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# The EDRS mission and its operational experiences to date from GSOC perspective

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**Abstract**

Since 2016, the European Data Relay System (EDRS) – also known as SpaceDataHighway – is serving as a geostationary (GEO) relay system offering unique laser communication services for satellites of the low earth orbit (LEO). As the satellite market evolves, today´s LEO satellites produce more accurate, more precise, and more detailed data, and thus struggle with the task of bringing huge amounts of data to ground. EDRS offers a convenient solution to that challenge by its data transfer service via its GEO nodes to ground. In addition to this basic concept, the EDRS mission also involves the technology of optical communication: the space-to-space link is performed in optical frequencies by the means of so-called Laser Communication Terminals (LCTs), offering a secure and high-speed data transfer.

Currently, EDRS consists of two nodes: EDRS-A is a hosted payload on the Eutelsat-9B satellite which was launched in January 2016. It was complemented by the satellite EDRS-C, launched in August 2019, dedicated for the EDRS mission. Both payloads, as well as the EDRS-C satellite platform, are operated by the German Space Operations Center (GSOC), which is part of the German Aerospace Center (DLR). The EDRS program itself is a public-private partnership between ESA and Airbus Defence and Space as the industrial prime contractor. The LCTs are manufactured by TESAT Spacecom, while the 3-ton-class SmallGEO platform built by OHB is the satellite bus for EDRS-C. In addition to the LCTs, which are the prime payloads on both nodes, GSOC also operates a Ka-Band relay antenna as supplementing part of the EDRS mission, a Ka-Band transponder for AVANTI Communications, as well as a radiation monitor of ESA as secondary payloads.

The EDRS system is capable of performing up to 200 communication links with LEO satellites per node and per day. Until mid of 2023, though, the EDRS mission will consist of seven LEO customer satellites, as well as one Ka-band customer antenna (ColKa) on the Columbus module of the International Space Station ISS. All of them are using the EDRS service either via laser communication or the secondary Ka-band antenna. The high numbers of possible links as well as customer satellites pose a challenging task to the control centers at GSOC. For this reason, both LCTs are controlled using an automated operations engine, which is designed to supervise the complete cycle of telecommand uplink and execution as well as reaction monitoring of telemetry, giving GSOC permanent control and awareness. The system has proven to be very robust, is routinely used and led to over 60.000 successful optical links until mid of 2022. This paper gives an overview over the EDRS mission and shows how GSOC organises and performs EDRS-A and EDRS-C operations. It also describes how both operations evolved during the course of the project, which harmonisations were performed, and gives an outlook on how the future of the program might look from a GSOC perspective.
**Keywords:** EDRS, laser communication, data relay system.

**Acronyms/Abbreviations**

European Data Relay System (EDRS), geostationary (GEO), low earth orbit (LEO), Laser Communication Terminal (LCT), German Space Operations Center (GSOC), Ka-band customer antenna (ColKa), Technology

Demonstration Payload No.1 (TDP-1), Pléiades Neo (PNEO), International Space Station (ISS), Devolved Payload Control Center (DPCC), Satellite Control Center (SCC), Mission Operations Center (MOC) .

## 1. Introduction

It was with the first Starlink Satellites launched into low earth orbit (LEO) a few years ago, that searching for satellites on the night sky with bare eye became more and more popular. In fact, the number of LEO satellites orbiting and observing earth is continuously rising. However, not only are there more and more satellites in space, but all of these produce data in higher quality and/or resolution than ever before [1]. This can be compared to the well-known development of mobile phones: the cameras installed onto the small phone devices made huge advancements in the last years, and produce pictures of increasing quality and image resolution. This progress also holds for the satellite market. Concerning LEO satellites, a huge part of this data consists of images of the ground – using different parts of the electromagnetic spectrum –, and measurements of all kinds like e.g. radiation measurements, quantifications of the earth´s gravitational field, etc.

Fig. 1. TerraSAR-X, an example of a satellite with a Laser Communication Terminal on board, operated by the German Space Operations Center.

A bottleneck to this development of "more satellites, more data" lies in the capability of sending the huge amount of data back from space to ground, preferable in a reasonable time frame before the data might become too old to be useful.

Two ideas offer a solution to these problems: Laser communication and relay systems. Both concepts are used in the European Data Relay System (EDRS) mission.

Laser communication describes the transfer of information via the optical frequencies of the electromagnetic spectrum. Currently, radio frequency systems are still the most common way of data transfer in space, though, but there is more and more investment and progress in the field of optical frequencies [2]. Laser communication offers in general the possibility of higher transfer rates than radio frequency. Simply put, there are more electromagnetic waves per length unit to be modulated, i.e. to transport information [3-6].

In this context, a relay system refers to the usage of a relay satellite, in the case of EDRS a geostationary (GEO) satellite, that can be used by the LEO customers to route their data to its final destination on earth. Compared to the direct transfer to a ground station, its huge advantage is the high availability. The visibility of the GEO as seen from the LEO satellite is basically half of each LEO orbit, being drastically more than the visibility of a ground station. This allows for longer communication times and thus more transferred data, as well as shorter periods between data take and data reception on ground [3-6]. In addition, the number of necessary ground stations for the LEO satellites can be reduced, obviously.

While a relay system is in general a separate concept and can be used without the application of laser communication, the combination of both leads to advantages. In particular, optical communication works best for satellite-to-satellite links, since it can be disturbed by effects in the atmosphere as it is the case for space-to-ground links. However, laser communication does work and is in fact a very successful concept for the latter case as well [7].

The German Space Operations Center (GSOC), part of the German Aerospace Center (DLR) and located in Oberpfaffenhofen near Munich, operates already several spacecraft that involve laser communication. These missions cover a broad spectrum of different types of satellite missions: With the TerraSAR-X satellite (see Fig. 1), LEO-LEO as well as LEO-Ground-links have been performed [8,9,12]. In contrast to this 1.2 ton satellite, the CubeL mission (also referred to as PIXL-1) aims for LEO-Ground-links from a Cubesat [21,22]. The TDP-1 ("Technology Demonstration Payload No.1") mission, a predecessor of EDRS, uses a payload for laser communication on the geostationary Alphasat satellite to perform experimental LEO-GEO-links [3,10,11,12]. EDRS itself offers the same kind of links as part of a unique commercial service with high performance requirements of transferring data of LEO customer satellites to ground [12-18].

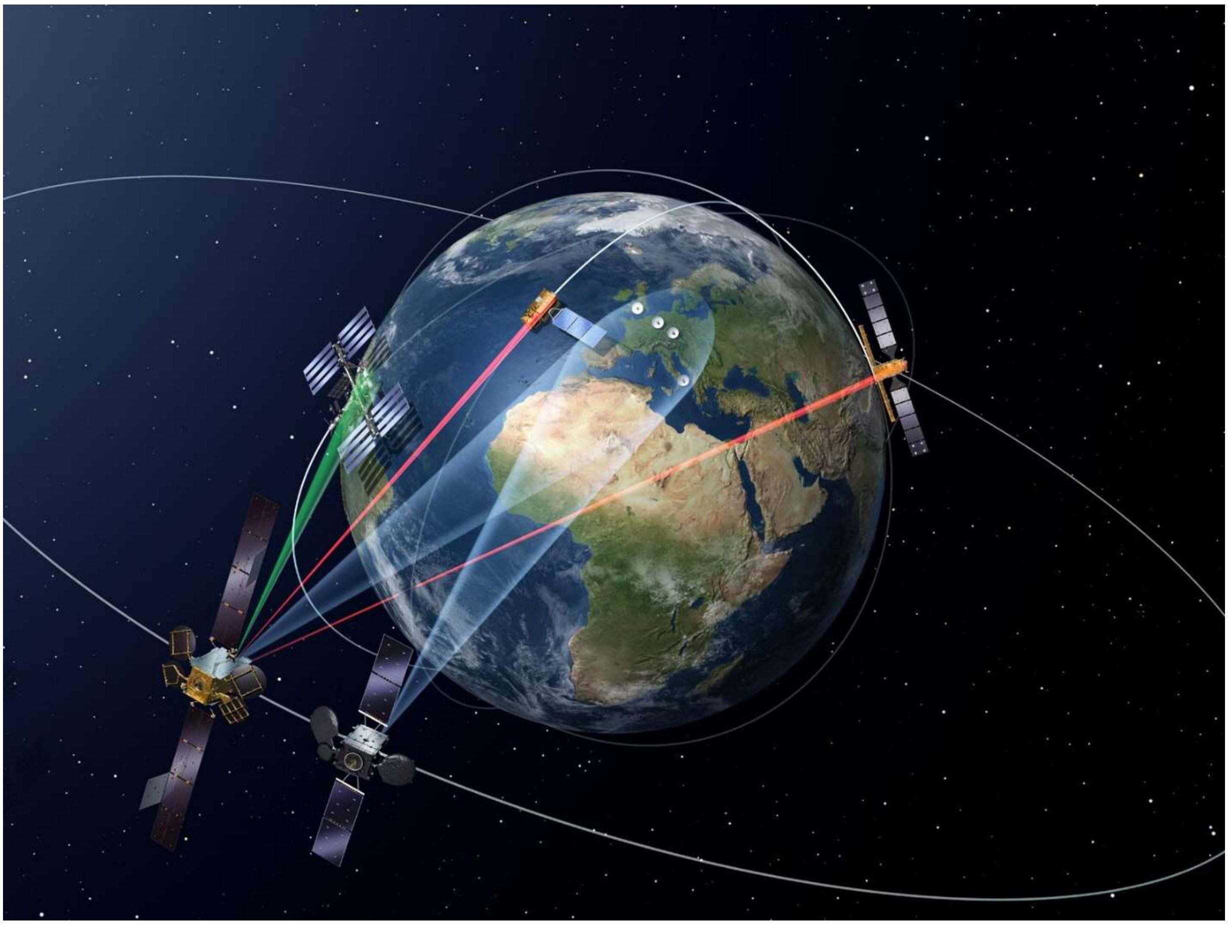

Fig. 2. An illustration of the SpaceDataHighway: EDRS-A and EDRS-C covering the hemisphere over Europe and Africa. Its data relay service (red lines: optical frequencies, green line: radio frequencies) is used by several LEO customers, while the data is routed to ground stations across Europe (white lines). (Courtesy of Airbus)

## 2. The EDRS mission

The EDRS project is often referred to as SpaceDataHighway, an expression that quite appropriately describes the basic idea of a high-speed data transfer service in space. The mission itself is a public-private partnership between ESA and Airbus Defence and Space as prime contractor and system operator in frame of the Advanced Research in Telecommunications Systems program (ARTES-7). DLR is responsible for major parts of the ground system.

Currently, EDRS consists of two GEO nodes: EDRS-A and EDRS-C. It was planned that these two satellites serve as communication relays for nine LEO customers until mid of 2023. Unfortunately, due to the failed launch of the second flight of Arianespace´s Vega C on December 20th 2022 [19], two of those customers, namely Pléiades Neo (PNEO) 5 and 6 will not be part of the customer group for now. Still, there remains a total of seven LEO customers using EDRS in the very near future, six of those using it already now, and the perspective of even more users in the future. An illustration of the SpaceDataHighway communicating with three LEO counterparts is given in Fig. 2.

All laser communication in the framework of EDRS is performed by Laser Communication Terminals (LCTs) manufactured by TESAT Spacecom; see Fig. 3 for an example of such a LCT. For the current EDRS nodes, these LCTs allow LEO-GEO-links in the optical spectrum with data rates up to 1.8 Gbit per second, which is an increase by a factor of 3.5 when compared to conventional X-band downlink rates. Newer versions of the LCT even support 3.6 Gbit per second.

EDRS-A consists of a LCT as well as a radio frequency payload (in Ka-band) on board of the GEO Eutelsat-9B satellite. It was launched in January 2016. The radio frequency payload offers an equivalent relay service as its optical counterpart. EDRS-C, on the other hand, describes a whole dedicated GEO satellite on its own and was launched in August 2019. It is based on the smallGEO platform developed by OHB. As EDRS-A, this satellite has a LCT on board to provide the optical data services. Besides this LCT, EDRS-C contains two additional secondary payloads: the HYLAS-3 Ka-band payload of Avanti, offering a commercial RF communication service, and ESA's Next Generation Radiation Monitor NGRM. Both EDRS satellites cover a hemisphere that includes Europe, with a position at 9° E and 31° E, respectively, roughly indicated in Fig. 2.

Four of the above mentioned seven (partially future) customers of EDRS are the LEO satellites of the Sentinel missions. These are part of the Copernicus Program of the European Union. Currently, three of these (Sentinel-1A, -2A, and -2B.) are in orbit and use EDRS for their data downlinks. Another one (Sentinel-1B) has been using the SpaceDataHighway until end of 2021, and will be de-orbited in the near future. Last but not least, the newest EDRS customer Sentinel-1C is planned to launch in Q2 of 2023. Another current customer is the Columbus Laboratory on the International Space Station (ISS), which is using the RF relay service on EDRS-A via a Ka-Band antenna. Since this is in contrast to the 'default' laser communication service of EDRS, it is illustrated in Fig. 2 with a green line compared to the red lines representing the optical frequencies. The last two customers of EDRS are the Pléiades NEO 3 and 4 satellites, that have been launched in April and August of 2021, respectively. Just as the Columbus Laboratory, these satellites use the Ka-band relay service.

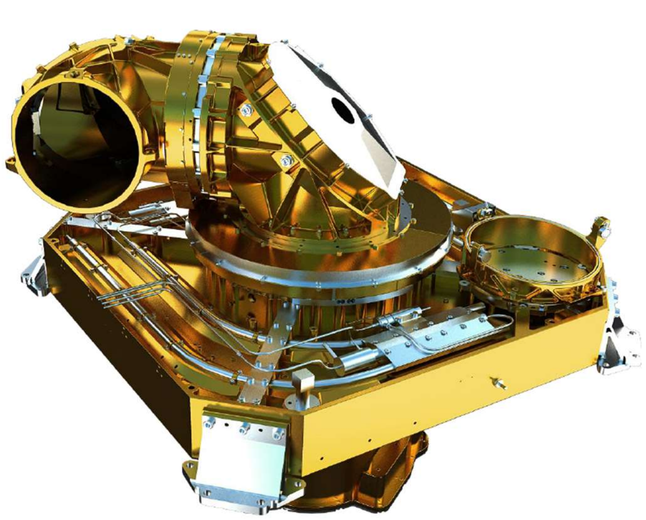

Fig. 3. An example of a Laser Communication Terminal manufactured by TESAT Spacecom, as it is used for the EDRS mission. (Courtesy of TESAT Spacecom)

## 3. EDRS Operations and its experiences to date

Concerning EDRS operations, GSOC is a central part. In principle, it fulfils two major tasks in this framework: For EDRS-A, it is assigned to fulfil the role of the Devolved Payload Control Center (DPCC). This implies all operations of the LCT as well as the RF payload on board the Eutelsat-9B. For EDRS-C, this role is extended to the operations of the whole satellite, meaning GSOC is in this case the Satellite Control Center (SCC). In both of these roles, GSOC is in close contact to the Mission Operations Center (MOC) in Ottobrunn, Germany, which is under responsibility of Airbus Defence and Space. At the MOC, the link planning and scheduling for EDRS is performed. Thus, it is also the interface to the LEO SCCs as for example the ESOC in Darmstadt, Germany, for the Sentinel Satellites. The DPCC is of course additionally in close contact to the EDRS-A SCC of Eutelsat, operating the hosted satellite Eutelsat-9B itself. An overview of this concept is illustrated in Fig. 4.

It is worth noticing, that the performance requirements for the availability of the communication service are set to a very high standard. For this reason, the payload is controlled using a very advanced but robust automated operations engine, which is designed to supervise the complete cycle of telecommand uplink and execution, as well as reaction monitoring of telemetry [14, 15, 17]. This holds for both EDRS-A and -C.

Until today, the results of these operations are very satisfying. The primary objective is of course performing the laser links between the LEO and the GEO satellites. Table 1 lists the number of successful links, the sum of communication time in minutes, as well as the sum of transmitted data in terabyte from mission start until 2022 (included), for both EDRS-A and EDRS-C. Hereby, only the data transmissions via the LCT (and not the RF links) are taken into account, and the communication time only refers to the sole communication itself, not counting the time intervals in which the LCT is preparing the link (e.g. performing spatial as well as a frequential acquisition), or moving back to parking position. Summed up, the communication time is close to the amount of 1,000,000 minutes, a value that is possibly already reached the moment this paper is published. The corresponding number of laser links amounts to more than 67,000, the transmitted data is 3,931 terabyte in total. The values of these indices are not equally distributed between EDRS-A and EDRS-C. On the one hand, this is due to the obvious fact that EDRS-A was launched and thus began its operations earlier in time. On the other hand, a more equal distribution between the daily number of laser links between the two GEO nodes was implemented just recently. Thus, the gap between the numbers of the mentioned indices should slowly decline in the future.

Second are the Ka-band links of EDRS-A. This service is not used by the Sentinel satellites, who make use of the faster optical communication instead, but by the more recent LEO customers PNEO 3+4 as well as the Columbus module on the ISS. The amount of links to date is thus not as high as for the optical counterpart. From an operational experience, however, these Ka-band links are as successfully working as the laser connections.

It is worth noticing, that PNEO 5+6 would have used both the laser as well as the Ka-band link service of the SpaceDataHighway.

From a ground system perspective, it is important to mention, that all EDRS customers have successfully been implemented into the setup. While the first four Sentinel-Satellites are already part of the mission since some time, this is especially worth mentioning for the more recent implementations of PNEO 3+4 as well as the Ka-band antenna of Columbus on the ISS. Each of the commissioning and in-orbit testing phases could be successfully supported by GSOC.

In addition, the system itself is constantly improved. One current example is the automatisation of station-keeping maneuvres for EDRS-C. For more information on this challenging topic, we refer to [20]. Other former examples can be found in [14-17].

Table 1. Major performance indices of the EDRS service until 31st of December 2022.

| | via EDRS-A | via EDRS-C | Total |
|---|---|---|---|
| Number of successful links | 61,904 | 5,159 | 67,063 |
| Communication time in minutes | 887,405 | 66,933 | 954,338 |
| Transmitted date in terabyte | 3,655 | 276 | 3,931 |

The operations of EDRS by GSOC have not only made technical enhancements, but have also been improved in terms of organisation and management. The launch of EDRS-C happened during a time where EDRS-A was already operational. Since a launch is always a phase of high resource usage – not only but especially in terms of personnel –, different teams have been responsible for the two above mentioned DPCC and SCC tasks. During routine operations, as it is the status for both satellites to date, such a discrepancy between the teams can possibly make a project less flexible. Also, the information flow might occasionally be impaired, like e.g. a known anomaly in one part of the project might be unknown to the other. To maintain the project flexibility, common tasks have been merged in terms of one combined project organisation, while simultaneously taking the differences between DPCC and SCC into account more precisely. This is e.g. reflected in combined teams for similar subsystems, the usage of common tools, and a more combined appearance towards internal and external parties.

One other organisational aspect in GSOC´s operations for EDRS in the last years has of course been the Covid-19 pandemic situation. Fortunately, the impact on the mission could be reduced to nearly zero. On the one hand, a part of the operational tasks could be moved to home office. This is basically the usual way many companies coped with the challenges of Covid-19. However, for a mission concept as the one of EDRS, it is nearly impossible to shift all work to home office. The remaining tasks had still to be performed at GSOC premises, but this was done under the consideration of hygienic rules, organisational rules like tests or separated control rooms and workplaces, and a combined effort of all parties in terms of flexibility. As a result, the daily operations and the safety of the satellites were never affected. Only less important changes have been implemented with a time delay. This can be seen as a huge success, especially when comparing it with the impact Covid-19 had on many parts of our lives.

## 4. Outlook

As already mentioned above, the EDRS mission will receive another LEO customer in the near future with the launch of Sentinel-1c, planned for the first half of 2023. From GSOC perspective, it is expected to be certain that even more customer satellites will make use of the high-speed data service.

In addition, to cope for the increasing number of LEO users, more GEO nodes are planned. The first one is EDRS-D. In contrast to the current two GEO satellites, EDRS-D will cover the Asian / Western Pacific region, thus offering the downlink service not only, but especially towards data receivers in e.g. Japan, South Korea, and Australia. With another GEO node over the American region, as it is planned for EDRS-E, an EDRS GEO node would be available from every spot a LEO satellite could be located.

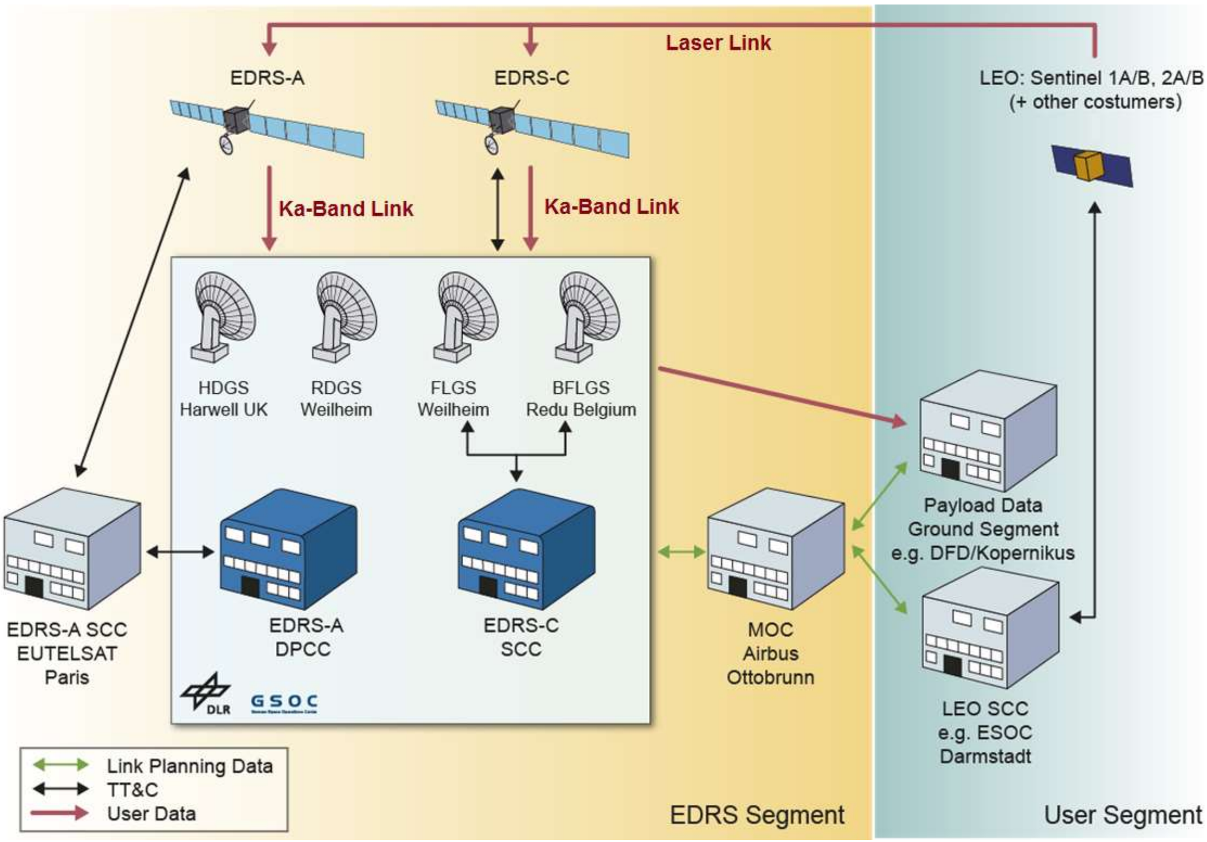


Fig. 4. Overview of the EDRS mission concept highlighting the main connections between the involved entities. The blue box in the center illustrates the two different tasks of GSOC: Devolved Payload Control Center (DPCC) for EDRS-A as well as S/C and Payload Control Center (SCC) for EDRS-C. Figure taken from [14].

Although some tasks are currently still in development as mentioned above, both the technical and organisational aspects of EDRS operations at GSOC have reached a satisfying level, with both projects in routine phase. During the future course of the mission, though, it is planned to constantly watch out for possible further improvements, as the mission can be expected to last for a long time.

## 5. Conclusions

Laser communication offers high-speed data transmission, a feature which is highly needed for today´s amount of data produced by the growing satellite market. This technology harmonizes well with the idea of a relay service, a fact which is the basis for the concept behind EDRS. This mission and its operational experience from the perspective of DPCC for EDRS-A and SCC for EDRS-C, both under the responsibility of GSOC, have been presented in this paper. The laser link service has been proven to be very reliable and is extensively used by several LEO customers. The secondary Ka-band link service, although in use for a shorter time frame, is also operationally successful with a growing number of links every day. The ground system of GSOC has been further technically enhanced throughout the mission, supporting the addition of new customers as well as implementing new features, a task which is partially still ongoing. But also the organisational aspects of the mission have been and will be constantly improved, which is especially important for long-term missions like EDRS. It is expected, that the mission will grow both in LEO customers as well as GEO nodes, enabling an easier handling of large amounts of data for even more future satellite missions.

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