EDRS-C – Challenging Way of Bringing the Second Orbital Node into Space

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Abstract

The European Data Relay System (EDRS), also known as the SpaceDataHighway, is designed to provide commercial data relay service to spacecraft in low earth orbit (LEO). It offers high data rates and short response times and uses optical and Ka-band links for two-way data transmissions. The project was established by the European Space Agency ESA in frame of the Advanced Research in Telecommunications Systems program (ARTES-7). ESA is also acting as an anchor customer contributing LEO missions from their Copernicus Program. The EDRS project was organized as a public private partnership (PPP) with the industrial prime contractor Airbus Defence and Space. Airbus owns, operates and provides commercial services for the SpaceDataHighway.

With EDRS-A, the first orbital node of the system started routine operations in late 2016. It is a hosted payload on the Eutelsat 9B spacecraft and is operated by the German Space Operations Center (GSOC) in a mostly automated way. In a second step, EDRS-C, a complete satellite has been added. This time, GSOC is responsible for both, platform and payload operations.

GSOC's work for EDRS-C was organized in two parts. The first part covered the preparation and execution of the LEOP as well as the in-orbit tests of platform and payload. The payload consists of 3 elements, the data relay equipment for EDRS, The HYLAS 3 Ka-band communication payload of Avanti, and ESA's Next Generation Radiation Monitor NGRM. The spacecraft is a 3-ton-class SmallGEO platform built by OHB Bremen, Germany, which was already operated by GSOC during the maiden flight, the Hispasat Advanced Generation 1 (HAG1) mission in 2017. For EDRS-C, the challenge was not only to perform another LEOP and IOT, but also to have the next project phase in view, the routine operations for platform and payload.

The second part comprised the development and implementation of the ground segment for EDRS-C, and the execution of mission operations for the 15 years routine phase. It was initially planned to do this in parallel to the LEOP and IOT preparations, but after coordination with the customer, a step-by-step approach was agreed. This approach allowed concentrating on the LEOP and IOT tasks in order to gain a timely launch readiness. As a consequence, the routine phase related components and operational products had to be completed in parallel to the already ongoing IOT operations.

This paper will give an overview of the EDRS-C mission and emphasize the challenges of the step-wise approach to prepare LEOP, IOT, and routine phase operation. It explains the integration of the new satellite with different technology into the existing SpaceDataHighway network, delivers an insight into the project management approach at GSOC for the different work tasks and contracts, and illustrates the harmonization of the EDRS-A and C payload operations. EDRS-C was launched in August 2019. The in-orbit test phase for platform and payload was completed successfully and the operational services could be started in 2020, so this paper can provide an up-to-date status of the mission. In addition, an outlook is given to adaptations and improvements of GSOC's ground segment components in preparation of further extension of the SpaceDataHighway fleet.

Keywords: SpaceDataHighway, EDRS, Mission Operations, Management, Project Management

1. Introduction

In recent years, the optical part of the frequency spectrum has gained more and more significance in the field of satellite communication [2]. In principle, there are two basic possibilities on how to use laser communication: Satellite-to-ground or satellite-to-satellite.

The first option enables a direct download to optical ground stations, just like ‘regular’ operations in radio frequency work. However, the optical frequencies are more vulnerable to influences of the atmosphere. Thus, the satellite-to-ground laser communication bears several challenges [3].

The second option, satellite-to-satellite, avoids these problems by using the laser communication only in free space, offering the possibility of very high data rates. These can be put into effect e.g. in combination with the idea of a relay satellite in geostationary orbit (GEO): A satellite in low earth orbit (LEO) could downlink its data via a detour over this relay satellite, using optical frequencies for the communication LEO-GEO and radio frequencies for

GEO-Ground. Due to its geostationary position, the relay satellite offers a permanent contact to ground, and a visibility towards the LEO satellite for half of the LEO´s orbit. Therefore, this downlink concept offers not only high data rates but also the possibility of data downlinks in (near-) real-time.

A perfect example for a successful application of this concept is the European Data Relay System (EDRS), also known as SpaceDataHighway [4 – 11]. It currently consists of the two geostationary nodes EDRS-A and EDRS-C, that are operated by the German Space Operation Center (GSOC) in Oberpfaffenhofen, near Munich, Germany. GSOC has already experience with the operation of laser communication technology in different satellite missions like TerraSAR-X [12, 13], TDP-1 [14 – 17] and CubeL [4].

In this paper we focus on different aspects of EDRS. In the following chapter 2, we will give a short introduction to the EDRS concept and its mission. In chapter 3, we describe the approach for the EDRS-C launch from a management perspective. The current status of EDRS will be discussed in chapter 4. We conclude and give an outlook to the next steps of the SpaceDataHighway in chapter 5.

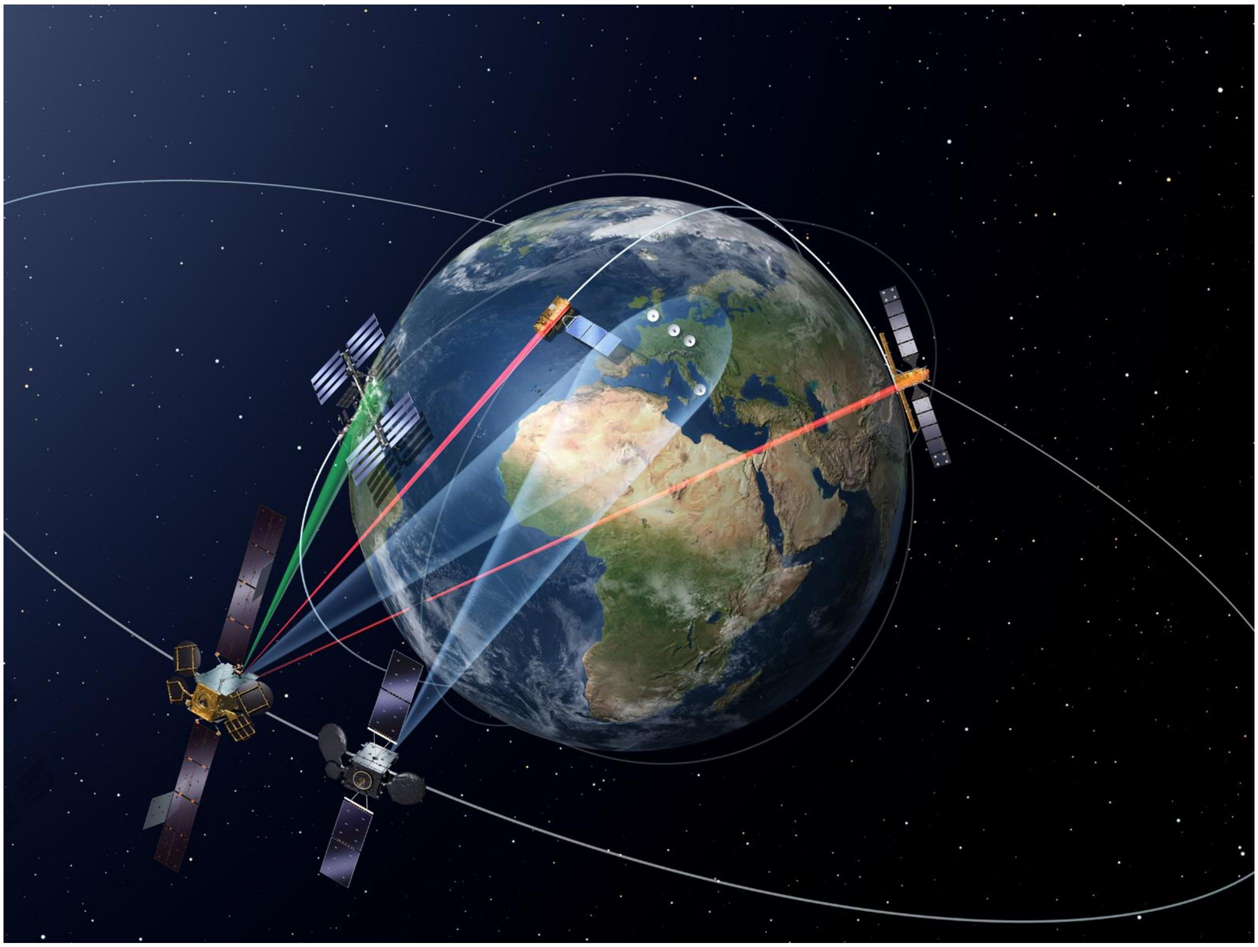

Figure 1: The current status of GEO segment of the Space Data Highway: EDRS-A and EDRS-C covering the hemisphere over Europe.

2. Overview SpaceDataHighway

EDRS was established by the European Space Agency ESA in frame of the Advanced Research in Telecommunications Systems program (ARTES-7). It is a public-private partnership between ESA and Airbus Defence & Space as prime contractor and system operator. DLR is responsible for major parts of the ground operations network.

The concept behind the project is a relay system on basis of GEO satellites. As described in section 1, these GEO data relay satellites offer a downlink service for LEO user satellites. The user satellite needs a so-called Laser Communication Terminal (LCT) to be able to communicate with the GEO relay satellites. These LCT payloads are manufactured by TESAT Spacecom. For the current EDRS nodes, these LCTs allow optical Inter-Satellite Links (ISLs) with data rates up to 1,800 Mbit per second, which is an increase by a factor of 3.5 when compared to conventional X-band downlink rates.

The first customers of EDRS are the four LEO satellites Sentinel-1A, -1B, -2A, and -2B. These are part of the Copernicus Program of the European Union. With this contribution, ESA is hereby acting as an anchor customer. Another user is the Columbus Laboratory on the International Space Station, which is connected to the EDRS system via a Ka-Band antenna (thus this project is also known as “ColKa”). ColKa is not using the ‘regular’ optical terminal as the other customers, but uses the relay service in Ka-Band, which is offered only by the first node of EDRS, namely EDRS-A. The ColKa terminal is now onboard the ISS/Columbus module and undergoing In-Orbit testing, which so far has been successful. The next customers of EDRS will be the four Pléiades NEO satellites, that are planned to be launched in 2021 and 2022. Ground segment testing of the EDRS-A systems to support Pleiades-NEO utilising the MOC (Airbus) and the DPCC have also recently been performed successfully,

In terms of GEO relay satellites, EDRS currently consists of two nodes: EDRS-A and EDRS-C. EDRS-A is a payload on the Eutelsat 9B satellite, which was launched in January 2016. EDRS-C, in turn, is a complete satellite on its own and was launched in August 2019. It is based on the recent smallGEO platform developed by OHB. This platform was already operated by GSOC during the Launch and Early Orbit Phase (LEOP) of the maiden flight, the Hispasat Advanced Generation 1 (HAG1) mission in 2017. Besides the LCT, EDRS-C contains two additional secondary payloads, namely the HYLAS 3 Ka-band payload of Avanti, offering a commercial RF communication service, and ESA's Next Generation Radiation Monitor NGRM.

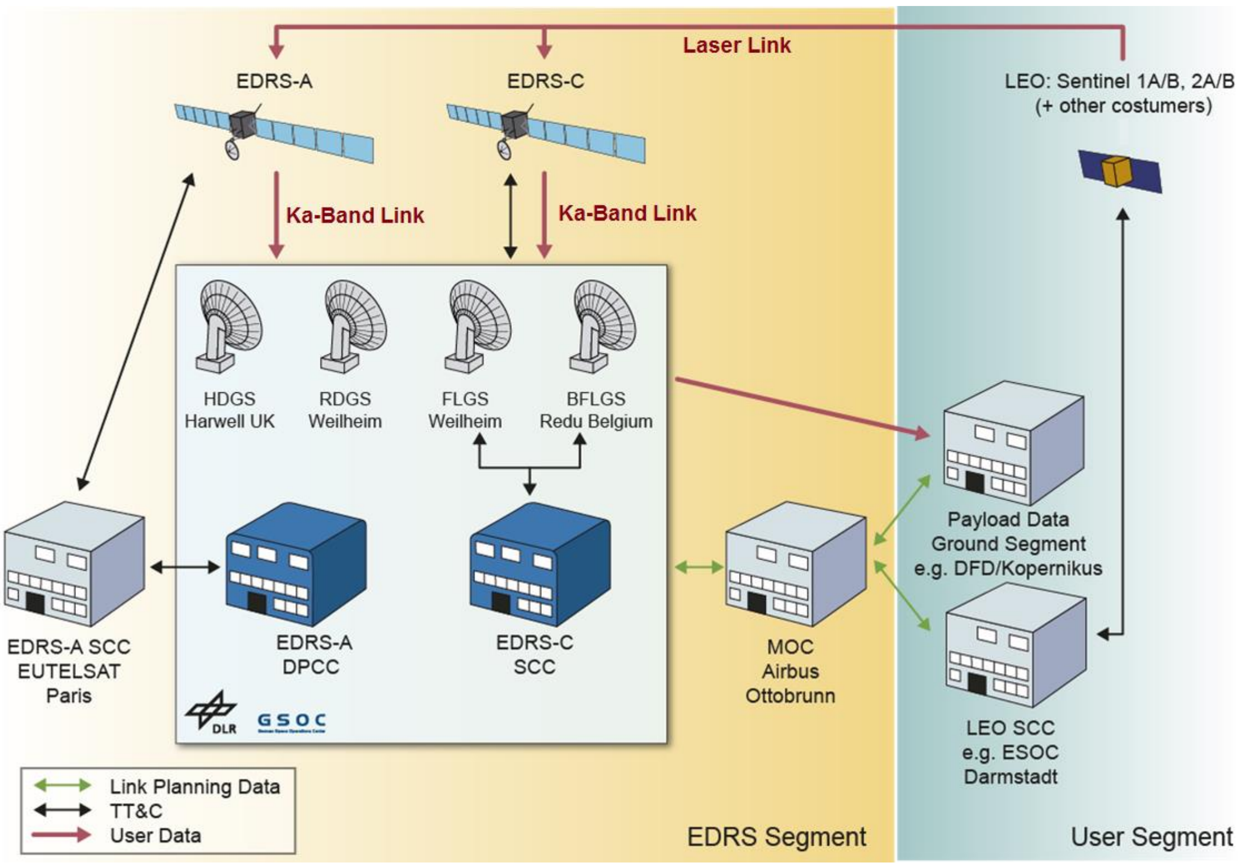

Figure 2: Overview of the EDRS mission concept. The blue box in the center illustrates the two different tasks of GSOC: Devolved Payload Control Center for EDRS-A as well as S/C and Payload Control Center for EDRS-C. The Airbus MOC is shown on the right side next to the blue box. Figure taken from [8] and slightly modified.

Both EDRS satellites cover a hemisphere that includes Europe, with a position at 9° E and 31° E, respectively, which is illustrated in **Figure 1**. More GEO nodes are planned to cover Asia and America.
GSOC performs two different 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 additionally acts as the Satellite Control Center (SCC). **Figure 2** illustrates this mission concept. Both the optical and Ka-band payload are operated fully automated. For more details on this operations concept, we refer to [6, 8 – 10].

The planning of the link services is performed by the Mission Operation Center (MOC) by Airbus, located in Ottobrunn, also near Munich. The MOC is responsible for the collection and consolidation of user requests from the different customers. Once all potential conflicts both onboard and on-ground have been resolved they are then planned in the form of Link requests which are sent to the DPCC or SCC, depending on which GEO satellite is to be used for ISL. The MOC is thus the interface to the User Segment of EDRS. The role of the MOC is shown in **Figure 2** as well.

3. EDRS-C Management Approach

3.1 Contractual situation

For DLR, the EDRS-C project started in 2013 one year after the EDRS-A kick-off. The duties of DLR GSOC within this project were defined in different contracts. Under contract with the industrial prime contractor, Airbus, the following SCC related tasks were covered:

- Implementation of the ground segment for the EDRS-C operations
- Preparation and execution of 15 years routine operations (platform and payload)
- Ground station support for the routine phase

Under contract of the satellite manufacturer OHB in Bremen, DLR was selected to perform the operations during LEOP and IOT comprising:

- Preparation and execution of LEOP and IOT of platform and payload
- Ground station support for this phase

The following Figure 3 illustrates the relations between the different parties.

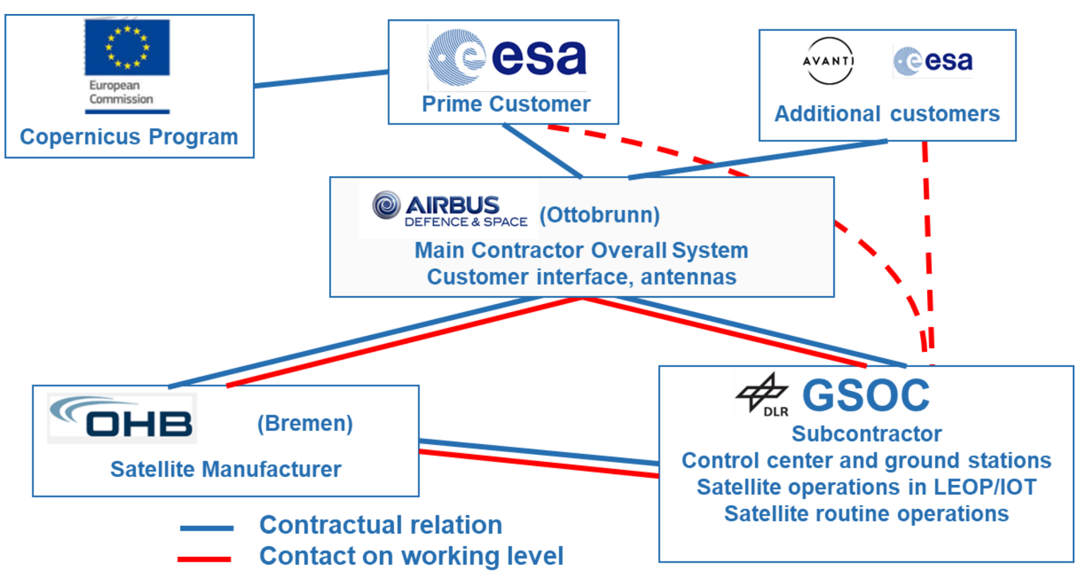

Figure 3: Overview EDRS contractual relationships and direct contacts on working level

From the GSOC point of view, the EDRS-C tasks seem to be split clearly between different mission phases, but some parts of the ground segment, being under the SCC contract responsibility, were also needed for LEOP and IOT. As a consequence, both customers were involved in all activities from the preparation phase on until completion of LEOP and IOT. The prime customer ESA was involved in the whole preparation phase. ESA representatives were present in all relevant meetings. They played an active role in reviews and were present in the control room during LEOP and IOT. There was no direct contractual relationship between ESA and DLR, but formally, official requests could be addressed through the prime contractor Airbus, whenever this was needed.

3.2 Milestones and reviews

For both contracts, separate reviews and milestones were initially foreseen. For instance, reviews have been foreseen for the critical design, technical acceptance, operational readiness etc. for both separately, for the SCC and for the LEOP/IOT. The possibility to combine comparable reviews at single events in order to reduce time and overhead was discussed, e.g. by performing only one technical acceptance review instead of two. Due to different start times of the contracts and the related work and asynchronous progress of the preparation and test activities, this could not be realized.

Later during the project preparation phase and caused by miscellaneous reasons, not all ground segment components and operational products could be completed early enough to keep the desired timeline. It was discussed between all parties how the available time should be used. The agreed solution was a staggered approach. For the remaining time until launch a clear prioritization for the use of the resources were given to the LEOP and IOT topics. Preparation work related to routine operations was performed at a later stage. The technical acceptance and the operational readiness of the LEOP and IOT systems and procedures were reviewed in dedicated events providing the go/no-go decision for the launch. In addition, the criteria for these reviews also covered the mission critical functions and components. With this, only pure work was shifted after the launch. Remaining development risks were avoided.

The remaining routine phase related components and products could be completed in parallel to the already running LEOP and IOT phase operations. This was approved during additional delta-reviews, so one one outcome of the staggered approach was the again increased number of reviews. In addition, training and simulation activities needed to be split too. Still, the result was that the spacecraft could be launched in time and the LEOP and IOT related contract could be completed without significant delay. The following figure provides an overview of the performed project timeline with the reviews and activity phases.

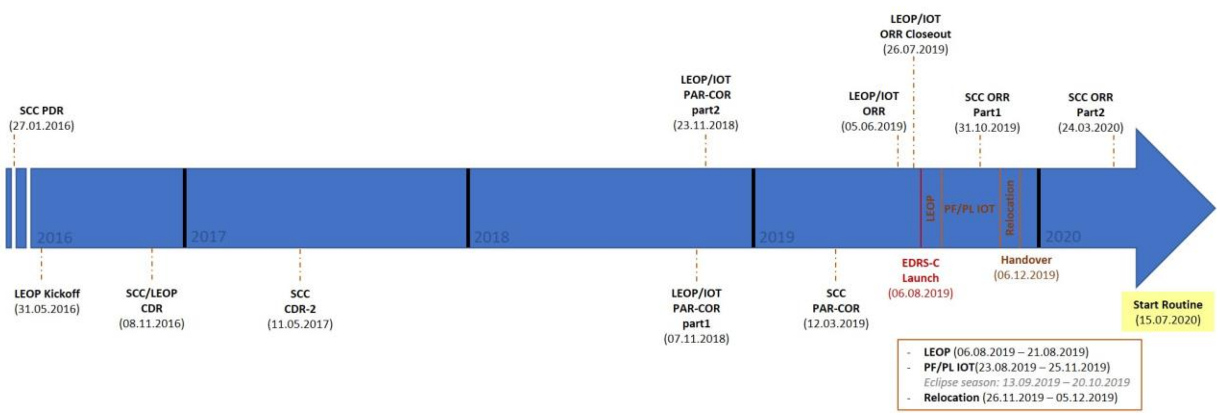

Figure 4: Project timeline with major milestones and reviews

3.3 Mission Management during LEOP/IOT

For the first phase of the EDRS-C mission, a clear setup of decision flows for go/no-go and critical situations was needed. In the role of the satellite manufacturer and main responsible for the LEOP and IOT operations phase, OHB filled the position of the mission director (MD) as the final decision instance in case of major anomalies. The MD agreed all major decisions with the satellite owner, which was already prime contractor Airbus at this time. Airbus in turn stayed in contact with the prime customer ESA.

The MD was in close contact with mission operations director (MOD) from GSOC. The decision flow during LEOP and IOT operations showing the information flow and the directives is illustrated in the following figure:

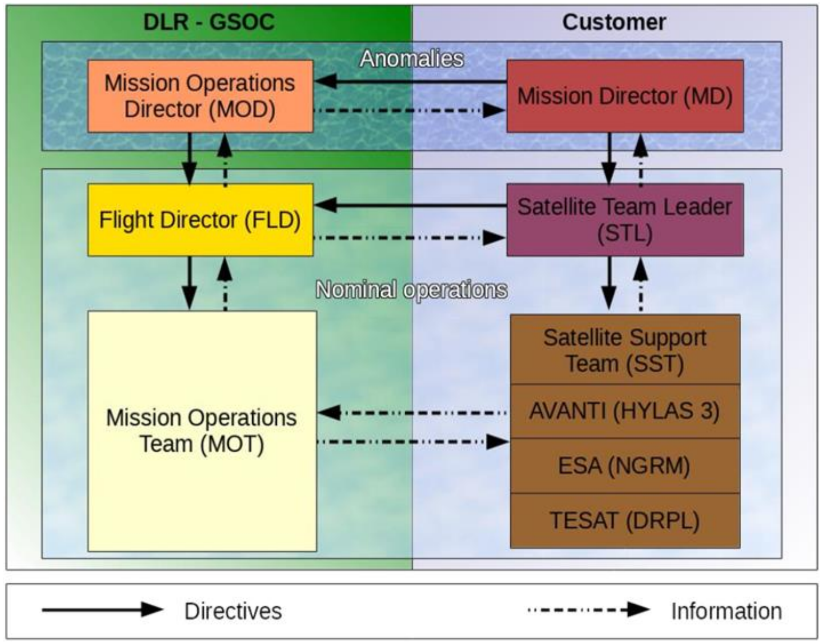

Figure 5: Decision flow during LEOP and IOT operations

The approach with a single mission director worked well. Required decisions could be provided within adequate times.

3.4 Running both EDRS missions in parallel

GSOC's approach to managing EDRS-A and C was to run both projects by separate teams with dedicated project managers. Of course there were obvious synergies and many engineers worked on both projects, but the scope of the projects and the way to operate them was different (LEOP and IOT for EDRS-C vs. routine ops for EDRS-A). During LEOP, there was almost no interaction between both EDRS-A and EDRS-C. For later IOT tasks, coordinated tests have been executed, but this could be handled easily by two different teams.

After completion of the EDRS-C IOT, the GSOC team started the harmonization of both project management teams. A single project manager was established covering EDRS-A and C. The operation teams are still in a process of harmonization. A 24/7 operator shift (level 1 support) covers both satellite operations. The merging of the two operations engineer teams (level 2 support, working during normal office hours and on-call for anomalies) is in progress. The ground segment components are already maintained by a single engineering team (see also chapter 4).

4. EDRS Mission Status

EDRS-A has already been performing routine operations supporting optical ISLs for several years. Since the first Sentinel-1a data download over EDRS-A happened in May 2016, the complete mission – including the geostationary node, the LCTs on the customer LEO satellites, the DPCC on DLR side, the MOC on Airbus side, and all the other involved parties – has proven to function extremely reliably. Already until April 2019, i.e. shortly before the launch of EDRS-C, more than 20.000 successful links have been performed by EDRS-A with a success rate of 99.5 %.

The LEOP and IOT of EDRS-C were carried out successfully after launch in late summer and autumn 2019. As mentioned above, one part of this phase was a repositioning of the satellite after the IOT. Also this could be performed without problems.

Many of the two ground systems of EDRS-A and EDRS-C on GSOC side are similar, particularly those involving the automated Link Request processing. Of course, some improvements have been implemented during the preparations for EDRS-C, to better match the exact requirements of the newer satellite. Where necessary these improvements were included in modifications and upgrades to the existing EDRS-A DPCC systems; for instance, to ensure compatibility with upgrade performed in external agencies, such as the MOCA. Since the beginning of the routine phase of EDRS-C, improvements are gradually implemented on EDRS-A side, together with other organizational and management harmonization as already mentioned in section 3.4. The technical or organizational improvements involved the support of ICD updates, Ka-Band upgrades, Ka-Recovery to allow recovery of Ka-Links

onboard, support for ColKa and Pleiades-NEO, and workflows concerning detailed aspects of the ground system, e.g. updates of the mission parameter base.
The GSOC ground system of EDRS-A and -C is thus also ready for new challenges such as possible extensions of the EDRS system itself, which we will describe in chapter 5.

5. Summary and Outlook

In this paper, we illustrated the current status of EDRS itself, gave insights of the project management part of its most recent GEO node EDRS-C, and gave a short overview of its mission status. Both GEO nodes and its payloads are operational and serve several LEO customer satellites. They are supported by a running and robust ground segment.

Still, there will continuously the possibility of improving and extending the ground system., an increase of automatization can lead to a decrease of human errors and reduce the workload of involved personnel. Of course, such automatization has to be thoroughly tested and has to take all special cases into account, though.

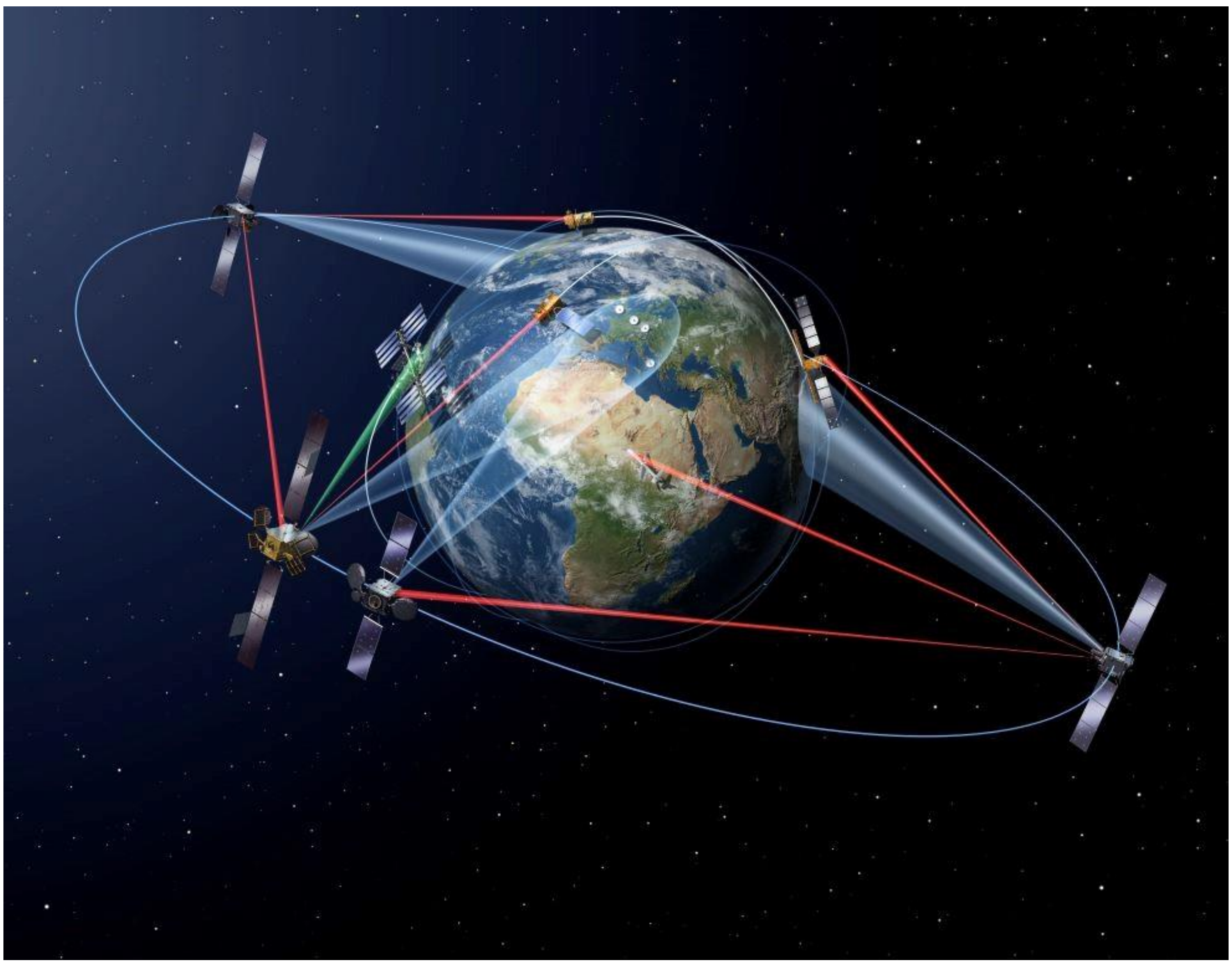

Figure 6: Potential future nodes over Asia (right) and America (left). In the center, the already existing EDRS-A and EDRS-C satellites are illustrated. Courtesy of ESA.

One already planned and important improvement is the automatization of the station-keeping maneuvers (SKMs). In the baseline design of the SCC, these are prepared, executed and evaluated manually by an operations engineer and supported by an operator. Step-by-step, this workflow shall be automated, until no manual interaction is needed except for the regular monitoring of the system. For more details on this approach, we refer to [1].

EDRS-A and EDRS-C cover the European and African part of the earth. Future nodes to cover the Asian / Pacific as well as the American region are being planned, see Figure 6. In other words: An EDRS node will be visible for the laser terminal on a LEO satellite, no matter where the LEO is currently located. The EDRS ground system at GSOC is prepared to cope for the implementations of these new geostationary laser terminals.

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