialist has a concept of the processes on board in mind.

The monitoring and control systems support the engineer on the ground, interpret the data, translate them into readable units, create diagrams and identify trends. Of course, the capabilities of hardware and software on the ground have grown inconceivably compared to the pioneering days of space travel, but the complexity of the on-board systems has also increased accordingly. The further development of mission control systems has to absorb the additional burden of the not arbitrarily reproducible experts by the constantly growing satellite fleets. The decision-maker on the ground must have all necessary information available quickly and reliably. Ergonomics and efficiency are the key words here.

With our experience and daily proximity to operations, we develop tailor-made software for our engineers and customers. Short ways as well as direct participation in the operations ensure short feedback paths, very short response times and optimal results in an iterative SW development. We are used to international space and development standards and processes within a control centre. Our software and software systems are written robustly and are tested in a standardized way.

4.2 Tool and System Maintenance

The portfolio of the MCS Group currently consists of 20 software tools of different complexity and size. These systems consist mainly of software modules, which are developed and maintained by us.

4.3 TM Delivery

Increasingly powerful payloads and satellite buses in orbit are increasing the amount of data to be processed, which the ground must receive. The infrastructure to be set up in order to receive, process and prepare TM is also becoming more sophisticated. We take care of all these and deliver the TM to you wherever you are. You can have access to live telemetry from your satellite or your payload wherever you are. We deliver TM files or only a subset of your telemetry in the format you want.
For further Telemetry analyses, automated anomaly detection or health and condition monitoring needs please refer to the service and products of the Mission Operations Technology team.

4.4 DataOps

The Monitoring and Control System and its associated software must run smoothly. Data and information are exchanged within the system and transported to the outside via interfaces. During critical and special operations it may be necessary to monitor the monitoring and control system continuously in real-time and to respond as fast as possible to anomalies. During routine operations a helpdesk combined with on-call may be sufficient. Our Data Operations Engineers blend skills of software and operation engineers. Their experience has been gained in more than 10 LEOPS in the last 15 years and through the MCS maintenance for more than 20 different satellite types, including geostationary communications satellites, low-flying Earth observation satellites, scientific prototypes and for human spaceflight. This and the deep knowledge of MCS systems is combined with great flexibility, speed of response and reliability. They monitor the system, analyse problems and take care for all measures within an operational environment with all standards and processes.

4.5 (Automated) Commanding

Increasingly complex tasks performed by spacecrafts require an almost unmanageable number of commands and a transmission of very long command sequences. Increasing the data throughput and the efficient organization of command chains are important tasks in a mission.

In order for you to be able to concentrate on the essential, the mission, we make sure that your commands for the bus or the payload arrive aboard. We take care of the way from the ground to the satellite. Our framework offers different command procedures for all concerns of a satellite mission. If, in addition to a fully automated approach, human interaction is required, be it for mission planning, flight dynamics or operational aspects, please refer to their services.

4.6 MCS Consulting

In more than 50 years GSOC has developed and built sophisticated monitoring and control systems for a wide range of missions and satellites. Benefit from the vast experience and in-depth knowledge of our system and software engineers and let them be on hand with help and advice for you.

4.7 MCS System Engineering

In more than 50 years GSOC has developed and built sophisticated monitoring and control systems for a wide range of missions and satellites. Benefit from the vast experience and in-depth knowledge of our system engineers and let them support you in the following tasks, among others:

- Technical coordination of all tasks within the mission control and data system
- Analysing the requirements with respect to the existing multimission systems and S/C data interfaces
- Implementing and testing the system software for the use in the project
- Testing the data interface to the satellite manufacturer's EGSE
- Preparing and validating MCS ground operations procedures
- Conducting tests at subsystem and system level for technical qualification
- Conducting interface tests involving all interface units
- Conducting simulations for operational qualification of personnel
- Monitoring of mission control and data operations
- Supervising operations of the software packages

If you are interested in system engineering services for other subsystems, i.e. Mission Planning or Flight Dynamics, please refer to the corresponding services.