18th International Conference on Space Operations, Montreal, Canada, 26 - 30 May 2025.

Automated Ground Segment Operations with EnMAP - Challenges and Experiences from the first Years in Orbit

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Abstract

The low Earth orbit satellite EnMAP (Environmental Mapping and Analysis Program) was launched in 2022 and is operated by the German Space Operations Center (GSOC) as part of the German Aerospace Center (DLR). The goal of the mission is to monitor and characterize the Earth's environment by using a hyperspectral camera system. During the planning and implementation of the EnMAP ground segment, a high degree of automation was targeted to reduce the effort of manual and repetitive activities as much as possible. This allows the operations team to focus on non-nominal operational activities as well as the support of other missions. Additionally, it reduces the impact of unforeseen challenges, such as the COVID-19 pandemic and its restrictions, where only a reduced number of personnel is available.

While numerous tools for the automation of spacecraft operations exist with a large diversity of programming languages and graphical interfaces, the baseline for the EnMAP ground segment was the usage of the Test and Operations Procedure Environment interface (TOPE), which is part of the SCOS-2000 monitoring and control system. By utilizing already available software, the level of complexity a new tool adds to the system, along with the effort of maintaining and monitoring it, can be kept minimal. This approach, which was originally developed for the TerraSAR-X/TanDEM-X missions, has proven to be reliable for supporting satellites on an active mission as well as satellites in the end-of-life phase, where ideally no manual interaction is required anymore. With the experience gained from these missions, a further step towards the goal of a fully automated operational concept was taken. This includes not only pure satellite commanding activities but also other aspects of ground activities, such as satellite monitoring, controlling data processing, distributing data and information between user groups and managing additional mission specific tools. It also shifts the main task of the spacecraft command operator from manual commanding and execution of support tasks, such as the preparation of operational products, to monitoring the automation system and supporting contingencies as well as recovery activities in case needed. Due to the multi-mission concept of GSOC, where only one command operator is supporting multiple missions and satellites outside of regular office hours, the usability and possibility of manual intervention play an important role in the development of automated processes.

This paper will provide an overview of the different stages of automation during the preparation and first years of EnMAP in orbit. This includes the implementation based on the information provided by the interface specifications of the satellite and other parts of the ground segment, as well as the adaptation due to experiences acquired after the launch and the identification of discrepancies. In addition, the effort in operating and maintaining the automation system will be discussed and the achieved performance, together with the ability to recover from non-nominal states, will be evaluated. Finally, the resulting limitations of this automation approach are discussed, and several lessons learned are presented, which will serve as input for the automation system design of upcoming missions operated by GSOC.
Keywords: EnMAP, Satellite Operations, Automation

Acronyms/Abbreviations

Antenna Aspect Angle (AAA)
Acquisition of Signal (AOS)
Environmental Mapping and Analysis Program (EnMAP)
Deutsches Zentrum für Luft- und Raumfahrt (DLR) – German Aerospace Center
External Command Handler (ECH)
GSOC Enhanced Command & Control System (GECCOS)

German Space Operations Center (GSOC)
Low Earth Orbit (LEO)
Loss of Signal (LOS)
Multimission Offline Processing System (MOPS)
Mission Timeline (MTL)
Procedure Tool Suite (ProToS)
Satellite Monitoring Tool (SATMON)
Satellite Control and Operation System 2000 (SCOS-2000)
System Report File (SRF)
Saved Stack File (SSF)
Tool Command Language (TCL)
Telecommand (TC)
Telemetry (TM)
Test and Operations Procedure Environment (TOPE)

1. Introduction

The EnMAP (Environmental Mapping and Analysis Program) mission consists of a scientific satellite equipped with a hyperspectral imager for Earth observations. The mass of the satellite is 916 kg and it was manufactured by the OHB System AG in Germany for an operational lifetime of 5 years. It was launched in 2022 from Florida, USA with a Falcon 9 rocket by SpaceX and deployed into a sun synchronous polar orbit with an altitude of ~650 km, an inclination of 98° and a local time of descending node (LTAN) of 11h. During nominal operations, four to six S-Band contacts via the Weilheim ground station and two to four X-Band contacts via the Neustrelitz ground station are scheduled per day. Additionally, two combined S- and X-Band contacts via the Inuvik ground station are scheduled per day to increase the usable downlink budget for payload operations. The hyperspectral instrument consists of a dual-spectrometer with a total of 242 spectral channels. The near visible and near infrared spectrometer covers the spectral range from 418.2 to 993.0 nm with an average spectral sampling of 6.4 nm. The short-wave infrared spectrometer covers the spectral range from 902.2 to 2445.5 nm with an average spectral sampling rate of 10 nm [1]. The goal of the mission is the investigation of globally interconnected processes, the study of the diverse effects of human interventions on ecosystems and the support of the natural resources' management [2]. The project management of the mission is carried out at the German Space Agency at DLR, whereas the scientific lead is located at the German Research Centre for Geosciences (GeoForschungsZentrum - GFZ). The ground segment activities are shared between three DLR institutes. The German Remote Sensing Data Center (DFD) and Remote Sensing Technology Institute (IMF) are responsible for processing, management and archiving of payload data. The German Space Operations Center (GSOC) is responsible for the satellite operations. This paper focuses on the automated ground segment operations performed at GSOC.

In the following sections, an overview of the automation system and the usage for the EnMAP project will be provided. Section 2 will outline the history and structure of the automation system. Section 3 will focus on the modifications and challenges required for adapting the existing automation for the EnMAP project. The last section will provide an overview of the performance and limitations based on the first three years of usage.

2. Origin and structure of the automation system

Origin of the automation system

The automation system was first introduced within the TerraSAR-X/TanDEM-X mission. It utilizes the TOPE engine as part of the GSOC Enhanced Command & Control System (GECCOS). GECCOS is a GSOC fork of the generic mission control system software SCOS-2000 Release 3.1 developed at ESA and is used in the multimission environment [3]. TOPE is connected to the External Interface (EXIF) of GECCOS which allows for Special Check-Out Equipment (SCOE) applications to connect as clients and execute control and monitoring functionalities with the included scripting environment. The TOPE test language is based on the TCL programming language with supplementary extensions to enhance the functionalities of the interface and to provide commands required for spacecraft checkout and integration purposes [4]. During the Assembly Integration and Test of TanDEM-X, the TOPE engine was used by the satellite manufacturer Airbus Defence and Space for extensive system tests. At the moment, the missions TerraSAR-X/TanDEM-X, EnMAP, BIROS and Eu:CROPIS are being operated by the automation system, the latter two being in their End-of-Life phase.

Structure of the automation system

The automation system is divided into a generic framework and a project specific part. With this implementation, the framework can be shared between different satellite projects without any modification. If updates are performed within the code of the framework, such as fixing a bug or the implementation of new features, no changes in the project specific routines are required. The software is versioned and maintained with git while the rollout of new updates is performed via the RPM Package Manager (RPM) on the GECCOS virtual machines [5]. The framework provides all basic functionalities to support the operation of satellites in the Low-Earth-Orbit, such as the identification of satellite contacts, the execution of telemetry checks and the uplink of telecommands provided in the SCOS Saved Stack File (SSF) format. For all activities which are project or satellite design dependent, a project specific part exists, which contains automation tasks to be executed within the framework. An automation task is dedicated to one specific activity of the automation system and is described within a TCL script file and optional support scripts.

The automation tasks can be grouped into four different categories:

- **Init Tasks**
  Executed only once during the start-up of the automation framework. Can be used for the setup of the automation system related local folder structure or to test the connection to the EXIF of GECCOS.
- **Cycle Tasks**
  Activities which shall be performed periodically outside of satellite contacts and can be used to provide status telemetry, to check if new contacts are scheduled or if new SSFs have to be prepared for uplink, or to manage and control support tools.
- **Pre/PostPass Tasks**
  PrePass and PostPass tasks are used for the execution of activities before and after the support of a satellite contact, such as the preparation of uplink files or the generation and distribution of products.
- **InPass Tasks**
  The InPass activities are used for the management of all activities during a satellite contact, mainly the uplink of telecommands and monitoring of satellite telemetry.

An overview of the different types of tasks can be seen in Fig 1. The modular concept of using independent tasks has several advantages. It is possible to add new activities without the adaption of the existing code and it provides flexibility to generate different sequences of activities without larger modifications. It also increases the overall robustness, since errors in single tasks do not necessarily lead to a malfunction of the whole automation system but only of affected activities. The number of currently active tasks within the automation system for EnMAP is 46.

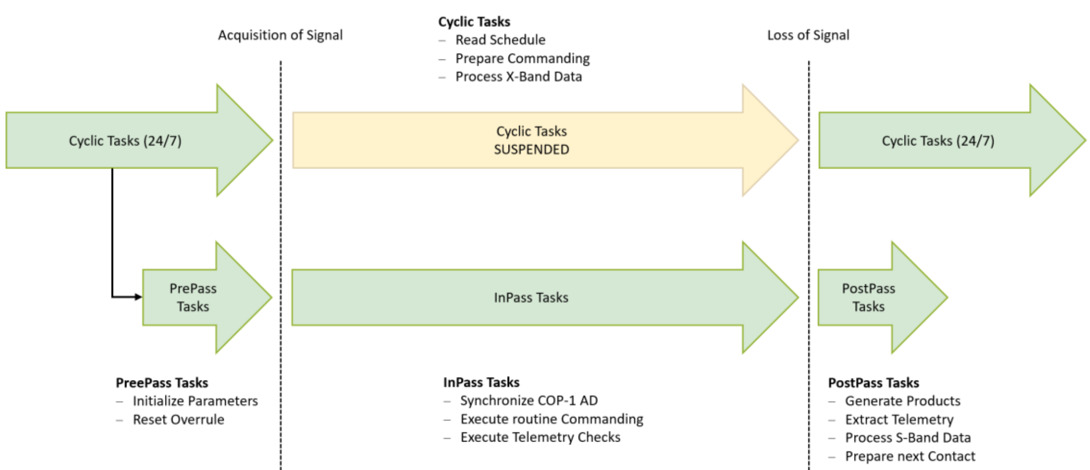

Fig 1. Categories of tasks in the automation system

Automated execution of satellite contacts

The automated execution of a routine satellite contact starts with the activation of the PrePass tasks. These are triggered a configurable amount of time (20 minutes for EnMAP) before the start of a scheduled satellite contact. As soon as valid telemetry frames are received from the ground station, the cyclic tasks are suspended and the InPass tasks are executed. While the uplink is not yet established by the ground station, the verification of a nominal spacecraft status is performed by checking the values of a specific set of telemetry. In case telemetry values are not as expected, the automation system can passivate and supress any automated commanding to the satellite. When all telemetry values are within the excepted range and a minimum elevation is reached (8° per default), the automation starts with the uplink of telecommands. These are prepared prior to the satellite contact by converting Flight Procedures from the SSF format to the TCL file format for automatic execution. The commanding window closes when the uplink of all prepared Flight Procedures is finished or the elevation of the satellite falls below a configurable threshold. The elevation of the satellite over the ground station is either calculated in real-time within the GECCOS system based on the satellite position and velocity telemetry provided by an on-board GPS receiver, or, if no reliable GPS telemetry is available, based on the satellite position velocity provided by the Flight Dynamics department. The release of automated commands can be observed via the TC History of GECCOS similar to manual commanding. For transparency, automated commands are flagged with “EX” for external commanding. When no spacecraft telemetry frames are received anymore at the end of the contact, the automation executes the PostPass tasks and continues with the cyclic tasks until the next satellite contact takes place.

3. Adaptions and challenges for EnMAP

As originally foreseen in the preparation for the mission, EnMAP was included into the multimission concept of GSOC [6]. This constitutes of sharing resources, especially infrastructure and personnel, between missions, such as TerraSAR-X/TanDEM-X, GRACE Follow-On and EDRS. In contrast to these missions, where the automation of processes in the control room were slowly phased in while being operational, a high level of automation was targeted for the EnMAP ground segment already during the design and preparation phase.

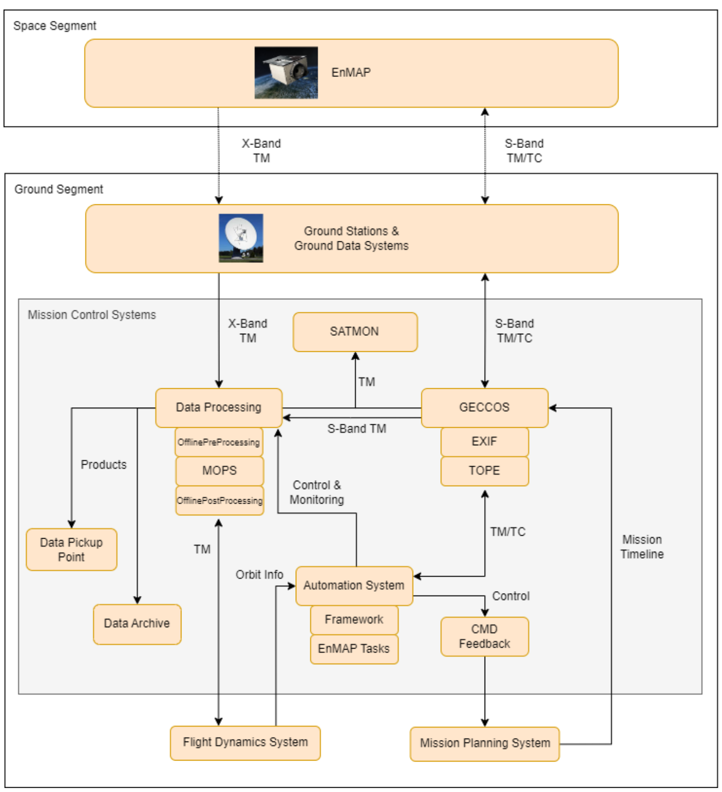

Fig 2. Extract of the EnMAP system architecture with the automation system

Satellite monitoring and commanding

In a first implementation phase, the existing automation framework was applied together with a basic set of activities which are used for all LEO missions with a running automation system. These activities include several InPass tasks during a contact, such as the execution of TM checks to confirm a nominal spacecraft status at Acquisition of Signal (AOS), but also PostPass tasks outside of contacts, e.g. the generation of operational products such as the GECCOS TC and Acknowledge History, and the reported on-board command schedule. The synchronization of the COP-1 Sequence-Controlled Service (AD Service) counter in GECCOS is also performed via an InPass task to ensure a sufficient level of protection against lost, duplicated, or out-of-order transmission of telecommands. Furthermore, a first set of Flight Procedures was prepared for automated execution, which contains the following activities:

- The signal acquisition with the setup of the logical TMTC connection, the connection test via ping command and the synchronization of the command authentication channel
- The request of extra telemetry packets, e.g. the list of the on-board RAM file directory as well as the list of the on-board command schedule
- The upload of the Mission Timeline (MTL) which is provided for every Weilheim and Neustrelitz S-Band contact
- The dump of the System Report File (SRF) and housekeeping file

The SRF contains system messages, software error messages and replies to time-tagged TCs. This is relevant for the analysis of satellite bus errors and for the confirmation of executed time-tagged TCs. The housekeeping file contains the on-board offline data recorded between satellite contacts. Contrary to most other satellite missions at GSOC, the downlink of on-board data for EnMAP is file based. Multiple TCs have to be sent, each requesting a block of 4 kilobytes of data, until the end of the file is reached. This is realized by using a task which repeatedly sends the TC for requesting a segment of the file while adapting the relevant input parameters via the TM-Injection feature of GECCOS. After the complete file was received on-ground, it is closed and deleted on-board to free up the RAM. By sending five request TCs, the housekeeping data of approximately one hour can be received. The majority of the released commands during a contact corresponds to the dump of on-board housekeeping data. With the implementation of these functionalities, most of the basic activities during a nominal S-Band contact were covered without the need for manual commanding.

In the following steps, activities with a lower frequency were handed over to the automated commanding system. This included the upload of orbit maneuvers, executed approximately every three weeks, or the bi-weekly update of the on-board orbit propagators based on provided input files by the Flight Dynamics team. During EnMAP's commissioning phase, additional activities were identified as suitable for automated execution during satellite contacts. The dump of payload logs in case of new entries or the reset of all on-board error parameters are examples of tasks that are now handled by the automated commanding system. A list of all the current commanding activities during a regular S-Band contact can be seen in Table 1. For all commanding activities which cannot be finished during an ongoing satellite contact due to a shortage of uplink time, a PostPass task evaluates if the task shall be resumed in the follow-up contact or restarted using a different Flight Procedure.

Table 1. Overview of the automated command activities during a regular S-Band contact.

Order	Activity	Pre-Check	Notes
00	Signal Acquisition	No	Execution of telemetry checks in parallel
10	Upload of Orbit Maneuvers	Yes	No check for Collision Avoidance Maneuvers
20	Upload of Mission Timeline	Yes	
30	Update of On-Board Orbit Propagator	Yes	Executed every two weeks
40 - 41	Execution of SRF and HK Data Dump	No	
50 - 52	Request of Payload Logs	Yes	Executed if new log entries exist
60	Request of System Configuration	No	Executed once per week
90	Deletion of On-Board Bus Errors	No	
91 - 92	Deletion of On-Board Payload Errors	Yes	Executed if payloads are in idle state

In parallel to the implementation of new activities, continuous optimizations of the existing ones were performed based on the feedback provided by the command operators. This was helpful for implementing workarounds for known limitations of the ground segment systems or handling of reoccurring problems while commanding the satellite.

It was observed for example that the reduction of uplink time, caused by the conservative approach of starting the commanding window at 8° elevation, led to incomplete housekeeping dumps during a large number of satellite contacts. To compensate this, the start of the command window was made dependent on the lock status of the on-board receiver. A stable uplink is assumed when the receivers are in lock for five seconds, which then triggers the start of the commanding activities. If no housekeeping telemetry is received by ground at the beginning of a scheduled contact and therefore a Blind Acquisition is required, the automation system waits until valid frames are received after a sweep of the uplink carrier and checks the bit-lock information within the CLCW. Only after a stable bit-lock is reached, the commanding sequence is started. Furthermore, an alarm is communicated via ground telemetry parameters when such a Blind Acquisition occurred, notifying the command operators to verify and report it in case it was unexpected.

Response of the automation in case of spacecraft anomalies

Besides the routine commanding functionality, measures were implemented to prevent the automated execution of commands that could potentially harm the spacecraft during a spacecraft anomaly. If, for example, the Orbit Control System suffers from an anomaly, it is not desired to upload a planned orbit maintenance maneuver which might cause further unwanted reactions by the on-board FDIR system. To prevent this, Pre-Checks in form of telemetry parameter value checks are defined which are executed before the upload of a specific activity. These checks are used to confirm that the spacecraft is in the correct configuration to receive and execute the commands that are about to be uplinked. For EnMAP, multiple of these checks are used for the upload of the Mission Timeline, Orbit Maintenance Maneuvers, updates of the on-board Orbit Propagator, the request of logs and other routine activities. No Pre-Checks exist for Collision Avoidance Maneuvers which get uploaded to the spacecraft regardless of the on-board status.

Furthermore, it is desired that regular downlinks of housekeeping and event log data of the on-board payloads are performed to make sure that in case of an anomaly all required information for analysis is available as soon as possible.

Managing of data processing and support tools

Compared to other missions, one major difference in the interface to the satellite is the missing PUS compatibility of EnMAP. An adapter is required to convert the PUS compliant packets to the EnMAP specific telecommand structure as well as the EnMAP specific telemetry data packages into PUS compliant ones. It prevented the need for adaptations of GECCOS and also manages the command authentication functionality. For the processing of all offline S-Band and X-Band telemetry data, a support tool, which prepares the data for the Multimission Offline Processing System (MOPS), was needed. This support tool, called OfflinePreProcessor, is controlled by the cyclic and PostPass tasks of the automation system. After the data is processed by MOPS, the OfflinePostProcessor tool generates the final products for data distribution. Two further support tools manage the processing attributes and metadata of all X-Band telemetry products which will be delivered to other DLR institutes for the processing of the payload image data.

Another essential support tool is the CMD Feedback Generator, which is triggered by the automation system during the execution of the PostPass tasks. This is used to provide feedback about the successful uplink of all prepared TCs to the satellite to the reactive planning system. If a TC for an image acquisition was not uploaded for any kind of reason, a negative CMD feedback is sent to the Reactive Planning System and the image request is re-planned for a later uplink and execution. All support tools are written in TCL to simplify the interaction with the automation system for monitoring and control.

User interface and reporting

To achieve a reduction of the workload for the command operator on shift, it is important to provide a user interface which is easy to monitor and operate. It must contain all information required to confirm nominal operations and - in case of problems - deliver enough information for the error analysis without requiring deeper knowledge of the TCL language or the automation system itself. Similar to the telemetry of the satellite, the automation system is generating ground telemetry which is ingested into GECCOS and can be checked by the command operator within GSOC's default Satellite Monitoring Tool called Satmon. An overview of the most important ground telemetry is shown in Fig. 3. This requires the definition of additional parameters and packets for the ground telemetry in the shared Mission Information Base (MIB) but has the advantage to be accessible from external locations. It is therefore possible for the ground system engineers to check and monitor the activities of the automation system during an anomaly even from home. Another source of information regarding the status of the automation can be found in the TOPE console which lists all currently running TCL scripts as well as their status information. Additionally, several ground commands for controlling the automation system have been introduced into the MIB, allowing operations like the starting, stopping, the suspension of tasks or the change of their configuration parameters to be commanded directly from GECCOS.

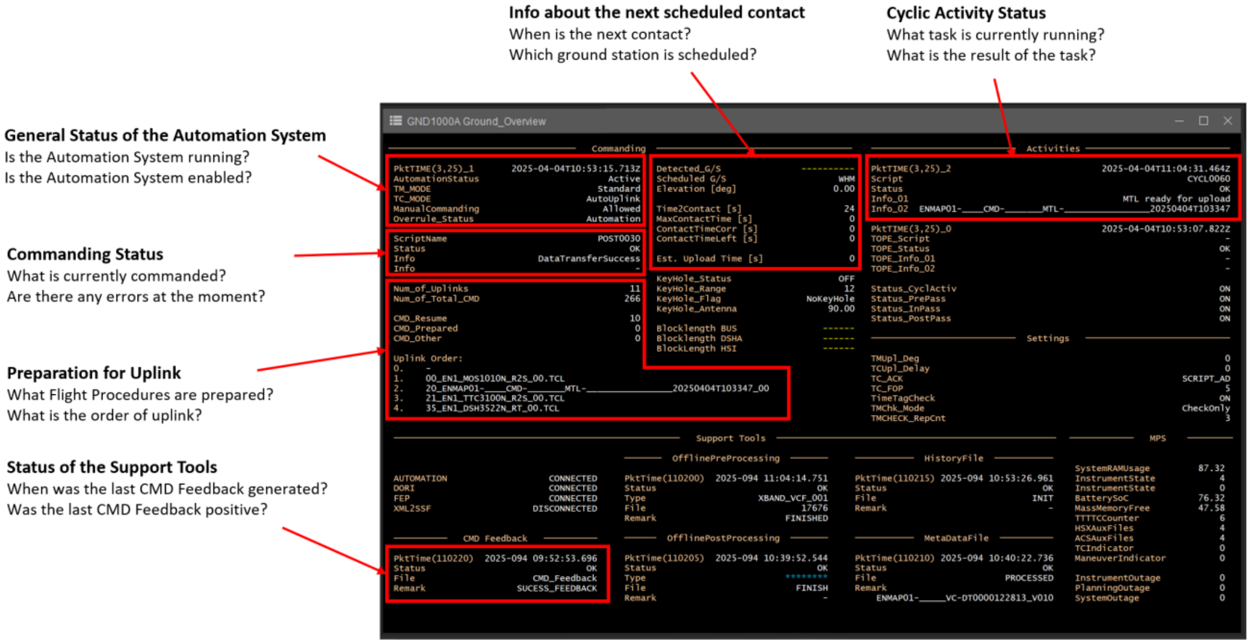

Fig. 3. Main telemetry overview for the EnMAP automation system and ground tools in Satmon

The reporting of activities during a satellite contact is provided in the form of a Pass Report which contains the time of the contact, the name of the used ground station, a list of the executed Flight Procedures, as well as a list of all executed automation tasks. A section of all observed anomalies can be filled flexibly by any running automation tasks. For the distribution of important information, such as telemetry check violations, offline telemetry data gaps or the content of on-board payload logs, a total of nine different E-Mail templates are used. These automated E-Mail are then sent to the command operator, the team of subsystem engineers, or both. For unsupervised satellite contacts, this ensures that anomalies on-board the satellite and on-ground are reported and the information is distributed accordingly. To cover the worst-case scenario where no automation system is running at all, the open-source tool Icinga is used, which monitors the status of all relevant virtual machines and applications in the multimission environment of the control room.

Reliability constraints

EnMAP uses a reactive planning system with an export horizon which only covers the timeframe until the next satellite contact [7]. This is intentional as it allows user requests to be considered on a very short notice, but demands a high reliability of successful mission timeline uploads. If an uplink of the timeline is not performed for any other kind of reasons, the scientific mission is interrupted until the next mission timeline upload is successful. This reduces the tolerance for errors not only for the automation system but the overall ground segment at GSOC.

Redundancy concept

In order to provide so-called “hot redundancy”, two independent GECCOS commanding chains (A and B) are running in parallel. If the prime commanding chain A is not responsive and cannot be recovered before the next satellite contact, a switchover to the backup commanding chain B can be performed. This switchover takes approximately 10 minutes and is documented in a Ground Procedure available for execution by a command operator on console or an on-call engineer. Due to its short start-up time, the automation system is installed on both chains but only running on one system, providing “cold redundancy”. The backup automation system provides the same functionality as the primary automation system. A synchronization of all relevant products is performed at the end of each automation task to ensure the availability on both chains. A switch can be performed at any time with the only constraint, that automated commanding cannot be performed when the backup system is started during a satellite contact. Regular tests with the backup chain are performed to ensure the correct functionality in case of a failure of chain A. After three years of mission, so far, no unplanned switch to the backup chain B was necessary.

4. Performance and limitations of the EnMAP automation system

The percentage of automated commanding over the EnMAP mission is shown in Fig. 4. It can be seen that for the first year, the percentage increased significantly due to the stepwise implementation of automated procedures as described in chapter 3 and the further optimization of tasks. By now, three years into the mission, the automation system is the source of approximately 95 % of all commanding to the spacecraft. The remaining manual commanding is mainly done for the training of new command operators or related to satellite anomaly handling, where less automated processes are used. Three spacecraft anomalies (October 2023, December 2023 and December 2024) can be identified in Fig. 4 based on a higher number of uplinked commands and lower percentage of automated commanding. Due to the high reliability of the automation system and the desire for further reduction of costs, the Inuvik passes are solely handled by the automation as of February 2024. These contacts are fully performed by the automation system and are only monitored by a command operator if time allows or if used for training purposes.

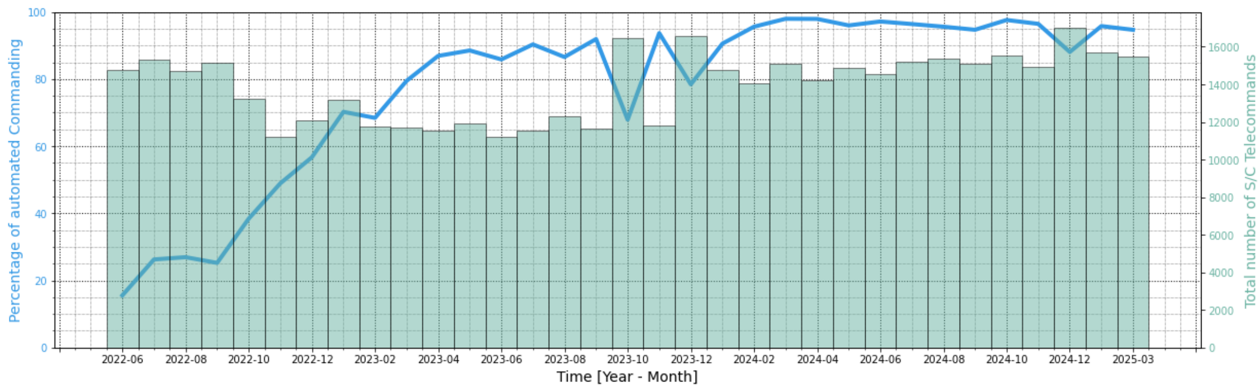

Fig. 4. Monthly overview of the percentage of automated commanding and the total number of TCs sent to EnMAP

Based on the unsupervised Inuvik contacts, several limitations could be identified. Since the communication with the GSOC network controller is purely based on verbal communication, it is not possible to automatically monitor the status of the network and the ground stations. It is also not possible to request any activities at the ground station in case of problems without the presence of a command operator, such as the execution of an uplink carrier re-sweep due to partial or unstable receiver lock. The current design of unsupervised contacts is not tolerant in respect to any problems between GECCOS and the ground station antenna, which can result in the interruption or complete loss of uplink capabilities or telemetry reception. The current lack of support for audible notifications also poses a risk, since a single command operator is responsible for multiple missions and does not always recognize visual alarms immediately.

For technical errors within the commanding chain, the automation system offers the possibility to perform commanding tasks on a manual or semi-manual basis. This approach proved to be valuable to ensure a maximum flexibility and robustness with respect to the overall interface stability between GECCOS and the automation system. In case of unsupervised passes and unintended errors in GECCOS, the automation system stops per default the uplink of commands to the spacecraft and changes into a passive state. It then offers the possibility to continue operations by manual interaction of the command operator with an overrule functionality. This feature also allows to deal with missing TC acknowledgments from GECCOS back to the automation system. If the automation system is not able to verify the successful execution status of a telecommand from the spacecraft, it stops any further commanding and waits for input of the command operator. After manual verification of the TC execution status in GECCOS, the command operator overrules the interruption which then results in the release of new TCs. To compensate the lack of a command operator, an additional workaround was set in place. When the automation system is missing a TC acknowledgement, a separate task requests again all command acknowledgments from GECCOS of the last minute. If the missing acknowledgment is then listed and confirmed successful, the release of TCs continues without the need of a manual overrule. Otherwise, an anomaly on-board the satellite can not be excluded and further analysis is required before commanding can be resumed.

Besides problems that impact the automated commanding, several smaller connection problems between GECCOS and the automation system were observed over time impacting smaller tasks, such as the generation of operational logging products. If these tasks receive a negative feedback, a second request to GECCOS is performed to avoid the failure of these tasks. By increasing the frequency of regular restarts and maintenances of GECCOS, the number of these small incidents was reduced significantly.

The most severe satellite related impact on the automation system are connection problems between EnMAP and the ground station caused by the effect of the Antenna Aspect Angle (AAA). The AAA describes the destructive interference by the omni-directional mounting of the two transceivers on-board which can be observed in certain spatial orientations with respect to the ground station. The subsequent link instabilities can result in the loss of single command and telemetry packets and with that a stop of the automation system. Manual interaction of a command operator is required to continue with the uplink activities. It is currently under investigation how the automation system can reduce the impact of such events and help restoring the TMTC connection.

A project independent limitation of the automation system is the usage of the TCL language itself. The current TOPE implementation in GECCOS is using TCL version 8.5.5 from 2008 without the plan of further upgrades. While TCL is easy to learn, well-structured and powerful for fast scripting, it lacks the distribution and community support of modern general-purpose programming languages, such as Python, Rust or Ruby. It can still be found primarily in embedded applications but for spacecraft operations engineers working at GSOC, TCL is no popular option for enhancing further programming skills. With the increasing complexity of the automation system, the limited availability of data structures and additional libraries becomes more relevant and requires more effort for the implementation of new features.

5. Conclusion and outlook

This paper presented an overview about the structure and functionality of the TCL based automation system developed at GSOC and its use for supporting the EnMAP mission. By choosing a modular approach, it was possible to implement new features in small steps and to adapt to the characteristics of the mission and the satellite. It significantly reduced the manual effort during nominal satellite contacts and helped gaining further experiences in automated satellite operations. While the automation system is still deployed and maintained for several satellite missions, the Procedure Tool Suite (ProToS) is being extended to replace it in the future. The tool is developed at GSOC and used within the EnMAP mission for the generation and management of Flight and Ground Procedures [8]. With an iterative development based on the feedback from the satellite missions, it focuses on a user-friendly approach and, similar to the TCL based automation system, contains an interface to write individual tasks. At the moment, ProToS is already in use for automatically operating the geostationary satellite EDRS-C and first tests were performed for the LEO mission GRACE-FollowOn [9].

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