EDRS Operations at GSOC- relevant heritage and new developments

Ralph Ballweg
DLR/GSOC, 82234 Oberpfaffenhofen, Germany

Dr. Frank Wallrapp
DLR/GSOC, 82234 Oberpfaffenhofen, Germany

This paper will illustrate previous GSOC missions with relevance to the EDRS program along with challenges and preliminary solutions for the EDRS constellation.

The EDRS network will include two communication payloads, one hosted on a dedicated spacecraft and one as piggy-back on a commercial satellite. EDRS is designed to reduce time delays in the transmission of large amounts of data and to allow faster access for the end users by using an optical Laser Communication Terminal (LCT) for the link between the LEO and the EDRS payload and a Ka-band link between the EDRS payload and the ground.

DLR's Operations Center (GSOC) role in the EDRS operations includes design, development and integration of ground infrastructure and operations of the satellites and ground stations.

Two challenging new technologies will be integrated in order to provide faster data turnaround times and downlink capabilities of up to 1800 Mbit/s: use of Ka-Band in the downlink and optical data transfer between satellites, which this paper will concentrate on.

GSOC already gained experience operating Laser Terminal in test scenarios on the TerraSAR spacecraft. This knowledge will be used to develop the EDRS operations concept. One major task is the planning of the laser connections and the required coordination between all parties. This paper will illustrate the development from the first activities at GSOC in connection with laser data transfer to a preliminary design of the operating system for the EDRS constellation.

I. Introduction

With the increasing amount of data being generated by earth observation satellites the traditional strategy of dumping the data during a ground station pass has reached its limits and is not feasible for future programs, like the European Global Monitoring for Environment and Security programme (GMES). It is estimated that this constellation will generate approx. 4 Terabytes per day.[1] Furthermore the need for timelier access to the data by the users is growing.

The characteristics of the ground station scenario are:

- Contacts with a spacecraft are only possible while direct visibility exists with the antenna. Unless the ground station is located in a polar region the number of such contacts are limited to 4 – 5 per day with an average time span of 10 – 12 minutes. This severely restricts the amount of data that can be downloaded and also the time commanding the spacecraft.

- Having the ground station in polar regions does increase the number of available satellite passes, but has the disadvantage of receiving the data at remote locations from where they have to be transferred to the end user.

The alternative is to place a relay satellite into geostationary orbit that is capable of transferring data with high rates in realtime or near realtime to ground stations with more favourable infrastructure or directly to the user. Part of this data transfer could be performed using laser technology to achieve the desired speed. This paper describes the technology and concept GSOC has been involved with in the operations of Laser Communication Terminals (LCTs) specifically designed for this purpose.

II. Data Relay Concept[2]

A schematic showing the concept of a geostationary data relay for earth observation data can be seen in Figure 1.

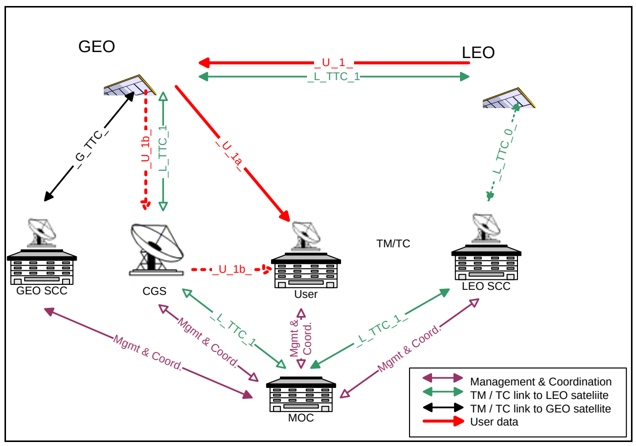

Fig 1: Concept of a GEO relay system for earth observation data

Components:

The components of the system are described in the following sections.

Low-Earth-Orbiting satellite (LEO)

The LEO is typically an earth observation satellite carrying one or more instruments that generate user data which have to be transferred to ground. In the conventional approach the data is transmitted to ground through ground stations for example in X-band (not shown in Fig. 1). In the case of a relay satellite the LEO transfers the data to the GEO satellite (link "U_1" in red). Consequently the LEO has to be equipped with a high-data rate LEO to GEO communication device. In order to be able to transfer large amounts of data, at least two technologies might be used:

1. Optical Communication with a Laser Terminal ("Laser Communication Terminal", LCT). Key figures and operational aspects are described briefly in chapter III.
2. Radio-Frequency Communication in Ka-Band. This technology and related operations are described briefly in chapter IV.

Note: for the sake of clarity, only one LEO is shown. In fact, various LEOs may use the relay satellite either in parallel or one after the other depending on the technical implementation.

LEO Satellite Control center (LEO SCC)

The LEO satellite control center operates the LEO satellite. It is responsible for housekeeping and payload operations. Among these tasks is the correct pointing and activation of the LEO to GEO communication device. For a correct pointing of the communication device towards the GEO the GEO orbit has to be known to the LEO SCC.

Geostationary Relay satellite (GEO)

The GEO receives the user data from the LEO satellite and relays it to ground. For this purpose it needs a receiver, which is compatible with the terminal of the LEO. Therefore the same technologies come into consideration, namely LCT or Ka-band. As for the LEO, these devices are usually steerable and have to be pointed towards the LEO, depending on the used technology.

To complete the relay function, the GEO needs a high data rate terminal to send the data to ground. The technology that can be used for this purpose is not dependent on the LEO to GEO link. To receive a comparable data rate Ka-band is used. The space to ground beam for a geostationary satellites may cover a very large portion of the earth which enables various ground stations spread over large distances to receive the data in parallel (link U_1a and U_1b in red).

GEO Satellite Control center (GEO SCC)

The GEO satellite control center operates the GEO satellite. It is responsible for housekeeping and payload operations. Among these tasks is the correct pointing and activation of the receiver. In order to correctly point the receiver to the direction of the LEO, the LEO orbit has to be known to the GEO SCC.

User Center

In the user center the data generated by the user platform aboard the LEO is processed. The data may be received at the user center directly with the user ground station (link U_1a) or from a central ground station from which it is transferred via conventional telecommunications infrastructure to the user (link U_1b).

Central Ground Station (CGS)

The central ground station receives and stores all data from all users. This enables checking of the correct execution of the data relay and storage of all data. Also, if a user does not have his own ground station, the user data may be transferred from the CGS to the user using conventional telecommunications infrastructure.

Mission Operation Center (MOC)

The MOC is the core component in the system. It interfaces with all other components and coordinates them. Its main purpose is to receive all the link requests from the different users and generate a link session timeline taking all known constraints into account. In addition it monitors and controls all involved infrastructure.

III. Key Technologies

The two key technologies under consideration for the relay tasks are Ka-Band RF and optical/Laser. The final design of the EDRS program led to the combination of Laser Communication Terminals (LCT) for the transfer from low earth orbiting satellites to the relay satellite and Ka-Band technology for the downlink of the data to the ground.

A. Laser Communication Terminals (LCT)

The LCT being used on TerraSAR was developed by TESAT Spacecom of Germany with funding by the German Space Agency DLR. It was designed with the goal of a high-rate data transfer from space to space and space to ground. Data rates of 5.625 GBit/s have been successfully demonstrated between the NFIRE and TerraSAR-X satellites. The distance between these satellites was 1000 km to 5000 km. The key figures for the LCTs which were verified in orbit are as follows[3]:

Mass:	35kg
Power:	120 W
Dimension:	0.5x0.5x0.6 m^3

Telescope diameter:	125 mm
Max Optical Transmit Power:	0.7 W
Bit Error Rate:	$< 10^{-9}$
Link Distance:	1000–5100 km
Link Duration	< 8 min
Data rate:	5.625 GBit/s

B. KA-Band Technology

Currently, there are several commercial satellite missions worldwide which provide high rate communication services at Ka-band frequencies (18-40 GHz) to various ground-based users. Putting in service higher frequencies allows several advantages. For example, Ka-band brings up to 600% link advantage over X-band. This advantage could be translated either into high data rate communication, longer distance of communication or smaller in size and therefore much more cost effective ground stations. Additionally, a smaller antenna beam of Ka-band ground station considerably reduces RF interference with other systems. In this respect, from one side the Ka-band technology is an inevitable part of the modern ground station complex which could be employed for future data relay satellites, but still a lot of effort is required to design, install and operate such a system.

IV. LCT operations development at GSOC

A. Operations TerraSAR X

GSOC became involved in LCT operations for the first time with the program TerraSAR-X, which hosted a Laser Communication Terminal as a secondary Payload. A second LCT is flying onboard the US satellite NIFIRE which is operated by the company Orbital Sciences Corporation (Orbital). NFIRE was launched in April of 2007 with TerraSAR following in June of the same year. GSOC is the operator of the TerraSAR-X and also commanding the LCT. The TerraSAR LCT is designed for two types of contacts, a satellite to ground link and Inter-Satellite-Links. As the objective in this case is test and evaluation of LCT operations the responsibilities are divided between GSOC as the satellite operator and the LCT manufacturer TESAT. The first LCT tests on TerraSAR were Spce-to-Ground links (SGL) performed with ground terminals located on DLR property in Oberpfaffenhofen near Munich and on the island of Tenerife. The first Inter-satellite Links were exercised starting January of 2007.

Essential to all LCT operations is the planning cycle which is an iterative process. Starting out with the different orbit information one party, in case of TerraSAR-NFIRE Inter-Satellite-Links (ISLs), Orbital, calculates the link options and makes a pre-selection with available links. GSOC then coordinates of the final link selection and publishes the deconflicted links to all parties. The two control centers for TerraSAR and NFIRE then prepare individually their respective LCT operations with input from the instrument manufacturer TESAT (in form of command input files) and their flight dynamics departments which are Chebychev coefficients for the LCT pointing. GSOC then produces the detailed sequence of events (SOE) and provides it to Tesat. After the links, GSOC and Orbital make a quick determination of the success of the operations and provide all the corresponding data to TESAT for evaluation. Results then flow into the input for the next links.
Occasionally other partners like the DLR Institute of Communication and Navigation (IKN) request the opportunity to perform Space–to-Ground-Links (SGLs) using their own optical ground stations. In that case those partners provide their objectives to TESAT for them to generate the LCT configuration files and GSOC again publishes the SOE and performs the operations.

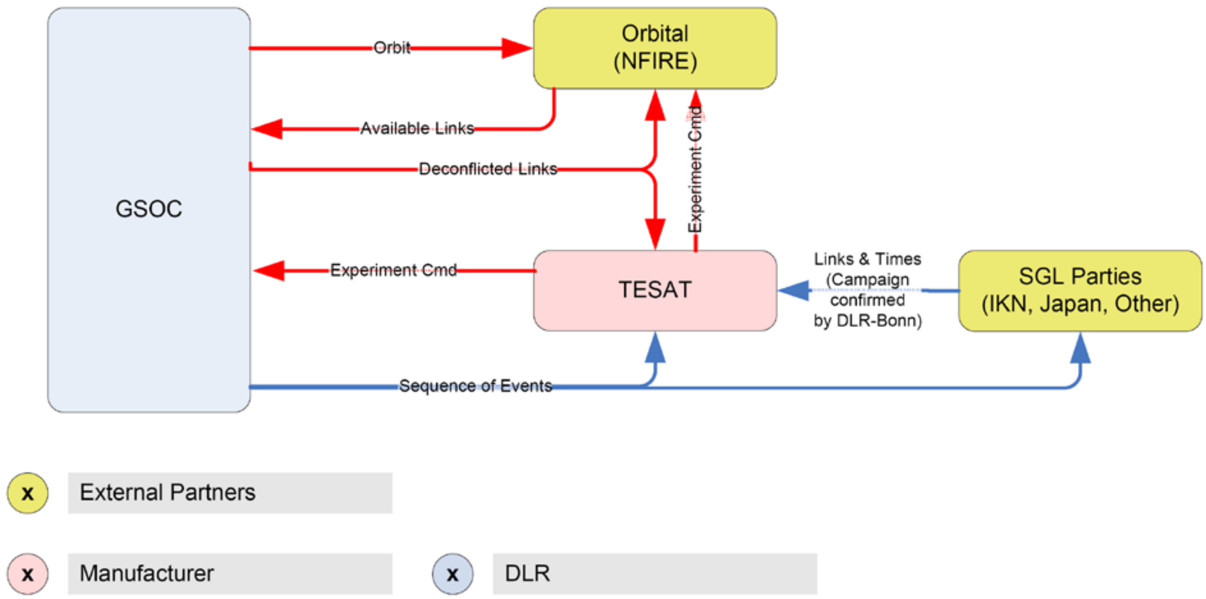

Fig 2: TerraSAR LCT operations concept

B. Concept TDP1

The next step in the evolution is the project TDP-1. TDP-1 is an experimental mission giving the proof of concept of a relay for earth observation data from LEO spacecraft via a GEO satellite using LASER as a transfer media. It is considered a precursor mission to the European Data Relay System (EDRS) project.

GSOC's objective in the program is to establish a control center for LCT relay operations providing end-to-end service of data transfer from a LEO spacecraft via a relay satellite to the final data user. That means in theory a handover of the data at the originating source, i.e. the LEO satellite and delivery to a dedicated ground station or end user. In practical terms GSOC will be capable to execute all data transfer functions, including the operations of all participating Laser terminals and RF equipment.

The TDP-1 payload hosted on a geostationary satellite consists of a laser communication terminal, mainly for the inter-satellite-link to a low earth orbiting spacecraft and a Ka-Band payload for the data downlink from the geostationary satellite. GSOC started preparatory design for the TDP-1 project in late 2011. The laser terminal also be pointed to an optical ground station, a functionality that will be used during the commissioning phase for calibration purposes. The launch of the geostationary relay satellite is currently scheduled for March of 2013 with the LEO customers to follow several months later.

The participating agencies it TDP-1 are the German Aerospace Center DLR as the contracting entity or customer, with its institutes GSOC and DFD, INMARSAT hosting the GEO payload, TESAT as the LCT manufacturer and the European Space Agency as the first LEO customers.

The concept of operations for GSOC is that GSOC collects the orbital information of all participating spacecraft and possibly the ground contact information of the LEO satellites. It then performs visibility calculations and publishes visibility reports for periods of one week and collects link requests. On a specific day GSOC forwards the final link selection to the TDP coordination office (TECO) at INMARSAT and receives feedback the next morning. Then GSOC prepares the command information for all participating laser terminals. The downlink from the ALPHASAT is received via Ka-Band at DLR's DFD Institute and the data is distributed from there. GSOC receives a report about the success of the link and LCT diagnostic data for Tesat for evaluation of the LCT performance.

The LCT terminal onboard ALPHASAT is also capable of contacting optical ground stations. This feature will be used for testing and calibration during the commissioning phase, when no LEO satellite is available. The first ISLs are planned for the first quarter of 2014.

The information being exchanged between the GSOC and the partners are:

LEO SCCs to GSOC: Orbit information, link requests, possible constraints, TLM
GSOC to LEO SCCs: Link possibilities, SOEs, LCT command inputs
INM/TECO to GSOC: Orbit information, deconflicted links, TLM, command logs
GSOC to INM/TECO: link list, SOE, command inputs, telemetry requests
Tesat to GSOC: link requests, command inputs
GSOC to Tesat: SOE, status reports, TLM, command logs

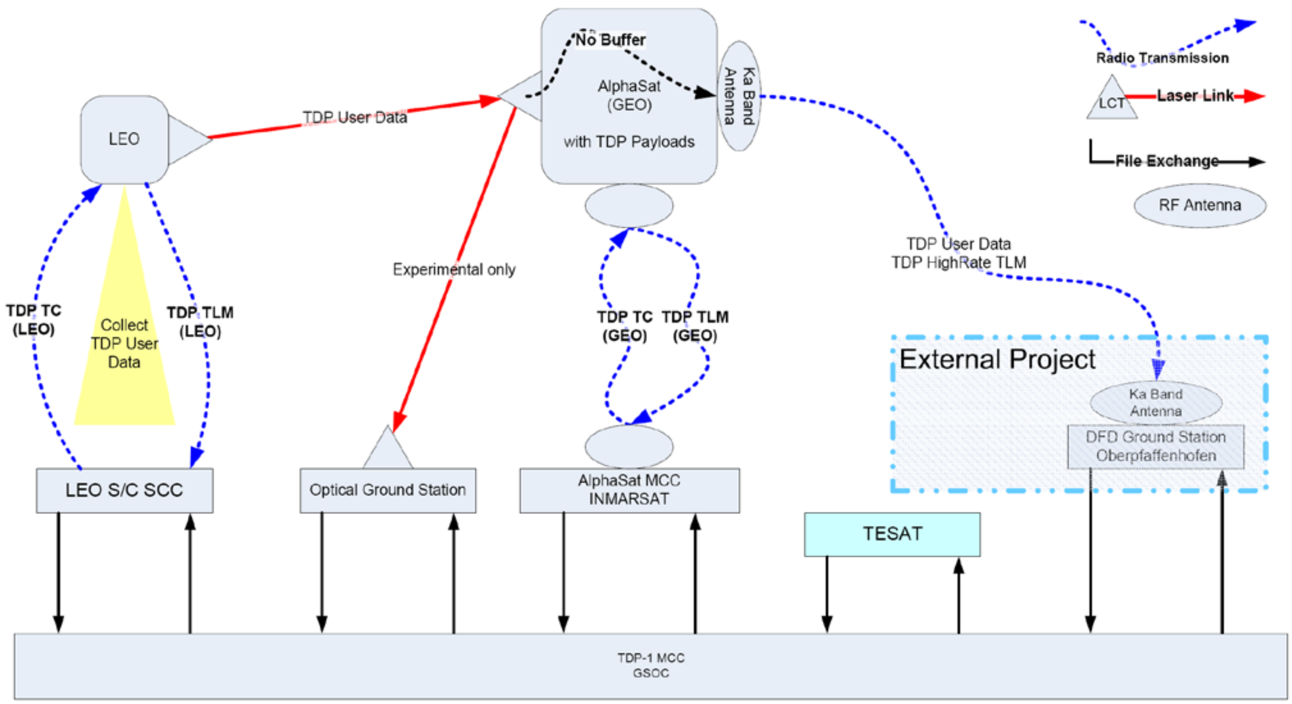

Fig 3: TDP-1 Project

C. EDRS Operations

The final step in the development is EDRS: Commercial operational transfer of data from low earth orbiting spacecraft via laser data links to a geostationary relay satellite and forwarding of the data to the end user.

EDRS is an ESA program for data relay featuring one dedicated satellite (EDRS-C) and one piggyback payload (EDRS-A). Both of them will be positioned in the geostationary orbit with visibility over central Europe. The dedicated satellite EDRS-C will be based on the new SmallGEO platform by OHB. The EDRS-A payload will be hosted on a EUTELSAT satellite. ESA will act as a major customer for Astrium paying for relay services of data from SENTINEL satellites. However the system is designed such that more customers can be integrated.
The link between the LEOs and the GEOs will be established through a Ka-band HF transponder or an optical laser communication terminal (LCT). For these links a data rate of 300Mbps (Ka-band) and 600 Mbps to 1800 Mbps is targeted (LCT). The data transfer between the GEO and ground will be established through a high bandwidth Ka-

Band link. Besides the main task, which is to relay earth observation data to ground (return link), the system will also feature the possibility to relay data from ground to the LEO spacecrafts (forward link).

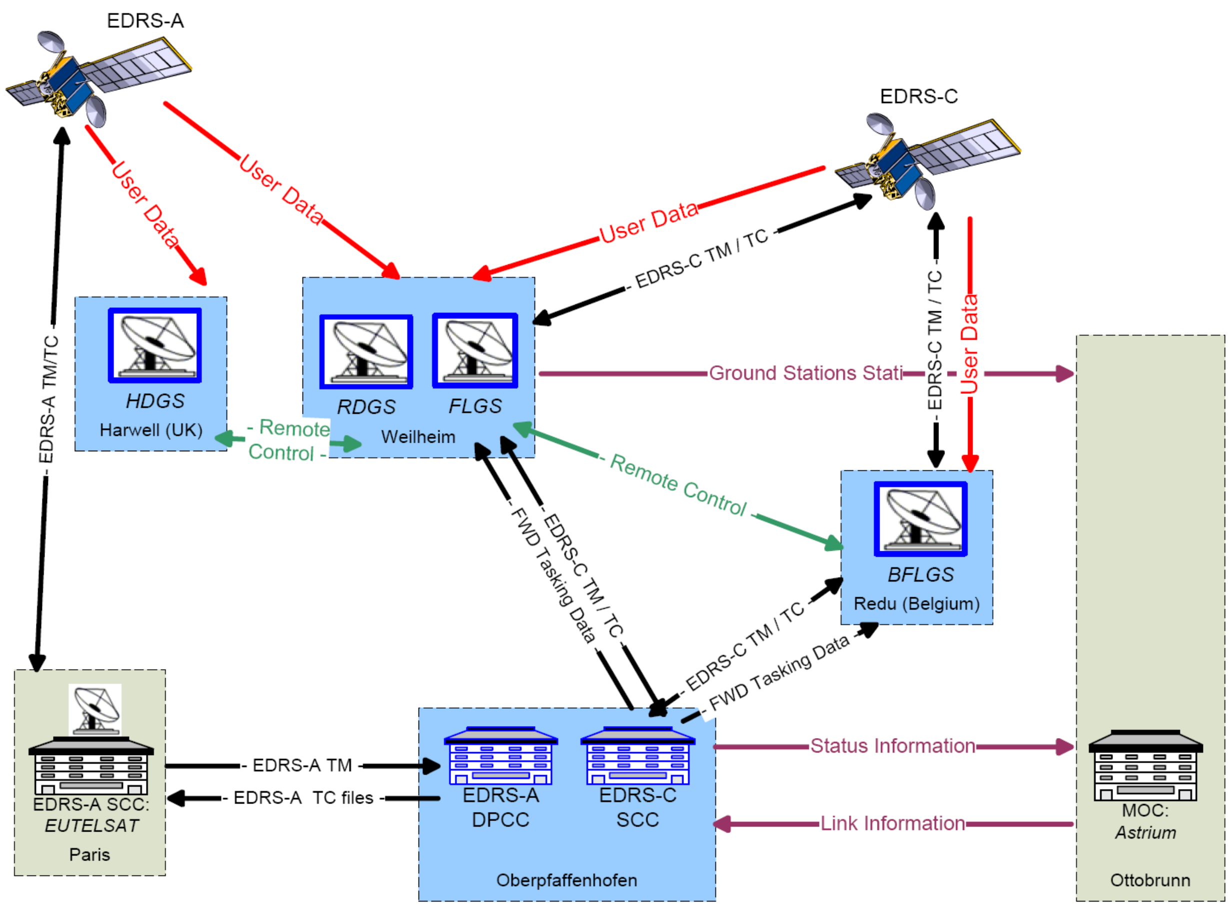

Fig 4: EDRS system layout

EDRS roles and responsibilities:

The Mission Operations Center (MOC), operated by Astrium Services, is the core of the EDRS activities. Its responsibilities are the coordination of the overall system, planning and scheduling of the links, management of User data keys, providing a User help desk for the customers and accounting and billing. Starting up to 75 days from a given T0 the MOC collects orbit predictions and operational constraints from all participating parties and publishes based on the evaluations possible link times. From T0-3 days to T0-8 hours the actual link planning takes place and the relevant planning information is sent to the individual SCCs for command generation and uploads.

GSOC will be in charge of performing the following tasks:

- Build-up and operations of the EDRS central ground stations in various places in Europe. All stations are operated from the DLR facilities in Weilheim. Stations located outside Weilheim are operated remotely using dedicated software developed at GSOC.
- Build-up and operations of the control centers for the EDRS-A payload, called Devolved Payload Control Center (DPCC) and the EDRS-C satellite (SCC). In the EDRS-A case, the TM/TC interface is connected to the Eutelsat SCC, from which the TM/TC data is transferred to the Eutelsat ground station controlling the EDRS-A host satellite. GSOC's role is to operate the EDRS payload onboard the host satellite. The EDRS-

A GEO SCC is thus shared between Eutelsat and GSOC. In case of the EDRS-C the TM/TC interface is connected to the EDRS ground station in Weilheim with the Redu station as backup. To this respect, GSOC fulfils the role of the EDRS-C GEO SCC.

In the operational phase GSOC will receive all link related information from the MOC with the exception of the pointing coefficients for the LCTs or the ILS Ka-Band antenna on EDRS-A.
The SCC/DPCC at GSOC will be designed to process up to 120 link requests per day and satellite, calculate LCT pointing angels, generate commands, manage the S/C time-tag-buffers, enable correct user data-encryption keys and log every activity for failure analysis.

For EDRS-A specifically the DPCC also has to calculate the Ka-band ISL antenna pointing angles, generate and send command information according to the ICD with Eutelsat, analyze the relevant host satellite TLM and coordinate all activities with Eutelsat.

D. Conclusion

At this time GSOC already has close to 5 years experience operating laser communication terminals for space-to-ground and inter-satellite links. The TDP-1 project will incorporate the GSOC mission planning system into the operational concept and with the implementation of the EDRS operations center we will be the leading control center for the operation of satellite data relay systems based on laser data transfer.

Appendix A
Acronym List

ABLE	Atmospheric Boundary Layer Experiment
DLR	German Center for Aerospace
DPCC	Devolved Payload Control Center
DFD	German Remote Sensing Data Center (Deutsches Fernerkundungs Datenzentrum)
EDRS	European Data Relay Satellite
(B)FLGS	(Backup) Feeder Link Ground Station
GEO	Geo Stationary (satellite)
GMES	Global Monitoring for Environment and Security
GSOC	German Space Operations Center
HDGS	Harwell Data Ground Station
ICD	Interface Control Document
ISL	Inter Satellite Link
LCT	Laser Communication Terminal
LEO	Low Earth Orbit (satellite)
MOC	Mission Operations Center
RDGS	Reference Data Ground Station
SCC	Satellite Control Center
SGL	Space to Ground Link
TDP-1	Technology Demonstration Program 1
TECO	TDP ESA Coordination Office
TLM	Telemetry

References

Reports, Theses, and Individual Papers

[1]"*The Sentinels/EDRS Operations Constraints and Concept*", ESTEC, 2010

[2]Wallrapp, F., Ballweg R. and Gataullin, Y, "*The European Data Relay System (EDRS) Operational Challenges*", IAC-11.B6.2.4, 2011

[3] Gregory M., „*Tesat laser communication terminal performance results on 5.6 GBit coherent intersatellite and satellite to ground links*", International Conference on Space Optics, 4 -8 October 2010