Satellite Operations

Satellite Operations

Thanks to our experience of five decades in space operations, we can offer Satellite Operations as a service. This service comprises every activity or action aimed at safe and secure operations through the different phases of the lifetime of a satellite or a satellite constellation. This covers as well the extensive preparation for the actual operation phase. Every type of satellite on Earth-bound orbits, e.g., geosynchronous communication satellites, low-Earth orbiting technology demonstration or Earth observation satellites is supported. We primarily focus on satellite platform activities. If required, mission-specifc payload operations can be offered with additional preparation time. We cover all standard project phases, i.e., feasibility study (0/A), preliminary design (B), detailed design (C), implementation (D), execution (E), and disposal (F). Subsets of these phases can also be supported.

Our Satellite Operations are provided via our own teams and infrastructure, such as Control Rooms, data systems and networks.

General tasks of satellite operations are the following:

- Monitoring of spacecraft health via received telemetry (TM) data
- Control of the spacecraft via telecommands (TC) sent through a ground station network
- Execution of orbit control manoeuvres, e.g., reference orbit control, collision avoidance, deorbit
- (automated) Execution of attitude manoeuvres, e.g., for image acquisition
- Logging of consumables, e.g., propellant
- Lifetime analysis and prediction

The service can be divided into the preparation phase (A, B, C, D) and the execution phase (E, F), whereby phase E consists of the Launch and Early Orbit Phase (LEOP), a subsequent commissioning phase and the final routine operations phase. Especially the LEOP benefits from the ample experience of our Control Center. In this critical phase the spacecraft is exposed to the environmental conditions of space for the first time.

Additional services that we provide:

- Ground Stations & Network Operations Center
- Mission Control & Data Systems
- Mission Planning Systems
- Flight Dynamics Services
- Training & Consulting

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2. Ground Segment Engineering

The Ground Segment Engineering is the process that drives Satellite Operations within the German Space Operations Center (GSOC). It is based among others on the recommendations of ECSS-E-ST-70 and maps the ECSS standard to the GSOC engineering process. It gives an overview of all ground segment engineering activities, processes and rules of interaction at GSOC. It also defines all required input and output documents of the system engineering of the ground segment and its lower levels during the project lifecycle.

A dedicated Project System Engineer is responsible for all phases of the ground segment of the S/C mission at GSOC and the compliance with the processes. He/she takes care of all aspects on system level, from feasibility to requirements, design, assembly, integration and tests to operations. He/she is the interface between the Project Manager (PM) and the Ground System Managers (GSM), who are responsible for their particular ground subsystems. At GSOC the ground systems usually are:

GSOC Ground Systems

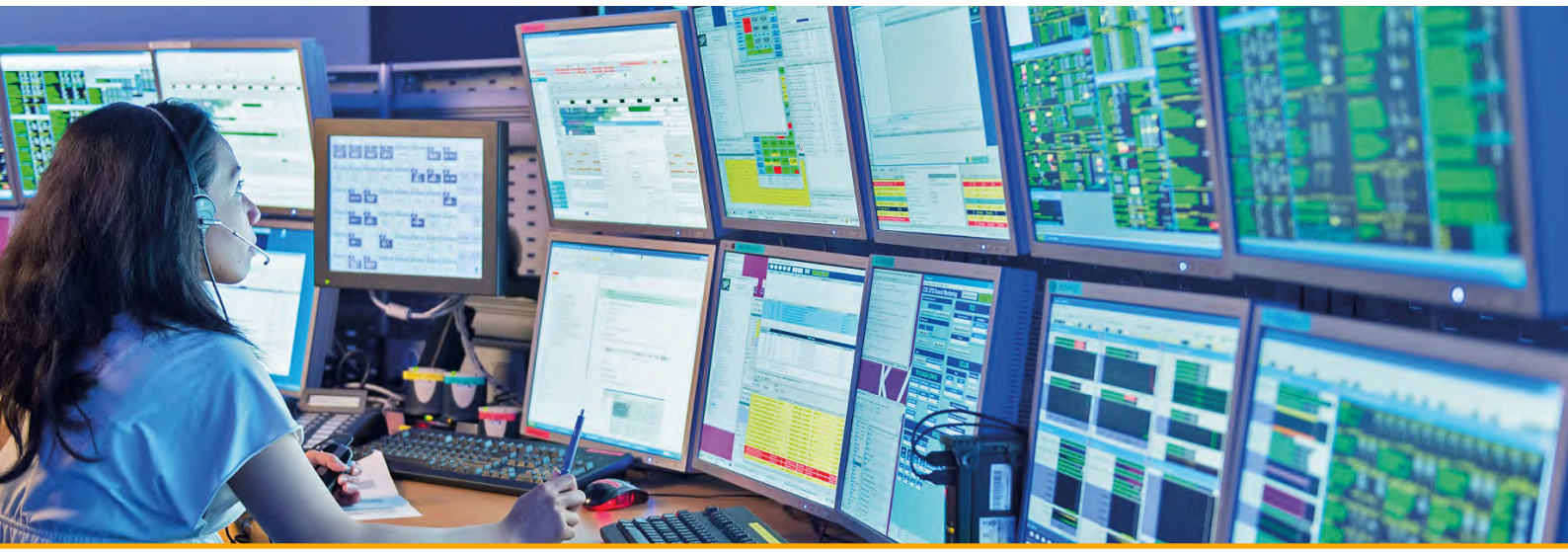
- **Mission Control and Data System (MCS)**
- **Mission Planning Systems (MPS)**
- **Flight Dynamics Services (FDS)**
- Facilities and Communication System (FCS)

If you are interested in system engineering services on sub-system level, please refer to the corresponding services.

In more than 50 years, DLR-RB has developed and built sophisticated ground systems for a wide range of missions and satellites. Customers benefit from the vast experience and in-depth knowledge of our system engineers, who give support in the following tasks, among others:

50 years DLR-RB experience for:

- Assisting the Project Manager in the management of the projects' ground segment related budget
- Interfacing with the Flight Director in order to define the technical aspects of the project, with the purpose of creating a system that is compatible with the operations concept
- Coordinating the work of the subsystem engineers
- Supporting project reviews
- Defining and monitoring of maintenance and obsolescence management



3. GSOC Infrastructure

Our Satellite Operations Services are provided with our own infrastructure. It is set-up and maintained internally and can be adapted to mission specific requirements from our customers. A detailed description of our control rooms and network infrastructure follows in the section below.

3.1 Control Rooms

The DLR site at Oberpfaffenhofen is located near the A96 motorway between Munich and Lindau, the site is home to ten scientific institutes and currently employs approximately 1,800 people. The institutes are mostly hosted in dedicated buildings.

The Mission Control Centers are located inside the buildings of the German Space Operations Center (GSOC) at Oberpfaffenhofen (GSOC-OP) – buildings 140-1, 140-3, 140-4 and 133 (see Figure 3-1).

Due to its criticality, power supply of the Mission Control Centers is divided into three levels:

- Main power supply – Regular power grid
- Diesel buffered power supply (NEA) – Backup power grid
- Uninterruptable power supply (UPS) – UPS power grid

Thus, in case of an outage of the regular power grid, power supply for the Mission Control Centers is still guaranteed.

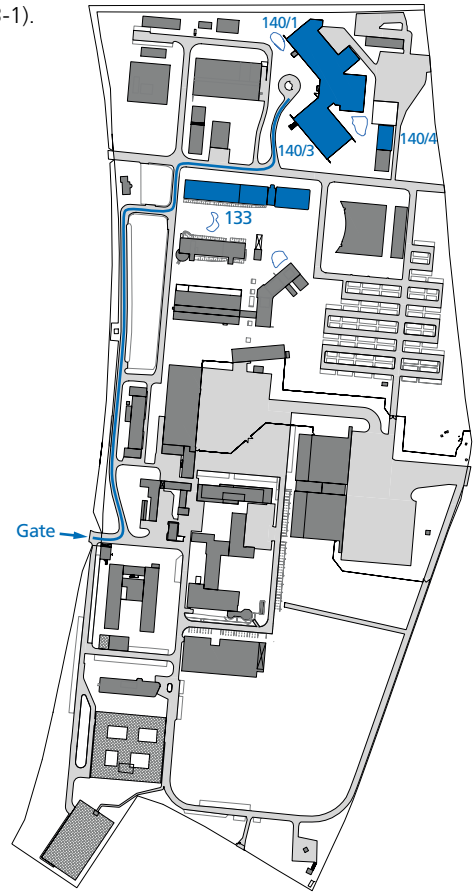


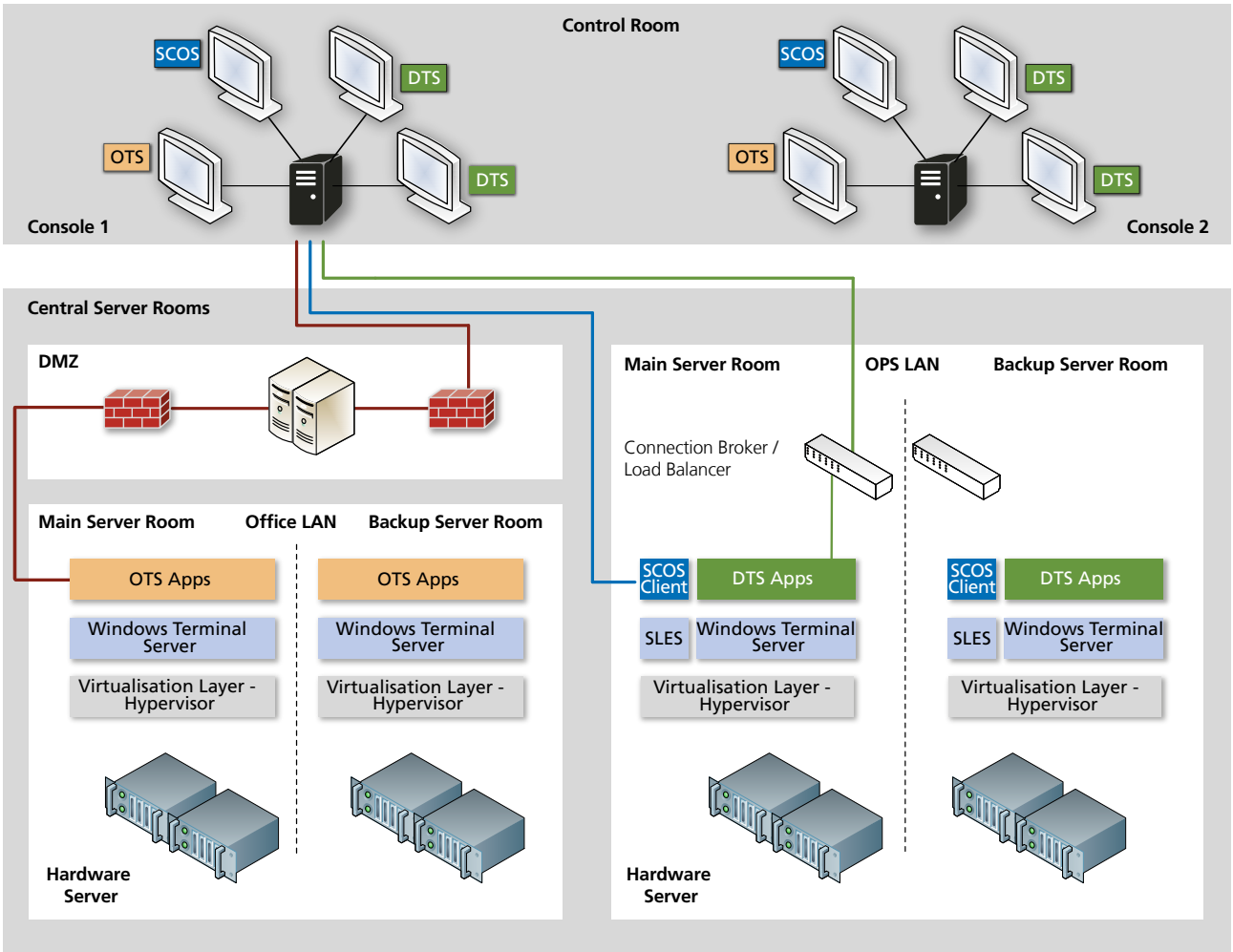
Fig. 3-1 Mission Control Centers (in blue)

Virtual Control Rooms

For many years, a GSOC standard control room was dedicated to one specific space mission. The typical layout was comprised of consoles allocated to dedicated project roles. Traditionally, those consoles were equipped with at least two PC-type computers and multiple monitors attached to it. A very common setup consisted of three workstations (e.g. DPC (Display PC), OPC (Office PC) and SCOS-PC for commanding), each of which was used for specific tasks. For security reasons, every computer was connected to one and only one network segment and the configuration of these computers regarding the installed operating system, software and applications was highly dependent on the specific tasks associated with the project role.

This previous control room setup has served the satellite missions at GSOC very well for many years. However, there were only a relatively small number of simultaneous projects at that time, so that the limited number of control rooms always was sufficient for performing all kinds of operational tasks. Since then, the situation has been changing slowly but steadily. In addition to the older long-term missions, several new projects are now in parallel in the preparation phase and/or already in the operations phase at GSOC. This, of course, has led to increased infrastructure requirements and a strong demand for new control rooms by the Space projects. In this context the control rooms play a particularly important role because the provisioning of additional rooms is not easily possible and furthermore expensive in terms of construction and maintenance. In addition, avoiding new (physical) control rooms means also saving of other resources like power, air conditioning, etc.

Fig. 3-2 Virtualised control room. Applications hosted in the redundant server infrastructure are accessed from a single client device.



Starting in early 2014, one of the large LEOP control rooms at GSOC has been constructed according to the concept of control room virtualisation. The idea behind this concept is that the needs of future satellite missions could be better fulfilled by using modern virtualisation techniques instead of the legacy control room setup. The control room can be used in a much more flexible way when it is equipped with standard thin clients without project-specific software from which connections to the desktops of different satellite projects running as virtual machines in the server rooms can be established. With this setup, a control room is available for training, simulations and operational tasks of several missions without large reconfiguration efforts. The entire system has a redundancy by design, so that there is no undesired operational impact if one of the components fails (see Figure 3-2).

Up to now, the virtualisation of the K1, K6 and K9 control rooms has been completed. For these rooms a process is in place to coordinate the usage: the "GSOC OP control room console planning" (IMS-450-00-003). The virtualisation of other control rooms (K2 and K2a) is still in progress.

The positive effect of GSOC control room virtualisation is that in 2017 there were five space missions in preparation, in parallel, in the virtualised control rooms. The big LEOP control room K1 especially, was the main bottleneck in the past, which was "overloaded" by multiple uses at the same time. This is significant since in the past usually K1 was blocked for a period of more than two years in advance of a LEOP for one specific project which means an increase of efficiency by a factor of more than five times.

Another advantage to be mentioned is increased flexibility. With the GSOC virtualisation concept every console has the capability to support a multitude of projects. This means that the control rooms and consoles can be scheduled in a more flexible way. As a consequence a control room planning process where the resources were allocated efficiently was introduced. This implies that for single user tasks like ops procedure development or operations validation activities, only single consoles can be booked instead of blocking a whole control room.

Fig. 3-3 Typical GSOC-OP mission control room (K4)

Mission Control Rooms

GSOC in Oberpfaffenhofen has 18 Mission Control Rooms which are typically shared between the different projects. All control rooms have access control security and are air-conditioned. Depending on their size, they are equipped with up to 23 Consoles, 24 Voice Keysets and 16 big screens.

The control rooms K1 to K4 can be observed from a visitors' area (or "Bridge"), which is also utilised for staging of PR events. Satellite LEOPs are usually conducted from control room K1. The room floor is designed in three different height levels rising from front to back. The complete room has a double floor that is accessible for maintenance of power and network devices. A typical GSOC OP mission control room is shown in Figure 3-3.

Fig. 3-4 Standard console layout

Due to the virtualisation of some control rooms the hardware of a standard console for Col-CC Control Rooms and Multi-Mission Control Rooms differ to some extent. This is described in Table 1.

Table 1: Standard console equipment

Col-CC (K3, K4, K11, GOCR, BUGOR)	Multi-Mission (K1, K2, K2a, K5, K6,K8, K9)
3 workstations with client software (Connected to OPS LAN, OPS Support LAN and OFFICE LAN respectively)	1 workstation
3-5 screens (1-2 to OPS WS, 1-2 to OPS Support WS, 1 to OFFICE WS)	3-4 screens
1-2 Voice keysets (2 headset outlets each)	1 Voice keyset (2 headset outlets)
1 footswitch	1 footswitch
1-2 keyboard / mice	1 keyboard / mouse
1 telephone	1 telephone
1-2 seats	1-2 seats
1-2 card reader	-

Offline / User Rooms

The offline / user rooms available are listed in Table 2. Some of them can be used by all projects and have to be requested in advance. All of them (except the Break Room) are air-conditioned. Some are equipped with consoles and can be upgraded to small control rooms.

Table 2: GSOC-OP offline / user rooms (status as of September 2017)

Designation	Consoles	Access Control	Voice Keysets(1)
K34 (User Room 06)	3	(keys)	-
K33 (User Room 07)	-	(keys)	-
K32 (User Room 08)	-	Yes	-
K22 (User Room 13)	3	Yes	**2**
K23 (User Room 14a)	3	Yes	**2**
K24 (User Room 14b)	4	Yes	**2**
K25 (User Room 15)	3	Yes	**2**
K27 (Network Mgmt.)	7	Yes	**1** + 2
VAMPIR	4	Yes	**3**
Break Room	-	No	-

(1) Frequentis systems bold

Server / Equipment Rooms

There are six server / equipment rooms: the Test Facility Room, Central Server Room, B/U Server Room Col, TQVS H/W, Archive and Col/MM Equipment. All rooms have access control and are air-conditioned. The rooms have double floor that contain the cabling runs. The equipment is stored in standard 19-inch server racks with all project dedicated servers hosted in the same rack.

Backup Concept

The backup servers of the Col-CC are (per ESA requirement) maintained in a physically separate building. This building also houses some backup components for Multi-Mission projects. The remaining backup components are accommodated in the same area as the main components.

Meeting Rooms

There are nine meeting rooms available for up to 124 participants. These are available for all projects and must be booked in advance.

Project-Specific Rooms

Various user rooms and meeting rooms can be dedicated to a special project or project phase (e.g. can be occupied during LEOP of a satellite for some weeks). This has to be decided on a case by case basis.

If you have questions concerning our Control Rooms, please don't hesitate to contact us.

Fig. 3-5 Worldwide-Network

3.2 GSOC Network & Datacenter Infrastructure

Information exchange via computers or mobile devices as well as data storage and availability have become one of the most important assets in our daily work. Today, the challenges for these basic IT services are the availability and the scalability.

The IT infrastructure at the German Space Operations Center (GSOC), including the Mobile Rocket Base (MORABA) in Oberpfaffenhofen (OP) as well as the Weilheim (WHM) Ground Station ZDBS (Zentralstation des Deutschen Bodensystems) is under the responsibility of and administrated by the DLR Space Operations and Astronaut Training (RB) network infrastructure and data center services groups (NIS and DCS teams).

The network was designed and built in the year 2002 in the framework of the Columbus Control Center activities. It consists of two hot redundant core areas distributed in two data centers. Following the information technology evolution in hard- and software and changing space project requirements, the network is under continuous development. The latest refurbishment of the core areas infrastructure was done from 2018 to 2020.

The Network Infrastructure Subsystem (NIS) implemented in GSOC (OP and WHM) supports all ISS-Columbus and satellite projects. It consists of switches, routers, security devices and connectivity hardware implemented to ensure high operational proficiency and data security, divided into different LANs separated by firewalls and demilitarized zones (DMZs).

Different LANs

- Office LAN (OFF): for internal office use and internet access
- Operations Support LAN (SUP): planning and operational support tasks
- Operational LAN (OPS): real time operations, carrying TM and TC data
- Management LAN (MGMT): out of band data center administration and monitoring

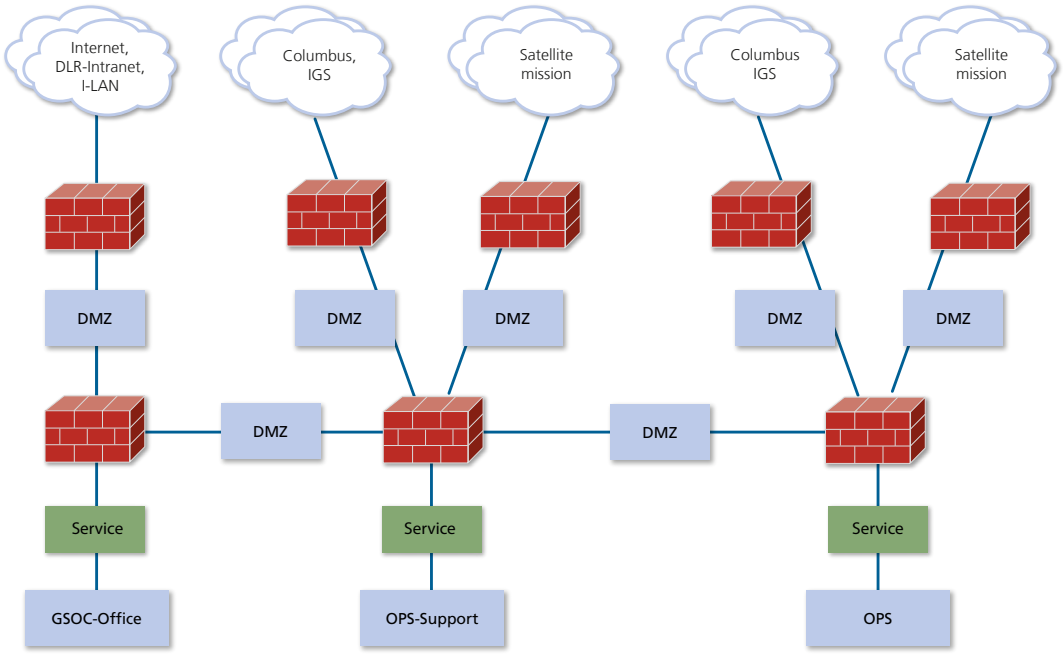


Fig. 3-6 Communication Network

The network areas (OFF, SUP, OPS) are based on a modern L3-datacenter-design and built on a complete redundant hardware platform. This platform was built to support actual and future technologies like virtualization, container-networking and SDN. For project purposes, operational areas at GSOC and Weilheim are connected to the respective project partners via dedicated lines (MPLS, leased lines, V-SAT, etc.).

Every area has its own service and security segment, hosting proxies, virus scanners, authentication, name, time and file servers. All basic network services have been hosted on virtual machines for several years. Besides those common services, complex space project services have been successively migrated into the virtual environment. Today, more than 95 % of all former physical server installations at GSOC have been converted into virtual machines. Virtualisation is nowadays also being implemented in the switching and firewalling infrastructure, resulting in a reduction of the hardware components in the data center.

Monitoring of services and network infrastructure

The GSOC ground control team monitors the Col-CC NIS elements using the Integrated Management Subsystem (IMS). The operational responsibility of the NIS resides with the GSOC-OP Network management group. The basic services of the NIS are monitored by the DLR developed software product NEMO.