THE MULTIMISSION OPERATIONS CONCEPT AT THE GERMAN SPACE OPERATIONS CENTER

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ABSTRACT

Different kinds of satellite missions require different approaches to manpower teaming, software configuration and the use of operations infrastructure. The German Space Operations Center GSOC tries to harmonize the setup of manpower and tools wherever possible, taking into account that all projects require some specific solutions.

The GSOC multimission approach uses a common team of operators for more than one mission. This makes maximum use of the available manpower and it allows preserving the operational experience while essentially reducing the costs.

To ease the work in different missions it is very important that a common user environment is offered to the different users that follows a generic approach. An additional aspect and benefit from harmonizing the user environment is a more consistent installation and a very compatible computer inventory.

This paper gives detailed insight into this approach and the operations tools that are used within GSOC.

1. INTRODUCTION

The German Space Operations Center is the national control center for commercial, governmental and scientific satellites and the Columbus module of the International Space Station.

At any time several missions are operated or are under preparation. Most control centers set up dedicated operations teams and mission control systems which are optimally adapted to the mission requirements.

This approach is in many cases not economic. Considering long launch delays for example are a common fact in space business, a dedicated team cannot easily be used for other tasks in the mean time. Another example is the operations of a single Low Earth Orbit (LEO) satellite that requires three passes in the morning and three in the evening.

Also often encountered is the situation that each project has a different spacecraft manufacturer providing a different monitor and control system. The control center ends up with maintaining the knowledge and training for several different systems.

Figure 1: The GSOC main building in Oberpfaffenhofen near Munich. It houses offices, control rooms and space simulation facilities.

2. MULTIMISSION OPERATIONS AT GSOC

GSOC is going a different way. In all projects we strive to build a similar system that follows an “in-house-policy”. This allows that all members of the operations team can be trained on all the satellites. In that way GSOC performs the routine operations of the scientific satellites BIRD, CHAMP and the twins GRACE 1 & 2 from a single control room involving one single team. Currently also the satellite missions TerraSAR-X and TanDEM-X are under preparation of being included into the multimission environment once they are in the routine phases.

For some projects we could not entirely deploy GSOC’s project independent common multimission system mainly due to contractual obligations where GSOC had to follow as a subcontractor the requirement of the customer. In that case software like the graphical user interface for the spacecraft telemetry (SATMON) is installed and offered to GSOC’s operations personnel as an addition to the customer provided systems. Like this we still manage to provide the operations team with a common system interface.

2.1. The Multimission Control Room

Satellites in routine phase are considered part of multi-mission at GSOC. Their operations are performed from a single control room, 5 x 12 meters in size. 12 positions are currently available plus additional workspace for offline tasks (Figure 2).

Figure 2: Panoramic view of the Multimission Control Room at GSOC. GRACE 1&2 operations are preformed from the two rows of consoles in the background at the left side, CHAMP consoles are in the middle part, and BIRD consoles are in the background to the right.

Each project has one position for commanding (CMD), one for the Mission Operations System Manager (MOS) to execute supervisory functions and several subsystem engineer consoles (SUB). For science data monitoring (SCI), the GRACE project also uses a number of additional laptops, which are connected to the real-time data streams. The offline position (OFL) provides history data processing for all missions. The multi-mission support personnel use this console for monitoring the de-packing processes and to prepare and conduct file transfers. Mission related offline data are available at each console.

Figure 3: A typical console workplace with three monitors on two computers. Also visible is the Voice intercom touchscreen.

A typical control room position consists of two TM display screens connected to one PC, a voice intercom station, and an additional office PC (**Figure 3**).

The office PC provides the electronic workspace for the operations personnel. Standard applications, project specific programs and offline analysis tools are available. The PC is also connected to the in-house web system, which provides general and project specific information (e.g. flight procedures, project documentation, sequence of events, shift plans, on-call schedule and flight dynamics products). In contrast to these standard consoles, a command position is also connected to the project command system. Only this position is allowed and able to transmit commands to the satellite.

BIRD and GRACE have more consoles available than are actually needed for routine operations. Thereby, the allocation of additional workspace is deliberately kept flexible in order to be able to respond to sudden changes in the project requirements (e.g. extended test campaigns). For example, a BIRD console can be changed into a GRACE position within a few mouse clicks.

3. COMMONALITY

3.1. A Common Team

The multimission operations team is supplied as a whole by a contractor company typically under a 3 years contract. The multimission team consists of a team of 10-12 persons that work in a shift scheme and are present on site 24 hours a day, 7 days a week with at least one person. In times of higher work-load a second person is added. Their tasks cover the preparation of the passes according to requests by mission planning, the execution during the pass (sending the timeline commands and monitoring the telemetry) as well as logging and reporting after the pass.

If new personnel are introduced, they are trained on the job with the living satellite, accompanied by an experienced operator for several weeks before being allowed to perform operations alone. In that way the experience and knowledge is optimally preserved. As a rather large pool of people is available, adapting the shift plan for vacations and sick-leave poses no serious difficulty. Training on a flying satellite is also more demanding and is very rewarding. This aspect is extremely important especially for young team members.

Regarding the preservation of knowledge, it is important to note that staff from the multi-mission team also gives support to projects in the system development phase. In that way the experience gained in day-to-day operations of existing satellites contributes directly to the build-up of new projects.

The operation of different spacecraft is organized in three levels:
Level 1) the 24 hours / 365 days a year shift teams. At GSOC there a three Level 1 teams involved. The multimission operator team deals with the real-time operations, i.e.

a) preparing all commands for an upcoming 10-minutes pass of a satellite over one ground station.
b) sending the prepared commands to the spacecraft during the pass and checking in parallel the real-time housekeeping telemetry
c) analyzing the download house-keeping telemetry data that has been recorded on board of the satellite in the past hours.

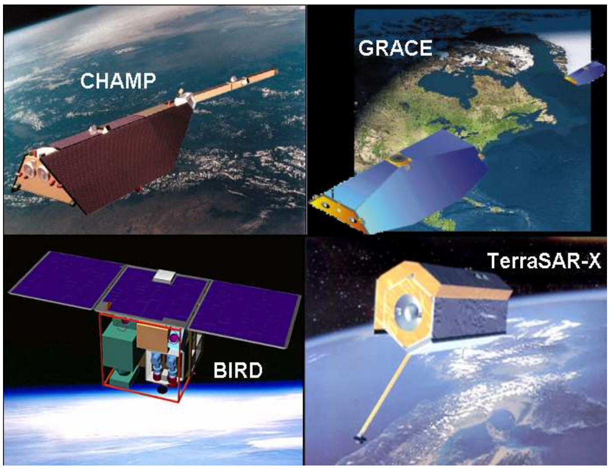


Figure 4: Views of the spacecraft CHAMP, GRACE 1&2 and BIRD that are already flying in multimission operations at GSOC. TerraSAR-X is due for launch in June 2007 and will be included into multimission after the commissioning.

The ground operations Level 1 system team configures and monitors the ground data system in the control center and ensures the proper data routing between control center and ground stations. GSOC uses mainly its ground station at the DLR Weilheim and Neustrelitz. Also during the routine phase there is always the need to augment the number of contacts with the satellite by using ground stations of other partner agencies.

The third Level 1 shift team at the Weilheim ground station prepares and configures the ground station antennas for all passes over Weilheim.

Level 2) the spacecraft operations engineers have prepared the procedures for the mission operations in the years before the launch. In the Launch and Early Orbit Phase of the relevant mission these subsystem operations engineers conducted on console the mission operations bringing the satellites after some weeks into stable conditions. In the routine these engineers can step back to an off-line position. In principle during normal office hours they oversee the midterm planning of the planned operations and analyze the housekeeping data of the relevant subsystems. They perform long-term trends on the subsystem behavior. On a rotation basis they are also available on-call for the multimission operations. This means up to 4 weeks in a 3-month period they can be contacted at any time if a situation arises where a second opinion is needed or in case of anomalies corrective actions have to be discussed.

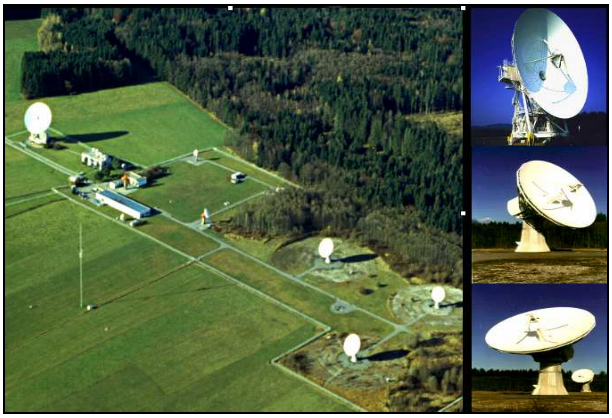


Figure 5: The ground station complex of GSOC at Weilheim. The main multimission antennas are two 15 m S-Band dishes.

At home, the subsystem engineers even have access to telemetry data, which greatly improves communication with the on-site staff by telephone.

The engineers on the other hand are not needed to work 100% for the missions that have reached the routine phase. At GSOC they are already involved in the preparation for new satellites projects, usually of a similar nature as the ones in routine operation. The gives the benefit that operational experience gained by doing the operations can be often transferred as “lessons learned” into the new projects. This combination substantially increases the motivation of the operations engineers since they have already the new project as a mission task. The danger of loosing experts to other projects or organizations/companies is thus minimized.

Level 3) especially in the first year and in the years approaching the end of the envisaged lifetime the probability of observing spacecraft anomalies is an issue. Therefore the intensive knowledge of the spacecraft manufacturers regarding spacecraft hardware and software is to a certain extent secured for the project by placing a support contract.

One of the main steps on the way to multi-mission capability is the commonality of the systems for the users across the different projects. The spacecraft operators shall be able to concentrate on the peculiarities of the satellites and not on those of the various monitoring and control systems.

Using a common M&C system is already a big step forward to cost-savings fulfilling the multi-mission and the project specific requirements which have to be implemented additionally.

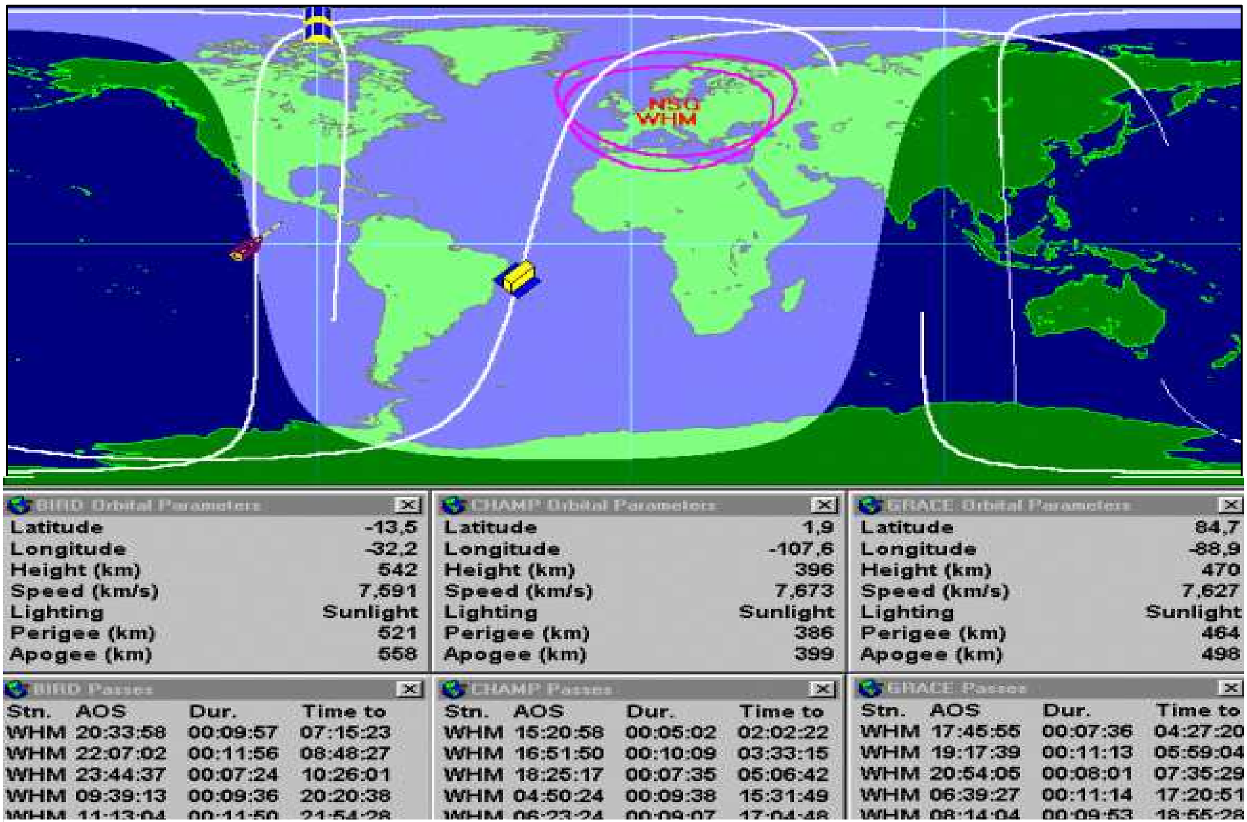


Figure 6 The Multimission Orbit Display gives the team a quick look at the current orbit position and upcoming ground contacts. The data is propagated from regularly updated orbit elements.

There might be cases where the operations staff alone can not completely analyze the status of the satellite, a subsystem or a hardware unit or an onboard software module.

3.2. A Common Environment

Normally every satellite monitoring and control application brings along its own integrated display system. These are usually fully sufficient for operations under “standard” conditions putting no specific requirements to flexibility and scalability.

3.3. A Common Platform

As already explained an important aspect of multimission operations is the use of common user interfaces and applications.

This leads directly to the next step to also use the same computer platform for all operations. GSOC has made a consolidation and streamlining of the operating systems in use. The basis is now to use Microsoft Windows on PCs in the control rooms and LINUX on the TMTC servers. The use of SCOS client for the command operations position however breaks this rule.

Possibilities around this situation are currently under investigation. Using virtual machines is one of the options considered and is already being used.

Currently techniques like virtualization or deployment systems are investigated. They allow to completely freeing a console's function from the machine hardware. The selected installation can be started from the network or from a mass storage device (HDD or DVD).

The ultimate goals are to

a) be able to freely move and copy positions among all the control rooms and to
b) upgrade and replace the hardware independently of the installation

This makes testing and configuration control easier. It also allows to easily relocate operations of a satellite or the complete multimission environment to another control room without interruption of operations.

In the year 2000 GSOC started to look for a replacement of its legacy systems and decided to switch to SCOS 2000. An important goal was the harmonization with the systems at ESOC and to promote this standard in industry.

The legacy system was a combination of FRAMTEC (TM processing), CCS (TC) and GSM/EDS (display). This system was developed during the 1980s. The TM and the TC components are still in use for the ongoing projects BIRD and GRACE.

Project CHAMP was selected as a test bed for the adaptation and phase-in. The old system is still in use as a fallback system in parallel to the new system. The new project TerraSAR-X which is due for launch in 2007 is the first mission at GSOC that is fully dependent on SCOS 2000.

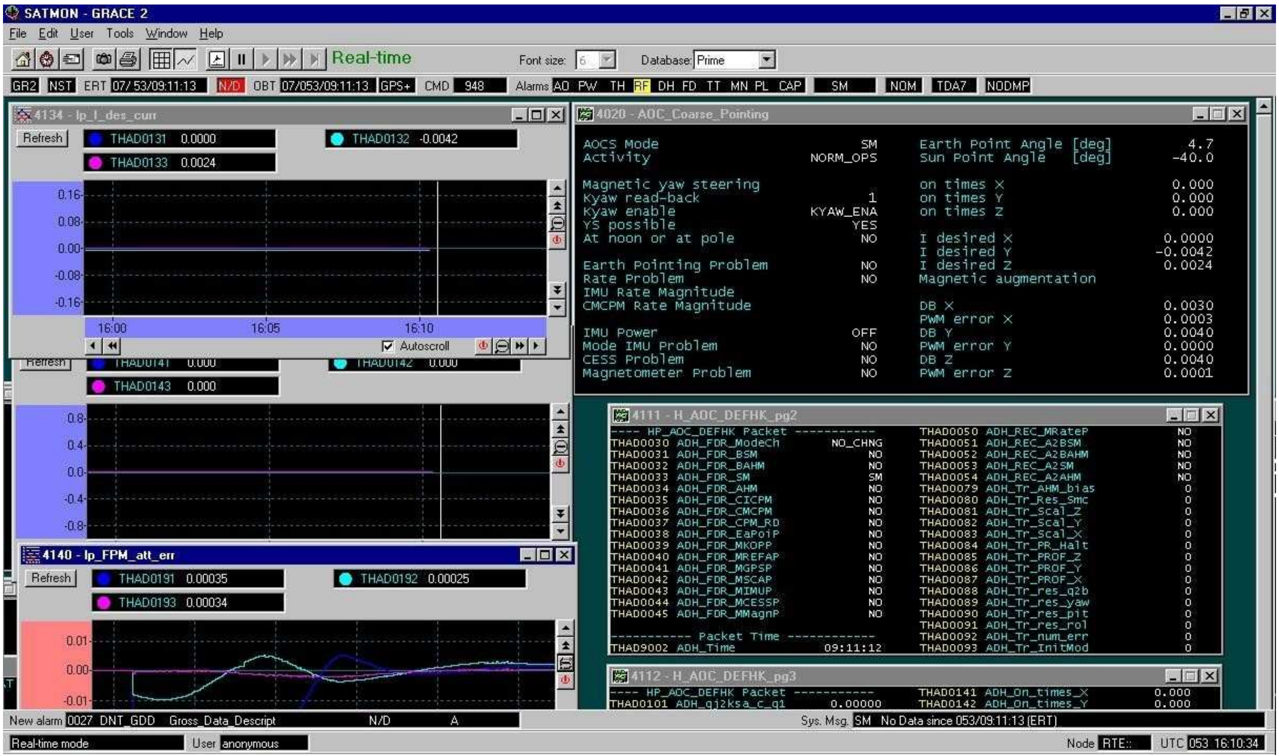


Figure 7: Sample screenshot of SATMON. It shows the page-types line-plot and alphanumeric. Any number of pages can be open at the same time. Also visible are the header and footer line that show the most important information independently of opened display windows.

4. APPLICATIONS

4.1. SCOS 2000

SCOS 2000 is a Monitoring and Control System developed and maintained by the European Space Operations Center ESOC in Darmstadt. It is freely available for use by other european space agencies.

GSOC is supported in the adaptation of SCOS by external contractor companies that have long experience in SCOS development at GSOC, ESOC and other control centers.

Currently SCOS is used in version 3.1 patch 5, but has received a lot of enhancements and bug-fixes that will eventually be included in the official releases. The move to higher versions is envisaged to be done in 2009 to version 5.1.

For the TerraSAR-X mission SCOS was also used as a check-out system (CCS) during the integration at the Astrium facilities and at the final check-out at the launch site in Baikonur. For CCS operations also many enhancements were integrated. At CCS and in the Mission Control System (MCS) the same version is used and maintained.

4.2. Display System

GSOC has chosen SATMON as its main display system. The SATMON software is developed by Heavens-Above, a small contractor company. GSOC is the main customer and has largely specified the software requirements and the design. The system is however available for other customers and is for example also used at EUMETSAT in Darmstadt, Germany.

SATMON has undergone some design modifications in the past but the developments are now converging. The system is now divided into four major components (**Figure 8**):

SATMON Gateway, which is the interface to the telemetry processor application. Examples for established interfaces are EPOCH 2000, SCOS 2000 and the Columbus MCS.

SATMON Server, which keeps the list of parameters, collects the updating telemetry values in calibrated format and, if available, in binary format, and receives the status and alarm flags. The server keeps an archive of all telemetry values. The Server establishes a connection to the Gateway.

The third component is **SATMON Display**. In its user multi-window frame the user can open a random number of pages that can be of different sizes and can contain an arbitrary number of telemetry parameters (**Figure 7**). The main page types are alphanumeric for text and parameter fields in a user defined arrangement and plot pages. The plot pages can contain several plot panes that are stacked vertically and that share the x- or time-axis. Each plot pane can display several telemetry parameters with different colours. For each plotted parameter the value is also displayed as alphanumeric text.

The fourth component is **SQUAT**. This is a command queue tool that interfaces with the telecommand processor. It allows managing several manual command stacks in parallel. The commands in these queues are pre-validated for consistency against the spacecraft database. No TC processing tasks are handled in SQUAT. The SQUAT queues can be displayed in SATMON client and are thus visible from all telemetry monitoring positions.

Since the year 2000 SATMON became the only GSOC display system used in all projects. Currently those projects using a previous version of SATMON are being upgraded. After that only one code base has to be maintained and the last minor differences in usage are removed.

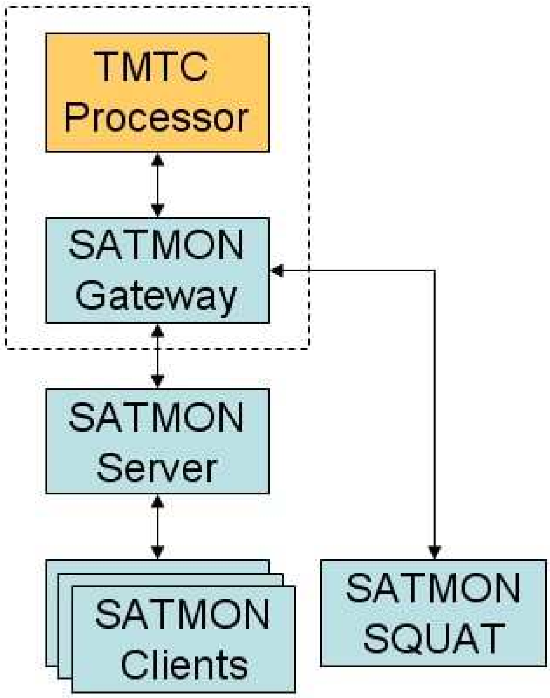


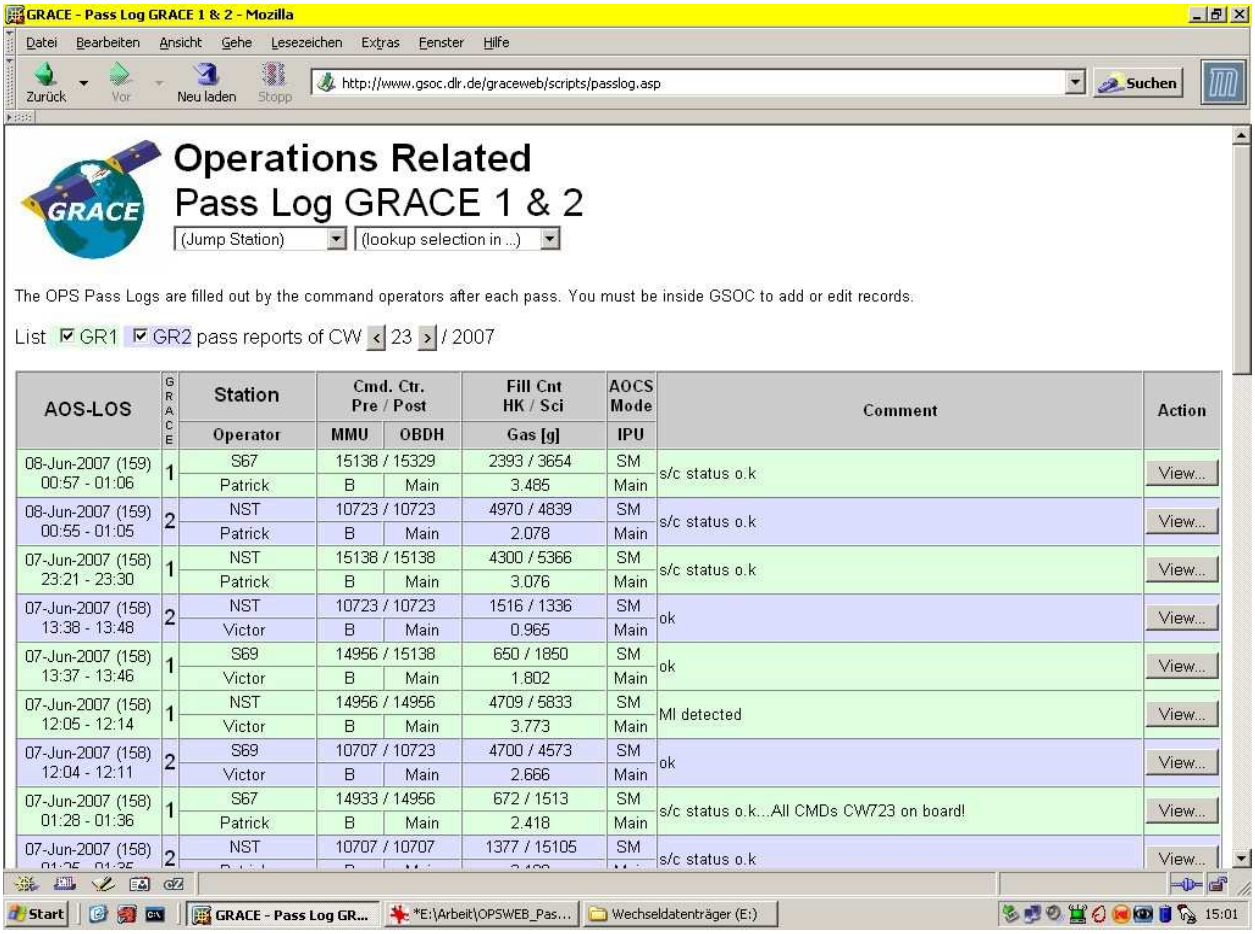
Figure 8: The four SATMON components connected to a TMTGC processing application.

4.3. Operations Intranet (OPSWEB)

OPSWEB is an intranet that is used in all satellite projects. It is designed not only to provide static documents but also to allow access to the spacecraft databases. An important task is the creation and handling of logs and reports. These can be created and viewed directly in the web application. Logs are created by the command operators and also the flight director. Examples for reports are anomaly reports and recommendations.

The web is used throughout mission preparation, LEOP, commissioning and routine phases. It is accessible from the control rooms, the networking central, the offices and partially also over the internet. The US-German GRACE mission keeps the US partners at JPL informed via the OPSWEB. DLR's operations engineers for CHAMP and BIRD are able to check the mission status from home when need arises or on a regular basis when being on-call.

components offered by SCOS 2000 will be the basis for future development.



AOS-LOS	GRACE	Station Operator	Cmd. Ctr. Pre / Post MMU	 OBDH	Fill Cnt HK / Sci Gas [g]	AOCS Mode IPU	Comment	Action
08-Jun-2007 (159) 00:57 - 01:06	1	S67 Patrick	15138 / 15329 B	 Main	2393 / 3654 3.485	SM Main	s/c status o.k	View...
08-Jun-2007 (159) 00:55 - 01:05	2	NST Patrick	10723 / 10723 B	 Main	4970 / 4839 2.078	SM Main	s/c status o.k	View...
07-Jun-2007 (158) 23:21 - 23:30	1	NST Patrick	15138 / 15138 B	 Main	4300 / 5366 3.076	SM Main	s/c status o.k	View...
07-Jun-2007 (158) 13:38 - 13:48	2	NST Victor	10723 / 10723 B	 Main	1516 / 1336 0.965	SM Main	ok	View...
07-Jun-2007 (158) 13:37 - 13:46	1	S69 Victor	14956 / 15138 B	 Main	650 / 1850 1.802	SM Main	ok	View...
07-Jun-2007 (158) 12:05 - 12:14	1	NST Victor	14956 / 14956 B	 Main	4709 / 5833 3.773	SM Main	MI detected	View...
07-Jun-2007 (158) 12:04 - 12:11	2	S69 Victor	10707 / 10723 B	 Main	4700 / 4573 2.666	SM Main	ok	View...
07-Jun-2007 (158) 01:28 - 01:36	1	S67 Patrick	14933 / 14956 B	 Main	672 / 1513 2.418	SM Main	s/c status o.k...All CMDs CW723 on board!	View...
07-Jun-2007 (158)	2	NST	10707 / 10707		1377 / 15105	SM	s/c status o.k	View...

Figure 9: The GRACE pass log. An overview of the most recent entries is shown here. A Click opens the view to more detail.

The reporting applications are inherited from older projects and are gradually improved. They are bridging the differences between different underlying systems. For example the spacecraft database viewer was used with the old GSOC telemetry processor system as well as with the current SCOS mission database. The use of scripting for the intranet applications allows easy adaptation of the applications arising from the different project requirements.

4.4. Offline Processing

Currently the only non-standardized component at GSOC is the offline processing system. Each project developed its own tools and processors only in some parts using standard components. An initiative is underway at GSOC to set up an integrated offline processing and analysis system that offers a large variety of processing and distribution options. The experiences of the TerraSAR-X mission with the offline

5. Conclusion

Since the year 2000 GSOC successfully operates four satellites in multimission-mode. Most of the projects in the next years will be added to the system. Coming from a rather diverse system architecture and dedicated operations teams, projects in routine phase are now using the same system in one control room with one team.

This strategy has resulted in considerable savings especially over the full mission time which is often a lot longer than originally anticipated. Also in the mission preparation phase the efforts are actually reduced, because only configuration and minor adaptations have to be done, given that spacecraft are adhering to common TMTC standards like CCSDS.