Transforming Flight Operations Segment Engineering Services for the European Commission Copernicus Sentinels

Franco Marchese[a], Islam Alizada[b], Jose Morales[a], Aurea Cors Espinal[b], Javier Hernando Bravo[b*], Frank Leake[b], Fernando Pina Caballero[c], Pierre Le Nahedic[d], Paul Bearman[e]

[a] *European Space Operations Centre (ESOC-ESA), Darmstadt, Germany, {franco.marchese, jose.morales}@esa.int*
[b] *Serco Services GmbH, Darmstadt, Germany, Darmstadt, Germany, {islam.alizada, aurea.cors-espinal, javier.hernando-bravo*, frank.leake}@serco-eu.com*
[c]*Deimos Space, Tres Cantos, Spain, fernando.pina@deimos-space.com*
[d] *CS-Group GmbH, Darmstadt, Germany, pierre.lenahedic@c-ssystems.de*
[e] *Telespazio Germany GmbH, Darmstadt, Germany, paul.bearman@telespazio-vega.de*
* Corresponding Author

Abstract

Copernicus, previously known as GMES (Global Monitoring for Environment and Security) is an European Commission space program whose Flight Segment component, the Sentinel Family Spacecraft, is currently formed by six different missions operated by the European Space Agency (Sentinels 1, 2 and 5P) and EUMETSAT (Sentinels 3 and 6 as independent spacecraft and Sentinel-4 and Sentinel-5 as instruments carried aboard the Meteosat Third Generation (MTG) and the MetOp Second Generation satellites respectively).

The European Space Agency (ESA) works closely with industry to provide operational services for their missions. Over time, ESA has integrated industrial outsourcing and managed services closely with their operations, providing increasing accountability to industrial partners and service providers to bring innovation and integrate best practices into a common approach. The aim is to bring increased agility and flexibility within the service, allowing for capacity planning and operational concepts that can meet activity and workload peaks whilst efficiently utilising resources.

ESA's European Space Operations Centre (ESOC), located in Darmstadt, Germany, is responsible on behalf of the European Commission for the flight operations of Sentinel-1, Sentinel-2, Sentinel-3 (LEOP And Commissioning), Sentinel-5P and Sentinel-6 (LEOP only). With the Agency having to focus more and more on the new Copernicus missions and thanks to the recurrent nature of the C and D models, ESA has decided to adopt a stronger managed service approach for the routine operations and recurrent launches of the Copernicus missions. This triggered a process of rethinking the interaction with the providers of engineering services and to a new ITT that was released in September 2020.

A joint consortium led by Serco Germany and comprising Telespazio, Deimos and CS-Group as the subcontractors was awarded the contract. The consortium has implemented the provision of the engineering services in line with the Agency new requirements, successfully completing the 5 months of Phase-In and delivering the service since January 2022.

This paper describes how the new concept of managed service for Copernicus Sentinels flight operations defined by ESA and the Agency has managed the related transition. It describes as well how the industrial consortium has responded and implemented the Agency request and managed the ramp up of the new service. The new concept covers the different areas of the Flight Operations Segment (Operations, Flight Dynamics, Data Systems, Collision Avoidance) and encompass all service aspects e.g., team training and certification, efficient organisation of the resources, and synergy of ESA and industry facilities and IT resources.

The paper describes also what lies further beyond, i.e., a homogenization of the different processes and working practices between the Copernicus Sentinel missions will be put in place, all along with an increasing automatization of some of those processes, which will allow a simplification of routine activities.

Keywords: Copernicus, Sentinels, operations, service, resources

Acronyms/Abbreviations

ESA	= European Space Agency
ESOC	= European Space Operations Centre
EUMETSAT	= European Organisation for the Exploitation of Meteorological Satellites
FCT	= Flight Control Team
FOS	= Flight Operations Segment
GMES	= Global Monitoring for Environment and Security

ITT = Invitation To Tender
LEOP = Launch and Early Operations Phase
MCS = Mission Control System

1. Introduction

Copernicus, previously known as GMES (Global Monitoring for Environment and Security) is an European Commission space program whose Flight Segment component, the Sentinel Family Spacecraft, is currently formed by six different missions operated by the European Space Agency (Sentinels-1, 2 and 5P) and EUMETSAT (Sentinels-3 and 6 as independent spacecraft and Sentinel-4 and Sentinel-5 as instruments carried aboard the Meteosat Third Generation (MTG) and the MetOp Second Generation satellites respectively).

Most of the Sentinel are based on a constellation of 2 satellites in the same orbital plane, with the exception of Sentinel-5P that flies a single satellite. This configuration allows to fulfill the revisit and coverage requirements and to provide a robust and affordable operational service [1]. The lifetime of each individual satellite is set up to last at least 7 years, with consumables allowing mission extension up to 12 years. A third and fourth model have been prepared for launch in order to secure the replacement of the original units.

Sentinel-1 is a C-band interferometric radar mission to provide continuity of all-weather day-and-night supply of imagery for user services. These cover applications such as: Monitoring sea ice zones and the arctic environment, and surveillance of marine environment, monitoring land surface motion risks and mapping of land surfaces (forest, water and soil) or mapping in support of humanitarian aid in crisis situations. The final constellation of two satellites provides a worst case 6 day revisit time, while achieving full European and Global coverage in 2 and 12 days respectively.

The Sentinel-2 mission provides global systematic high resolution (10-20 m) multispectral optical observations with a high revisit time of 5 days. These possible applications include land cover, use and change detection maps, risk mapping and fast images for disaster relief. The mission will provide coverage of land surfaces within a [-56 deg - +83 deg] latitude range with the aim of delivering cloud free products at a frequency of 15 to 30 days.

The Sentinel-5P mission, or also known as Precursor mission, is the first Copernicus mission dedicated to monitoring the atmosphere. The mission consists of one satellite carrying the TROPOspheric Monitoring Instrument (TROPOMI) instrument. The main objective of the Copernicus Sentinel-5P mission is to provide timely data on a multitude of trace gasses and aerosols, ozone & UV radiation, affecting air quality and climate monitoring and forecasting.

The Sentinel-3 mission is devoted to operational oceanography and global land application, thanks to its payload composed of a set of optical and microwave instruments to measure variables such as sea-surface topography, sea and land surface temperature, ocean colour and land colour with high-end accuracy and reliability.

The Sentinel-6 mission is a multi-partner programme to continue the Jason satellite altimeter data services beyond legacy Jason-2 and Jason-3 missions. It consists of two identical satellites flying in sequency to prolong the climate data record of sea level accumulated by the TOPED/Poseidon, Jason-1, Jason-2 and Jason-3 missions from 2020 to 2030 and beyond.

Additionally, ESA-ESOC also operates Sentinel-3 during the LEOP and Commissioning and the LEOP of Sentinel-6 before handing them over to EUMETSAT.

The Copernicus Sentinels Ground Segment is in charge of the overall commanding and monitoring of Sentinel-1. Sentinel-2 and Sentinel-5P as well as Sentinel-3 (only for LEOP and Commissioning) and Sentinel-6 (LEOP only). The acquisition, processing, and dissemination of their observational data. The two primary components of the Ground Segment are the Flight Operations Segment (FOS) and the Payload Data Ground Segment (PDGS) [2].

The FOS facilities provide the main functions for spacecraft monitoring and control, including execution of all platform activities and the commanding of the payload schedules during all relevant mission phases according to the baseline Sentinels Operations Concept. The principal FOS components are the Ground Station and Communications Network performing telemetry, telecommand and tracking operations within the S-band frequency and the Flight Operations Control Centre (FOCC) located at ESOC-Darmstadt. The latter includes: the Sentinels Mission Control System (MCS) and Mission Planning System, the specific Sentinel-1/-2/-3 Spacecraft Simulators to support procedure validation, operator training and the simulation campaign before each major phase of the missions, the Sentinels Flight Dynamics System, for all activities related to attitude and orbit determination and prediction, preparation of slew and orbit manoeuvres, spacecraft dynamics evaluation and navigation, and a General Purpose Communication Network to provide the services for exchanging data with any other external system during all mission phases.

ESA has decided to adopt a commercial managed service approach for the support to the routine and critical operations of the Sentinels and associated FOS, moving from a more institutional scheme employed until the end of 2021. A joint consortium led by Serco Germany has implemented the provision of the engineering services in line with the Agency new requirements, successfully completing the 6 months of Phase-In and delivering the service since January 2022. The new concept of managed service for Copernicus Sentinels flight operations defined by ESA covers the different areas of the Flight Operations Segment (Operations, Flight Dynamics, Data Systems, Collision Avoidance) and encompass all service aspects e.g., team training and certification, efficient organization of the resources, and synergy of ESA and industry facilities and IT resources. Further beyond, a homogenization of the different processes and working practices between the Copernicus Sentinel missions will be put in place, all along with an increasing automatization of some of those processes, which will allow a simplification of routine activities.

2. Operations Management

The design of the ground segment and operations concept for ESA missions is defined with the objective of optimizing resource usage and reducing the lifetime costs. ESOC is involved from the early phases of the mission lifecycle (Pre-phase A or Phase A) in order to provide feedback into the mission design that will ensure optimal operability of the mission and compatibility with existing ESA infrastructure and operational methods. The operations concepts for ESA missions are being developed within a "Family of Missions" framework. This groups missions into families with similar operations concepts such as data download strategies and commanding frequencies. Operating missions in families allows reuse of personnel, accommodation, hardware, software and infrastructure [3].

The Sentinel missions require a high degree of reliability and availability, also at the level of the ground segment, while minimizing the operational effort associated with the routine mission phase. This in turn calls for implementation of advanced on-board autonomy functionality, and definition of an innovative operational concept, aimed at minimizing ground intervention both in nominal and contingency situations [4].

With the Agency having to focus more and more on the new Copernicus missions and thanks to the recurrent nature of the C and D models for each mission, ESA has decided to adopt a managed service approach for the support to routine operations and recurrent launches of the Copernicus missions. This triggered a process of rethinking the interaction with the providers of engineering services and to a new ITT that was released in September 2020. A joint consortium led by Serco Germany and comprising Telespazio, Deimos and CS-Group as the subcontractors was awarded the contract. The consortium has implemented the provision of the engineering services in line with the Agency's new requirements, successfully completing the 6 months of Phase-In and delivering the service since January 2022.

This period presented different challenges and obstacles. Over 40 engineers, controllers and analysts had to be trained and certified, including those teams which have never had a certification process in place. A complex training program was created to support different stages of the learning curve and the new certification process was put in place covering all the units. As a result, the consortium was ready for a full and successful service at the scheduled time.

2.1 Mission requirements

The Copernicus Sentinels missions require a high level of service in order to fulfil the availability of the data. This is combined with a considerable level of flexibility required to adapt any evolution of the service, whether planned or unplanned. Finally, the service was required to be delivered using the ESOC existing infrastructure, leading to a solution implying both on-site and remote access. The core requirement was to procure the service end-to-end allowing the Service Provider to plan the resources overall, not only limited to one mission operations team (real time operations operators and spacecraft operations engineers) but the entire Copernicus FOS team, including flight dynamics, data systems, collision avoidance and ground operations.

2.2 Service Design

The COP-2 consortium designed the service in a way that, the entire FOS team acts as "one team" allowing the resources to shuffle from one activity to another in case of unexpected high workload or events. While the external service provider is focused on routine Sentinel operations, ESA could spend more time on the upcoming "first time" or "prototype" missions where deep knowledge and experience is required. This allows the Agency to achieve more with the same number of internal resources in long term. The service is designed on three main fundamental pillars, allowing the Agency to spend less time on recurrent activities – Performance, Reaction Time, and Flexibility.

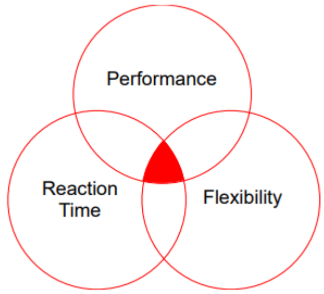

Figure 1. Illustration of the 3 service design pillars.

This service requires high level of performance, hence Serco selected best in their expertise areas subcontractors. Combining the technical expertise of the subcontractors under the Serco's proven service management approach ensures that all FOS operations are executed in a timely and proper manner, in accordance with operational procedures and standards. The service is run based on the Performance Indicators (PI) and Key Performance Indicators (KPI) monitored internally at the Service level every month and reported to ESA every quarter.

Proactive internal service mindset and clearly defined roles and responsibilities allow the service provider to deliver the response to any changes or adaption to the new requirements near real time, which is very critical within the spacecraft operations domain.

Based on the service design philosophy – "one purpose, one team", Serco reallocates the resources depending on the activities and milestones to be achieved. The first kind of event is expected to be with Sentinel-1C launch which is planned to be in 2023. This will allow the service provider to confirm that, high degree of flexibility could be achieved if the service is managed by the single provider. Moreover, the service is designed to deliver non real time operations service outside of the Agency premises, allowing them to reduce the internal office cost, also giving the freedom to the service provider to manage the resources. This concept allows both the Agency and Service provider to define the clear objectives and expectations to both team members.

There are 9 (nine) operational units divided per technical domain and led by the management unit. These units are:

- Real-time Operations unit
- Sentinel 1 Spacecraft Operations Engineering unit
- Sentinel 2 Spacecraft Operations Engineering unit
- Sentinel 3/6 Spacecraft Operations Engineering unit
- Sentinel 5P Spacecraft Operations Engineering unit
- Ground Operations Engineering unit
- Flight Dynamics Engineering unit
- Collision Avoidance Engineering unit
- Data System Engineering unit

Each unit is managed by a technically expert Team Coordinator in order to efficiently interact with ESA at the same technical level. All the activities, tasks are assigned by the coordinator and priorities given based on the resource availability and the agreed schedule. Each Team Coordinator reports directly to the Service Delivery Manager who supervises and coordinates the overall service, where applicable re-allocates resources as needed. In addition to the Service Delivery Manager, there are supportive functions who's role is to provide required assistance in different areas: Information Technology Service Manager (ITSM) in charge of the IT related matters, Product and Quality Assurance engineer in charge of the quality and assurance aspects, Training Officer responsible for training and certification coordination, Service tool support engineer maintaining and developing service reporting tools and Service Administrator in charge of the administrative matters. Overall, the structure and service design proven to be effective in real operations, and shows the high degree of flexibility and autonomy. One of the cases occurred in January 2022 when Sentinel-1B had an onboard anomaly which caused the payload to be off. Due to the unexpected incident ESA's request to change the operations into the 24/7 monitoring service was implemented in less than 10 hours allowing the

Agency to monitor Sentinel-1A closely while investigating the issue with another one. This was achieved thanks to the strong, reactive and reliable service provider who designed the service to meet the needs of the high-level requirements of the European Commission.

2.2.1 Operational Tools

One of the key challenges both ESA and Serco faced during the Phase-in, was to get the solution in place to allow the service provider members to deliver non real time services outside ESOC. The service provider had to put in place the IT solution which would allow the ESA to bring their solution and validate it. This work was done in close cooperation with the Agency's IT operational teams and service members and the final solution was tested, validated, and accepted. In this transformation from the previous service contract to the fully managed service contract, the Agency had to change internally the way tools accessed, installed, and maintained. Thanks to the migration of the operational tools to support the near-site activities delivered by the Service provider, the Agency created an in-house knowledge and lessons learnt for the future service contracts.

2.2.2 Working areas

The COP-2 operations structure, as in the majority of the space missions, consists of different teams or Units that work together to provide a service. The Units, composed exclusively by employees from the external companies of the consortium, are: Collision Avoidance, Flight Dynamics, Data Systems (IT Support), Ground Operations Engineers, Spacecraft Operation Engineers (for the missions: Sentinel-1, -2, -3/6 and -5P) and Real Time Operations (Spacecraft Controllers and Analysts).

2.3 Training

As in many other fields, training is an essential part of potential good work, especially in specific areas such as operating a satellite. Moreover, in contrast to previous ways to perform operations, in this specific COP-2 contract, a Certification process has been carried out for all the employees. This required a trainer officer to set up, manage and supervise an entire training plan for each individual Unit within Copernicus FOS Operations to certify a member working within the unit. All training is recorded in a detailed timetable established and monitored by the Training Officer.

2.3.1 Training Phases

The training duration varies for each Unit within Copernicus FOS Operations. For each unit there are three different Stages: Stage 1 (Theoretical), Stage 2 (Shadow, including routine and on-call) and Stage 3 (Reverse Shadow, including routine and on-call).

After each phase, a report to evaluate the status of the training is created. It details the progress of the phase and enables the Training Officer to verify whether the objectives have been achieved, if any difficulties have been encountered and the possible improvements. These reports are used to support the follow-up meeting of the training courses where it should be decided whether to proceed to the next phase of training.

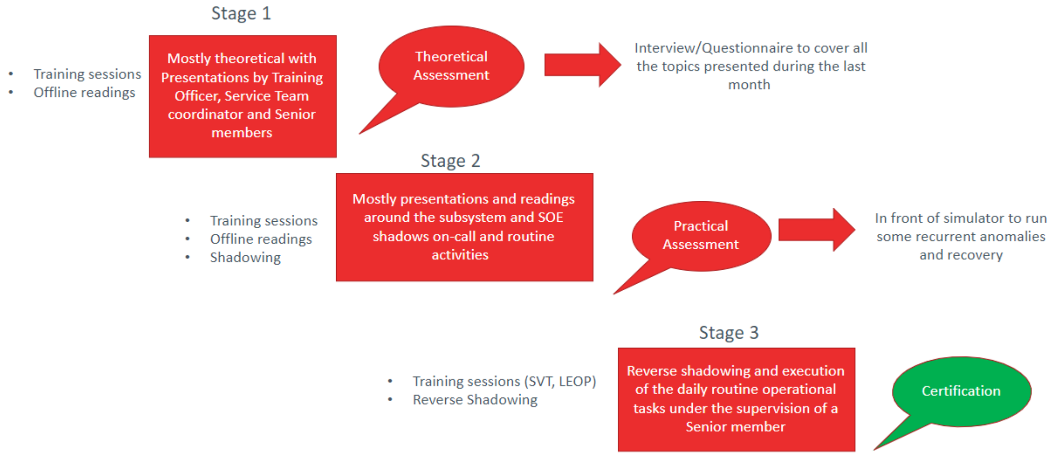

Figure 2. Training and Certification cycle for Spacecraft Operations Engineers

Stage 1 mostly covers theoretical part of the training, where an individual will receive presentations, seminars and documents to be read. All units a common general introduction to the services provided and a Unit specific introduction. Depending on the level of the knowledge, this stage could last from 2 weeks up to 6 weeks. After this stage, a Theoretical Assessment will be performed.

Stage 2 contains a mix of shadowing of all the activities and theoretical sessions, for on-call engineers this stage will be heavily used to perform on-call shadowing. Shadowing a current worker in a specific role or workplace, allows the newcomer to see how operational activities and each specific task might be executed, besides how to approach degraded cases or day-to-day troubleshooting. The end of this stage will be followed by a Practical Assessment.

Stage 3 is the last stage and is mainly focused on reverse-shadowing and more practical exercises. It consists of a period of time where the tasks will be performed by the newcomer, supervised by the senior employee or expert in the matter. The main objective of this phase is to ensure the self-autonomy of the newcomer while performing the duties and tasks. On a second level, this is also helpful to deal with degraded or contingency scenarios, where a diagnosis and a corresponding action must be performed. Upon successful completion of the stage, an individual will be allowed to enter the certification stage.

2.3.2 Certification Plan

A Certification Board will be appointed for every Certification Assessment to be performed. The Board is composed of, at least, the Trainer Officer, the team leader or another already certified member from the Unit. The process could be observed by an ESA staff member.

A candidate to be certified should have completed at least 80% of the training progress. The certification process has two main Parts: Theoretical part – where the board asks theoretical questions about routine, subsystem and or general questions selected from the database of questions. The usual duration of this part is 1 hour; Practical part – this part may consist of different subsections, some activities are performed in the Simulated environment, while some exercises could be run on the operational machines/systems.

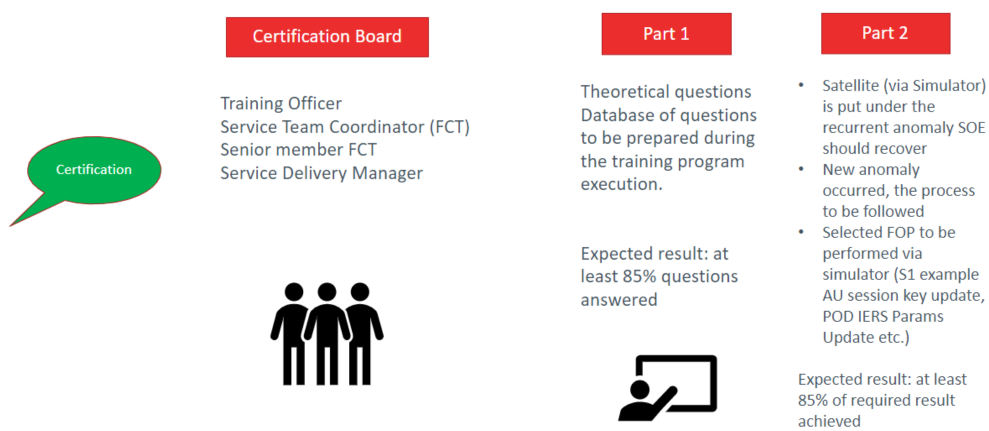

Figure 3. Spacecraft Operations Engineer Certification process

2.3.3 Self-training Phase

Beyond achieving a certification, the learning curve and training is expected to continue for every employee in the working group with dedicated training seminars to develop new skills or periodic refresher training to maintain and to improve the already acquired competences. This phase is also organized and tracked by the Trainer Officer to guarantee the progress of the team members.

3. Lessons learnt

The main lesson concerns the IT solution to remotely access the ESA infrastructure. Ideally, both sides should have pre-validated or protype IT solutions prior to the start of Phase-in. This would have allowed the Parties to transition to the service operations very smoothly. For schedule reasons this was not possible and caused delays in deploying the full near site solution.

4. Future Work

After the successful implementation of the new concept of managed service for Copernicus Sentinels flight operations defined by ESA, the focus has been set on the homogenization of the different processes and working practices involving not only the FCTs from the different Copernicus Sentinel missions but all the Units that are part in the delivered service. The goals to achieve are an even more efficient organization of the resources and facilities and a simplification of routine activities. One way to simplify these processes will be by increasing their automatization. For that purpose, different Working Groups (i.e.: Automation Working Group, Best Practices Working Group) have been created in parallel to the daily activities to coordinate the effort from the Units. Each Working Group is formed by a representative member of each Mission or Unit. In this way, all the Units will homogenize their processes and activities, paving the way for a potential interchangeability of workforce between Missions or Units to increase the agility and flexibility within the service and to guarantee a continuation of the service provided in case of unexpected events or workload peaks whilst efficiently utilizing resources.

5. Conclusions

More responsibilities entrusted to the Service Provider creates the value on both sides. On the service provider side, to be responsible for the work done and manage the teams allows to expand its know-how and reuse experiences in other scenarios. On ESA side, it allows to fulfil the Agency objective to push the European industry to be more competitive and to dedicate the internal resources where are more needed. This leads to the fact that, ESA enables industry to take the ownership of the services delivered on the other hand allowing industry to be more creative and bring a value into the spacecraft operations domain.

Acknowledgements

Spacecraft operations are a team effort requiring the support of multi-discipline expertise across ESA, industry and the scientific consortia. The authors gratefully acknowledge the excellent contributions of the ESOC Sentinels Mission Teams, the ESOC ground infrastructure division, the companies forming the Service Consortium, for the Sentinel Missions success and to the work behind this paper.

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