SpaceOps-2023, ID #374

OPSWEB – A comprehensive management tool for mission operations

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Abstract

The OpsWeb tool is one of the core applications at the German Space Operation Center (GSOC) when it comes to organizing and supporting multiple satellite missions, presenting quick access to operational data.

For the in-house satellite operations, OpsWeb is used to grant permissions for planned and ongoing actions, for reporting, hosting documentation, and providing access to spacecraft and ground segment data. OpsWeb serves as a central hub for easy access to information of other control room software. It is a web based, highly available software solution providing fast and easy access for flight managers and subsystem engineers from the internal networks but also from the internet. In the past years it has been constantly advanced and adopted to new requirements for LEO and GEO missions.

The multi-mission OpsWeb provides several reporting tools such as problem reports, pass logs, shift handovers and operational diaries. OpsWeb hosts a large number of operational documents either in a flexible document browser, or special displays for imported flight and ground procedures from PROTOS (a procedure tool developed by GSOC) [1] or MOIS.

OpsWeb also enables the subsystem engineers to search the SCOS TMTC database for distinct packages and parameters. Furthermore, the latest telemetry products for LEO missions are hosted by the OpsWeb and can be displayed e.g. labelled by the G/S passes in which they were received.

OpsWeb allows the user to gather information from other software tools such as telemetry displays, long-term analysis and visualization tools.

Recently, the Operation Support Tools for the Columbus Control Center for the ISS have been integrated into the OpsWeb framework running on dedicated servers, so as to meet the security requirements imposed by the project.

OpsWeb is using state-of-the-art web technologies. The streamlined web front-end is designed to minimize the workload for clients with a limited connection bandwidth. It is developed with plain Typescript to avoid unnecessary software dependencies granting long-term maintainability. The backend uses PostgreSQL as a database engine. GraphQL and REST APIs provide the interface between front and backend. Access control is handled by an Open ID connect service simplifying the integration into the pre-existing security infrastructure and adding multiple authentication factors when required. Furthermore, OpsWeb has a well-established backup and fail-over concept with automated live switch-overs in case one of the OpsWeb components goes offline.

With future updates, the hosts for the OpsWeb server applications will become platform independent, running on any kind of Linux, Windows or MacOS system.

OpsWeb is one of the cornerstones of mission operations at GSOC. It has been used during several LEOPs and supported numerous projects in countless hours of routine operations. It is the main tool to coordinate operations, organize daily tasks, provide quick access to essential information and provide interfaces to other tools in the control room and beyond. The whole OpsWeb framework is easy to maintain and highly adaptable to customer requirements. Moreover, the OpsWeb software is ready to be tailored for the requirements of control centres outside of DLR.

Keywords: DLR, Operations, Software development, Control room, process management, information system

1. Introduction

In over 50 years the German Space Operations Center (GSOC) has supported LEOPs and routine operations of numerous space missions, unmanned and manned. GSOC is part of the "Deutsches Zentrum für Luft- und Raumfahrt" (DLR). With this profound knowledge and space mission experience, a set of core utilities for mission operations has been developed at GSOC.

For over two decades **OpsWeb** is one of those core applications. Historically, coordinating and managing tasks in the ground and space segment involved a lot of paper work. Especially the process of signing all activities and reports filled meters of shelves with file folders. So, in 1999 a loose collection of web pages with flight dynamics data, reports and tickets was established. Here different types of data, reports and activities were stored for the ground and space segment for different missions (for example GRACE, CHAMP). One of the main tasks of this system was to allow digital signatures for each ticket and report. The first steps in the direction of today's OpsWeb were reported during the SpaceOPS 2002 in Houston, Texas [1].

Over the years this collection of web pages was unified under one platform which was called OpsWeb. It has been refurbished several times, new features were added, and the scope of this tool was extended.

Today, OpsWeb is much more than a simple ticket system. It is the central information and workflow hub for control room activities. Tasks are coordinated for the sub-system engineers, operators and flight directors. Reports and summaries are provided directly. Rapid and comprehensive access to important information and data are granted, such as flight and ground operation procedures (FOPs and GOPs), excerpts from the S/C TMTC database, processed telemetry products, important documents and many more. Part of this information is also available outside of GSOC for on-call personal, external partners or employees working in home office.

Moreover, OpsWeb provides an interface to other core applications such as the mission planning system or the telemetry archive.

It should, however, be stressed that OpsWeb's main purpose is to provide quick access to information for control room and other daily operations. Therefore, only the most important documents and only current TM products are made available. This puts OpsWeb in contrast to other dedicated in-house tools that are designed to store and manage documents and data over the long term.

OpsWeb has been used for numerous (GSOC) missions, such as: BIRD, the Firebird mission (TET, BIROS), TerraSAR-X and TanDEM-X, PAZ LEOP, HAG1 LEOP, CubeL, EDRS-A/C, TDP, EnMAP, GRACE, GRACE-FO, Eu:CROPIS, EnMAP and lately COLUMBUS/ISS. Also, other German sovereign missions are utilizing the OpsWeb tool.

2. General requirements on the system

The general requirements on the OpsWeb system include aspects as security, availability of service, integration of data products from and interfaces to other GSOC tools. Most projects at GSOC are hosted on the multi-mission OpsWeb (MUM). There are separate installations for the COLUMBUS project (see chapter 5.) and national missions. If not stated otherwise all explanations in this paper will refer to the MUM-OpsWeb.

2.1 Security

The MUM-OpsWeb system consists of several servers. The two redundant main servers are hosted in the De-Militarized Zone (DMZ) reachable from the internet. They host backend, including the Postgres database. It can be defined which (web-) sites and data should be presented internally or externally (to GSOC). Particularly sensitive data can be stored on dedicated servers only available from inside GSOC so that, by design, even on a compromised external server these data are secure from any adversary. While the old authentication system used data stored locally in the backend, we are shifting towards a new authentication scheme. Here we use the OpenID Connect service[1] (OIDC). The authentication requests are not handled by the backend, but passed to the OIDC server which issues an access token for the frontend that it can then use to fetch and post data to the backend API. The access token is valid only for a limited time, but is renewed automatically by the front-end before expiry. This delegation of user authentication to a dedicated OIDC server has multiple advantages: one can choose which authenticators to use. Currently it is LDAP (could be Active Directory as well), but additional auth factors (2nd or even 3rd one) are possible (e.g. FreeOTP, Smartcard, Tokes etc.). One can decide to use LDAP only as an authenticator and to manage the user roles locally. The user roles can also be imported from the remote LDAP tree. All user logons can be monitored for unusual behavior.

[1] https://openid.net/connect/

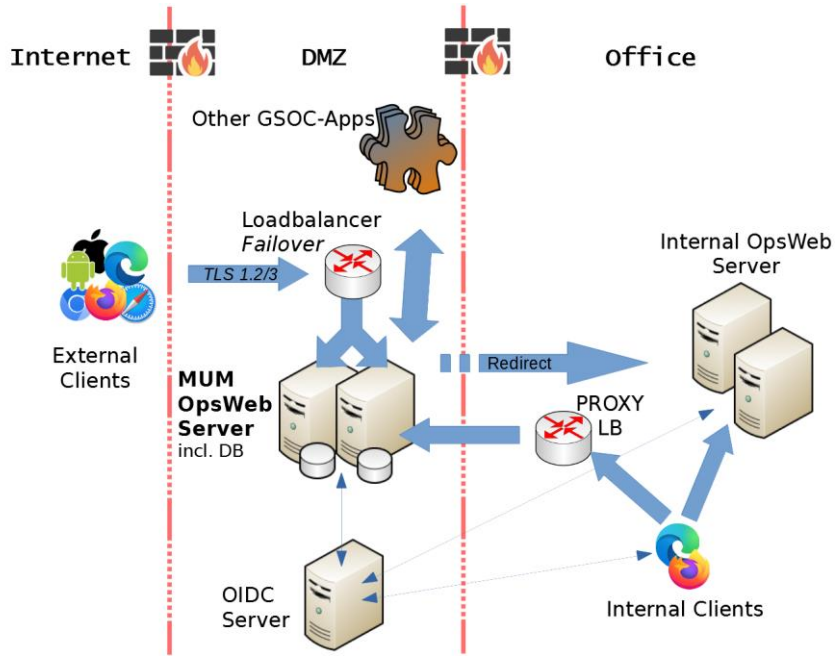

Fig. 1 – Infrastructure of Multi-mission OpsWeb servers

2.2 Availability

To ensure the highest availability our servers are designed redundantly. If the service becomes unavailable on the active server it is switched automatically to the hot-standby server. The service outage during the fail-over normally takes only a few seconds.

Some geo-stationary mission (GEO)projects have very specific additional tools, such as EDRS for the link planning interface between GSOC and MOC[2]. Tools like this are isolated on a dedicated additional machine from the main servers so that even under heavy load it is guaranteed that other projects are not affected by (very unlikely) performance issues.

The frontend is optimized for usage on desktop computers as well as for mobile devices.

2.3 Integration

Most of the data is supplied as files to the OpsWeb system. This can be e.g. telemetry products, flight/ground procedures (FOPs/GOPs), schedule files for the next ground station passes, user uploads, etc. Most of these files use the FTP based in-house file transfer daemon which also provides malware checks. The OpsWeb system can import FOPs/GOPs from MOIS or PROTOS. The TMTC database importer supports SCOS and GECCOS files.

We have a prototype of a GraphQL based interface to SatMon[3] for the display of TM parameters directly in OpsWeb updating in real-time.

2.4 Req. for LEO and GEO missions

While we cover the topic of OpsWeb usage for human space flight in section 5. There are particular requirements for satellite missions. In general, there are single and multi-satellite missions. For a single satellite, one project instance is created on the OpsWeb system. For multi-satellite mission there is the option to create one instance for each satellite, but with the possibility to clone and reference tickets between the individual instances (e.g. Tandem-X and TerraSAR-X). The other option is to use the multi-satellite support for the core tickets and forms (e.g. GRACE-FO).

The functionality of the OpsWeb system reflects the different operation concepts for low-earth-orbit (LEO) and geo-stationary mission (GEO).

LEO missions have only a few contacts per day between the spacecraft and the ground station. These contacts, more frequently called "passes", last normally no longer than 10 minutes. Within the passes, tele-

[2] Mission Operation Center by Airbus DS

[3] SatMon is a telemetry display system used at GSOC [1]

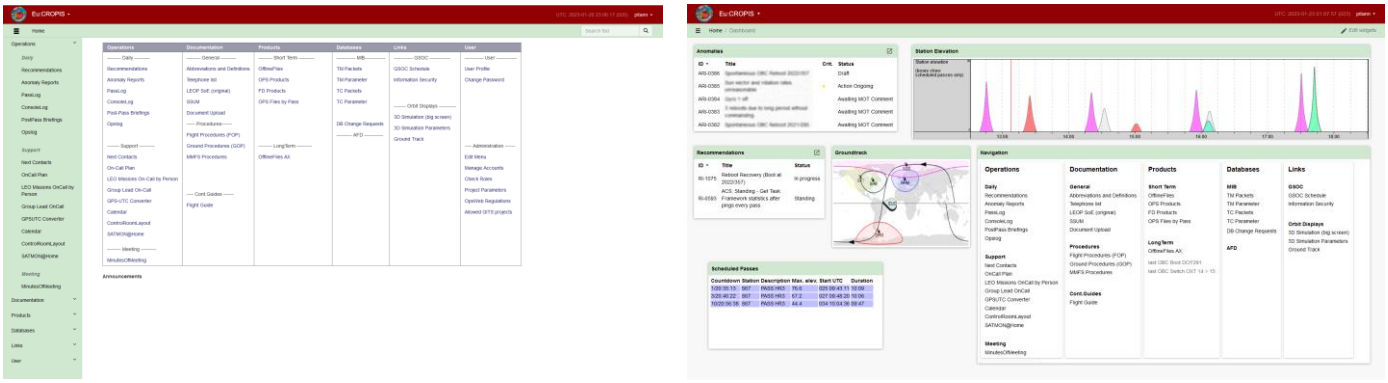

Fig. 2 - left the old mainpage of OpsWeb, right the Dashboard prototype

commands (TCs) are uplinked to the S/C, received live telemetry is monitored and records of the housekeeping telemetry in between the passes (so called "offline-dumps") are transferred to the G/S and to GSOC immediately afterwards. The passes for GSOC missions are planned by our GDS office. The schedule of G/S passes is imported into the OpsWeb system after creation and this information is used in multiple forms. After contact, the received offline-dumps from the G/S are processed by GSOC offline telemetry processor (MOPS). The available products are displayed in OpsWeb and can be checked by the engineers in the control room.

GEO missions have 24/7 contact to their satellites. Therefore, a schedule for dedicated G/S contacts are not needed. More important for the current running missions are the payload schedule. The OpsWeb offers a timeline based on the TimOnWeb which shows all payload activities and especially for the EDRS mission the planned inter-satellite links. The OpsWeb also make it possible to schedule maintenance, constraints and other outages to avoid a link request on the customer side or planning errors in the Mission Planning Software. After the link execution the operational software creates reports which will be automatically analyzed from the OpsWeb. The most important information of these reports will be provided on a dedicated page to the users. This overview makes it easy to identify issues during link executions and check the completeness of the data.

3. General infrastructure and architecture

The current MUM OpsWeb system is installed on virtual machines (VMs) running on ESXI servers by VMWare with Windows Server 2019. All servers have a hot redundancy (see chapter 2.3) utilizing local service probes and an additional load balancer which trigger server failover. The webserver only allows TLS 1.2 and 1.3 connections for security reasons. Fig. 1 shows the general server and network layout.

The frontend was developed using Microsoft's ASP.NET and plain Typescript with a minimum set of dependencies on other libraries. In the near future the code will be rewritten in .NET-Core to break the dependency on Windows and to make the OpsWeb platform independent. The backend uses MS-SQL as database. Gradually the backend is being migrated to PostgreSQL due to license costs and platform independency. The exchange between frontend and backend is handled by GraphQL and REST API requests. As described in section 2.1 OIDC is used for user authentication.

OpsWeb is currently develop for the latest stable and ESR releases of Firefox and MS-Edge. It also supports up-to-date Chrome-based browser and Safari.

Beside the operational servers, there are two test servers using the load balancer and the same fail-over mechanisms as the production system. Here, bug-fixes and new features can be validated before being deployed to the production servers.

4. Features and components

The OpsWeb system was designed for the best user experience. The whole framework uses responsive design features, so that all forms and pages are adopted to the user's screen size. Navigation elements are also rearranged for small screen devices such as mobile phones and tablets.

Traditionally the main landing page is a collection of links to all elements for a pre-selected project. All these links are also present as side bar navigation elements. A prototype of a dash board and free-to-place widgets already exist and will replace the traditional landing page in future versions (both are shown in Fig. 2). Most overviews of

the different types of tickets and reports are organized in columns. The user can configure which columns to display (as an example the Recommendation Overview is presented in Fig. 3). Such user preferences are stored in the browser storage of the local device and persist even after a current session has ended. In this way different pre-settings can be used for example by the same user on the office computer and the mobile phone.

Access to the different forms are managed by distinct user roles. These roles can be defined in the local database or imported from LDAP. A list of all reports and different kind of tickets is shown in Table …

Using the example of Recommendations (RI), the signature process will be illustrated: first, a normal user can submit a recommendation. Afterwards, OpsWeb waits for a signature of a user with the team-lead role (typically a flight director)[4]. The recommendation then enters the "Awaiting execution" state. If an operator or a subsystem engineer has completed the task, an execution note is added and the RI is closed.

For events such as newly created reports, e-mail notifications can be generated to all users who need to sign the reports. Minutes of meetings can also be distributed via e-mail to a group of recipients after finalization.

A list of the most important report and ticket types is presented in Table 1.

One central task of OpsWeb is displaying offline TM products. The raw dump files received from the ground station are available, as well as the already processed data packages (call offline-products), such as On-board Event History (OBEH), TC Acknowledge History (TCAH), TC-Logs etc. The corresponding files are displayed in a folder-like structure, in which files are sorted chronologically. A presentation with all files for each pass is also available. Offline files are deleted after 30 days unless otherwise configured.

For free text editing, a rich text editor was implemented. It is already implemented for COLUMBUS (see Section 5) and will be available for the MUM-OpsWeb soon.

The mission planning system at GSOC generates many products for operations. Some of them are directly displayed on the OpsWeb. They are imported as timeline views similar to Gantt charts with extensions, by the so called TimOnWeb in-house plugin (short for Timeline-On-Web). In this way, shift plans for on-call personal can be displayed with additional information, e.g. contact data. During LEOPs the Sequence of Events (SoE) is displayed, including manoeuvres, on-ground and on-board activities. Also, the schedule for G/S contacts, called "Next Contacts" uses TimOnWeb (presented in Fig. 4). The fly-overs of the S/C are displayed as a function of time and visibility-over-horizon per G/S. The actual scheduled passes are marked in this plot with additional information as tool-tips. Moreover, a ground-track map and a table showing the countdowns to upcoming passes are displayed.

We also have a prototype available to display selected real-time TM parameter in the dashboard widgets based on a GraphQL interface to SatMon [2].

In addition to the different types of reports and formatted data displays users have the possibility to upload documents in various file formats. These documents can be organized in folder structures. Inline views of images and pdf files are also available.

Also, an interactive 3D attitude and orbit display has been implemented for selected missions (shown in Fig. 5).

Table 1 - List of major report and ticket types in OpsWeb

Name	Abbreviation	LEO/GEO	Description
Recommendation	RI	Both (GEO LEOPs only)	All tasks during operations are requested, documented and approved here, scheduled G/S passes can be selected for task to be performed during a contact. Recommendations are the fastest and most controlled way to deviate from flight procedures or the nominal sequence of events. They are utilized also for ground segment activities with direct involvement of GSOC personal. A recommendation can refer to a flight procedure or parts or modifications of it or they can introduce entirely new actions. Team members can act based on finalized recommendations that were signed by the flight director.

[4] it is possible that also two or three team leads have to sign it (two-man-rule), depending how the signature process is configured for the particular project.

Anomaly Report	ARI	Both	Problems and anomalies in the space and ground segment are tracked by these reports. Anomaly Reports are used to track all unexpected circumstances observed on the spacecraft during operations. These reports allow to rapidly document these observations, to rally expert support and reach a flight team consensus about a situation. A report is finalized when it carries the signatures of the responsible team leads. A Recommendation may then be initiated based upon the Anomaly Report.
Minutes of Meeting	MoM	Both	Protocols from meetings can be stored and distributed via e-mail. They are quickly available to all members even for external partners.
Observation Report	OR	Both	They were used during the EUTELSAT project era and are still in use in some of the projects. Mainly they were used during the preparations phase and include observations on the spacecraft database and the ground installation.
Pass log		LEO	All activities during a G/S pass are reported, such as all FOPs uploaded to the S/C, received dump files, basic S/C parameters as reported by live TM, etc.
Console Log		LEO	Used during LEOP when one shift hands over the particular subsystem station in the control room to the next shift. Previous activities, problems and tasks ahead are being reported.
Shift hand over		GEO	In GEO they are used at hand over time to brief the next shift personnel about missions and ground system status and major events. It also contains the execution of mandatory checks during the previous shift. There are project specific fields and checkboxes to speed filling the form sheets. Usage is mandatory. The fields are purposely not automatically pre-filled. This enforces that the user is confronted with every single item and action is required.
Post Pass Briefing		Both	An extended version of the pass log form, used during LEOPs, with detailed information for each sub system.
OPSLOG		Both	In the OPSLOG all other reports, tickets, events created in OpsWeb are shown, also customized entries can be added. In GEO missions the OPSLOG is the central reporting tool for all team members, especially the flight director. All activities (space and ground system) are logged there including the execution of flight procedures, their start time, stop time and critical events. Together with the ARIs, the OPSLOG is the first place to search for earlier occurrences of observations. The entries can be tagged with the subsystem affected or customized keywords. This makes it easier to filter systematically.
Wiki			A simple wiki implementation, with tree-like hierarchy for the pages, access to certain pages can be controlled with user roles.
Project Calendar		GEO	This is intensively used by all GEO projects. It contains entries about system usage times (e.g. simulation or test times), team availabilities, planned events and activities
Mission specific tools (separate Server)		GEO	We use special script pages to display operational items like upcoming optical links in EDRS. These lists are automatically updated in near-real time from mission data. These lists can be annotated by the team and extracts are used for the monthly reporting to the customer. There are numerous other tools that display live ops information and allow interaction from users. Like "Payload Basic Request Tool", "Constraints Tool", "Maintenance Slots" etc.

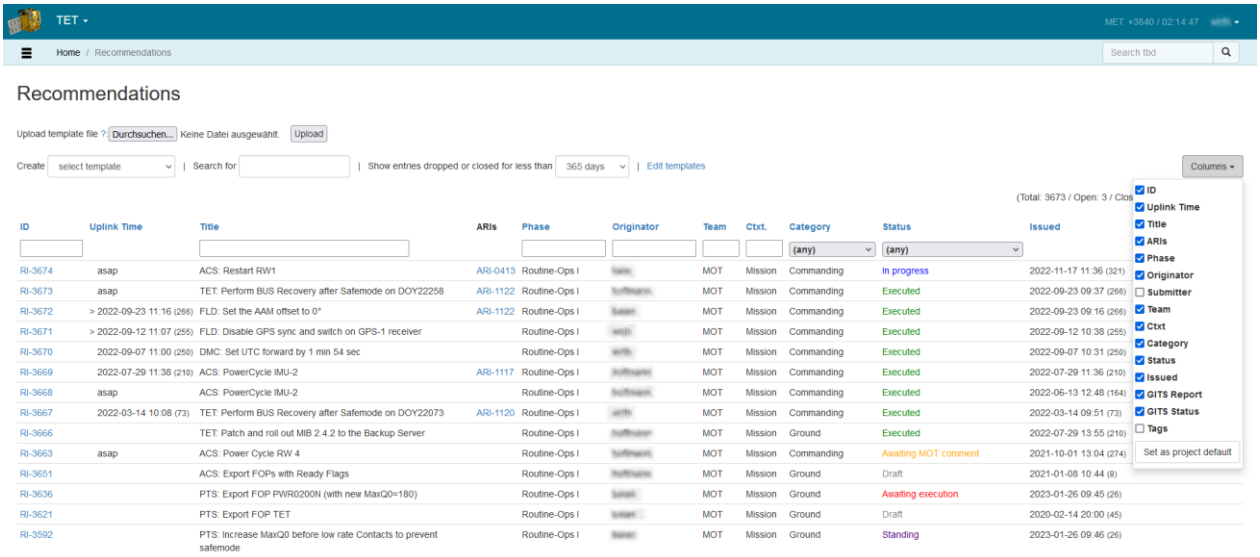

Fig. 3 - A typical overview page for our RI tickets

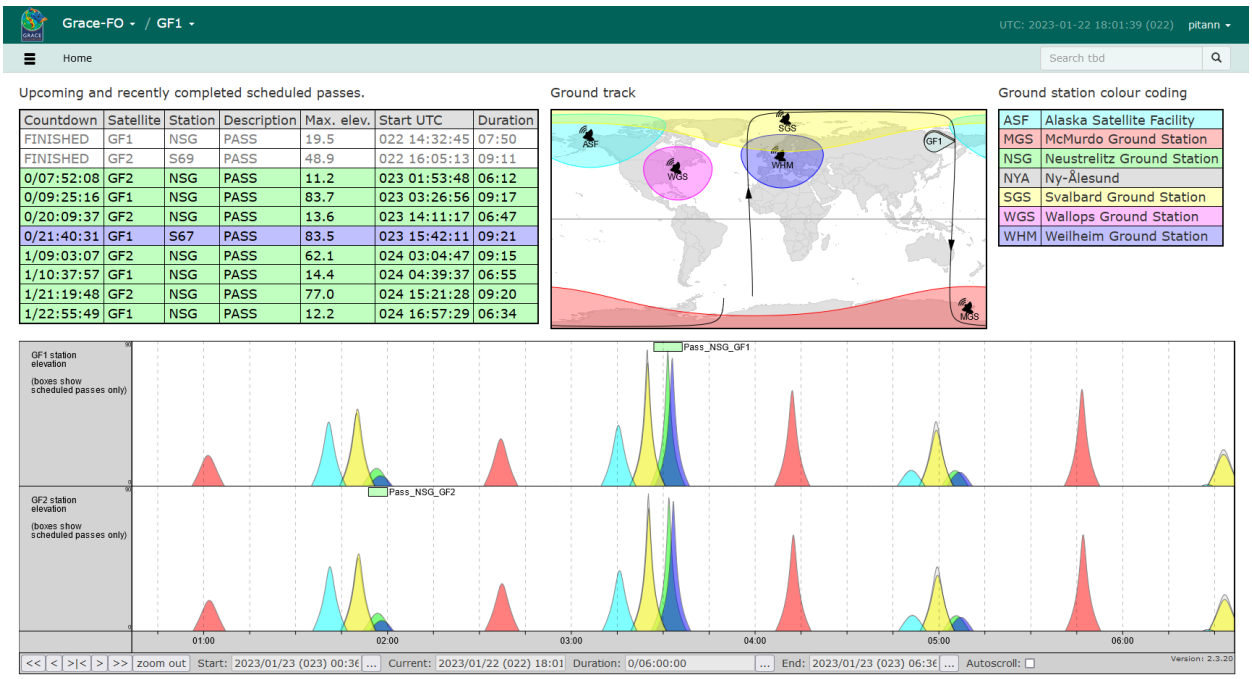

Fig. 4 - Real time display for the next G/S contacts, including countdown table, ground track and elevation mask

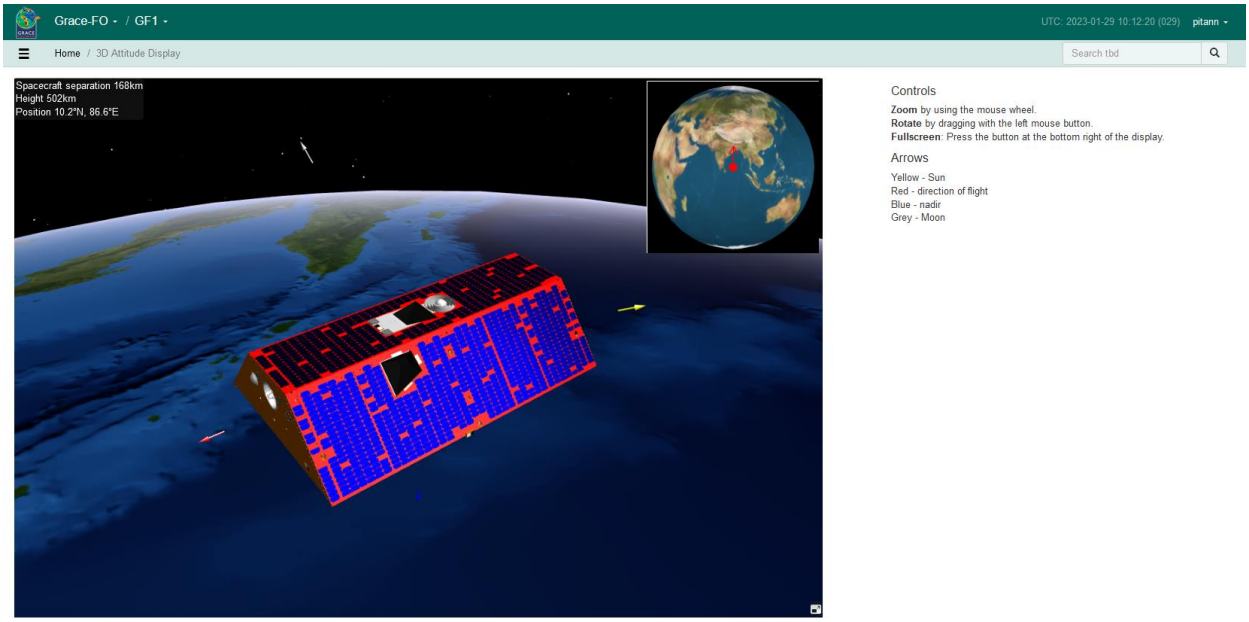

Fig. 5 - Interactive 3D Attitude and Orbit Display for one of the Grace-FO satellites

5. COLUMBUS migration to OpsWeb

In contrast to the MUM OpsWeb forms, the Columbus project uses its own set of tools. After the legacy implementation of the Operations Support Tools (COL-OST) was no longer up-to-date, it was time to modernize them. They were developed by an external partner as a heterogeneous collection of tools with different front- and backends. Therefore, it was decided that a single framework with a common database is needed to keep the software extendable and easy to maintain. To further reduce future maintenance costs, the pre-existing OpsWeb framework was selected to host the whole COL-OST functionality.

The old functionality was analysed and a set of new requirements was collected. Prototypes were then developed and deployed in a test project on the MUM-OpsWeb servers. Only non-sensitive data were imported to the test project. The developer team and responsible COL-CC engineers were thus able to validate and improve the prototypes even when working in home office - a huge advantage in times of the Corona pandemic. After the prototypes were finalized they were migrated to a server infrastructure newly set up in the COLOMBUS network segment. Currently, the new system is undergoing several simulations and test campaigns by the flight and ground control teams before it is made operational. Even if initial development costs had to be accepted, these will be quickly amortized due to the lower maintenance costs. Especially since the codebase is now the same as for the MUM OpsWeb system and the server infrastructure is similar.

6. Future developments and Conclusion

With OpsWeb, we presented a web-based platform for controlling workflows on-ground and on-board for GSOCs mission operations for LEO and GEO satellites. It is widely used in the control room to exchange information, provide documentations and current data products.

Over the past decades, OpsWeb has contributed to the successful execution of several LEOPs and the smooth routine operation of numerous missions. The OpsWeb system is permanently improved, new features are added and existing ones are extended based on new mission parameters.

In particular, the migration of the legacy COL-OST tools to the OpsWeb frame work is a prime example of how custom requirements can be met and a cost-efficient, maintainable environment created.

Future work includes moving the code framework to .NET Core to make OpsWeb servers cross-platform compatible (Windows, Linux, BSD, MacOS). Several improvements are planned, such as making the signature workflow more flexible and adjustable.

Several external partners have already expressed interest in using the OpsWeb software. In close contact with future customers, we are developing a licensing model and improving the possibility for further software tailoring according to customer requirements. Different support levels are conceivable, from simple provision of the software to the deployment and maintenance of a new system as a whole.

Acknowledgements

The authors like to thank Michael Schimdhuber for his comments and for the historical insights on the early days of OpsWeb.

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