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OUTLOOK ON EDRS-C

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I. INTRODUCTION

EDRS-C will operate on a geostationary orbit as the second node of the European Data Relay System (EDRS). The EDRS-C satellite, designed by OHB System as prime contractor, has been procured in the frame of a Public Private Partnership (PPP) between Airbus Defence and Space and ESA. EDRS-C is currently under assembly at OHB facilities in Bremen.

The primary objective of the EDRS mission is to provide a data relay services to the LEO satellites from GEO orbit by means of optical and RF bands. To this end the EDRS satellites feature laser communication terminals that significantly differentiates them from conventional telecom satellites. The terminal aboard EDRS-C is the Laser Communication Terminal (LCT) designed and manufactured by Tesat-Spacecom GmbH & Co. KG.

EDRS-C is designed and developed by OHB System on basis of the SmallGEO platform. In order to accommodate the LCT on the SmallGEO platform some adaptations to the existing design had been required. The adaptations implied a consolidation of the existing platform design, an extension of its competitiveness with reference to optical payloads, and an important milestone in the development and industrialization of the generic SmallGeo platform product line.

This paper presents the current integration status of EDRS-C and the design adaptations performed on the SmallGEO platform in order to provide the LCT with an environment that guarantee its full performances. The integration of LCT on the satellite will start in October 2016 after its delivery to OHB System.

II. EDRS-C - SGEO PLATFORM DESIGN

EDRS-C is developed on basis of the European satellite platform LUXOR (also known as Small GEO) designed and manufactured by OHB System.

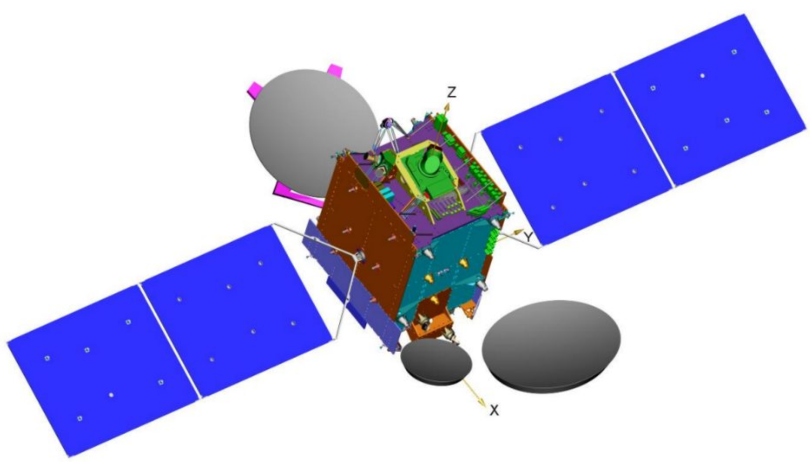

Fig. 1. EDRS-C

The Small GEO (SGEO) platform is addressed to the lower mass segment of GEO communication missions. The SGEO design is serving missions smaller than 3200 kg launch mass into geostationary transfer orbit (GTO) capable to support a total payload mass between 100 kg and 400 kg with payload power of 1500 W up to 4000 W End-Of-Life (EOL) for a lifetime of 15 years, which satisfies the payload requirements of the EDRS-C mission. Since the SGEO satellite bus is designed as a common platform for multiple payloads, its mode concept is modular and adaptable.

The design is based on a modular approach which offers parallel integration to achieve a targeted fast recurring delivery time, and allows for the platform to be tailored to a wide range of mission applications.

EDRS-C spacecraft is divided into the following 4 major modules: the Platform Core Module, the Propulsion Module, the Repeater Module and the Payload LCT Module.

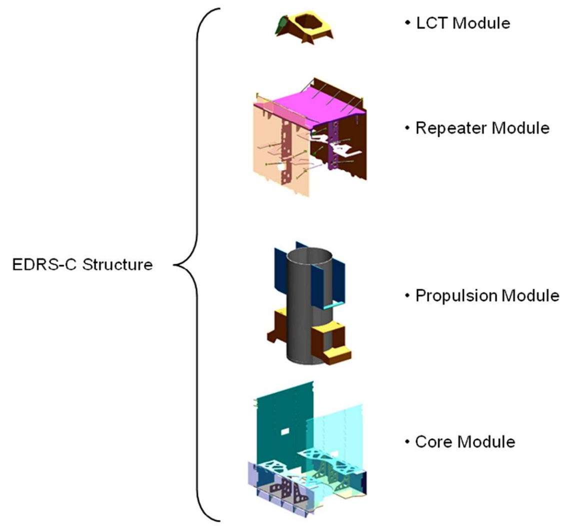

Fig. 2. EDRS-C Modularity Concept

III LASER COMMUNICATION TERMINAL

The main payload of EDRS-C is the Data Relay Payload design and manufacturer by Tesat-Spacecom. The Data Relay Payload concept is based on the maximum data transmission capability of Tesat-Spacecom Laser Communication Terminal (LCT). The payload allows different data rates for communication with various Earth observation satellites.

The LCT is showed in **Fig. 3**, it provides optical bidirectional data transfer between the GEO and LEO Satellite.

The Data Relay Payload will be capable of establishing and maintaining an optical communication link between the LCT located on the EDRS-C and a counterpart LCT on a suitable target LEO satellite 'User Space Terminal' (UST). The Data Relay Payload shall then guarantee the relay of the data to ground. Data transmission is possible in two different modes: Advanced mode in which the incoming data rate is 1800 Mbit/s and Sentinel mode in which the incoming data rate is 600 Mbit/s.

EDRS-C spacecraft also support the accommodation of 2 Hosted Payloads.

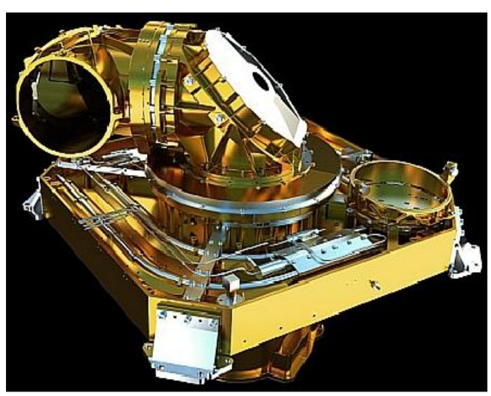

Fig. 3. Tesat-Spacecom LCT Embarked on EDRS-C

IV. SGEO PLATFORM ADAPTATION FOR LCT HOSTING

Among the various design aspects that might have impaired the LCT performances, it is worth to highlight the following measures:

- The thermo-elastic deformations (TED) effects have been mitigated by optimizing the accommodation on the spacecraft earth deck.
- The required pointing knowledge, needed for the link acquisition and tracking, has been ensured by selecting an AOCS subsystem with higher accuracy and performances with respect to the standard SmallGEO platform.
- The fine pointing stability needed by the laser terminal is ensured in two different ways:

- At design level by filtering the unavoidable continuous μvibration sources (RW, SADM);
- During mission by carefully combining the needed programmable events that may generate pointing degradation (station keeping, antennas repointing) with the operations of the laser terminal but still respecting the availability of the service.

- The stringent beginning and end of life contamination requirements meet by means of a dedicated cleanliness and contamination control plan.

A. Thermo-elastic deformation

The impact of TED on the LCT is mitigated by placing the LCT module structure in the center of the earth deck. All structural elements in this area are made of CFRP panels, which ensure that the TED will have minimized negative impact in this area. Furthermore this area is directly supported by the central tube which is the backbone and the most rigid element of the S/C.

In addition, the EDRS-C spacecraft features a dedicated LCT mounting structure to account for the mechanical and thermo-elastic impact on pointing of the structure and radiators. The mechanical interface of the LCT are its mounting feet on the LCT module. The thermal interface of the LCT are adapted according to the LCT support structure: the LCT thermal interface are connected via fit to purpose heat pipes directly to its dedicated radiator. This design allows distortions to be absorbed in such a way that resulting forces are not applied to the LCT mounting feet.

The LCT accommodation on the S/C is showed in **Fig. 4**.

Aside the TED effects, it is furthermore important to point out that the current accommodation and the tilt angle of the LCT module ensures a complete LEO Field of View for the LCT and star sensors free from obstructions under any scenario.

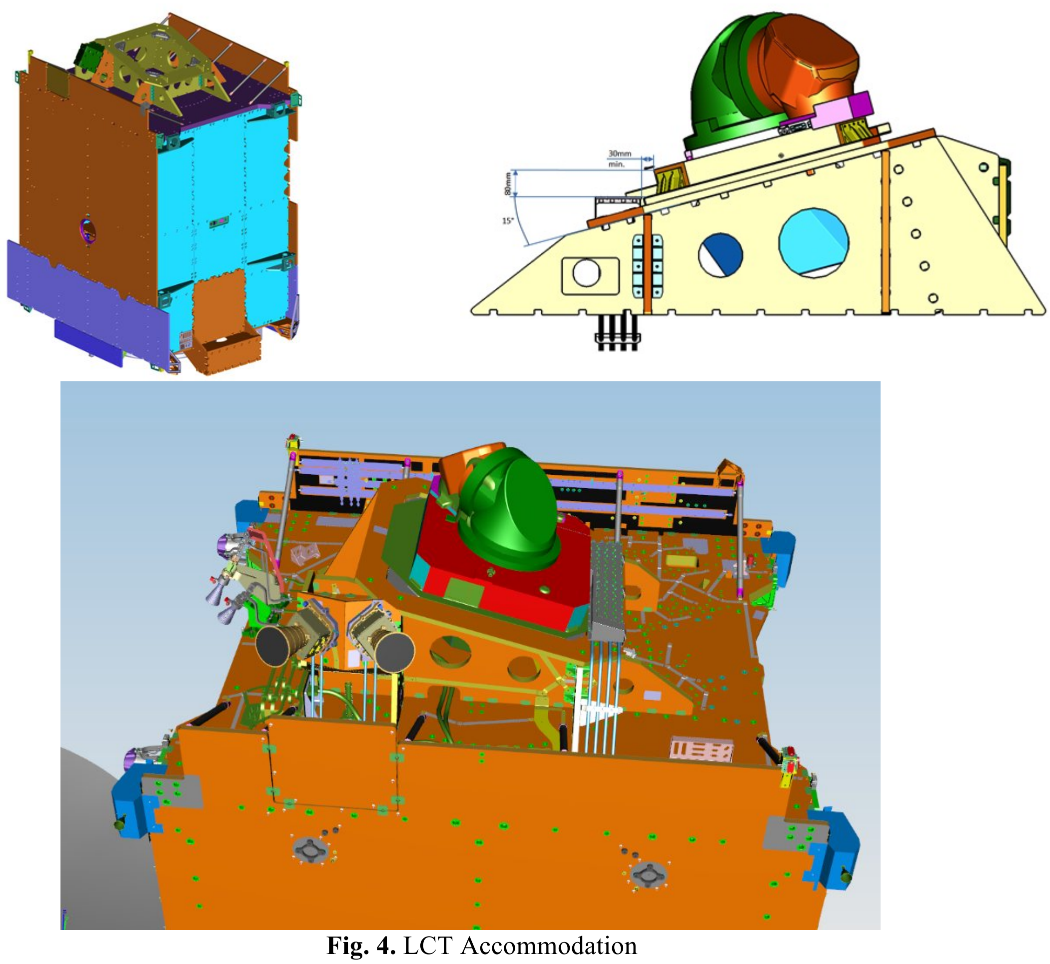

Fig. 4. LCT Accommodation

B. Pointing Knowledge

Accurate attitude and orbital position information is required as an input from the AOCS for operating the

LCT and guarantee its full performances.

In order to avoid excessive disturbance torque on the S/C, the maximum angular velocity and acceleration of the LCT needs to be limited during the link acquisition.

In case of performance reserves, these parameters can be adjusted once the satellite is in-orbit through telecomands upon AOCS telemetry inputs.

The nominal attitude determination is based on measurements from the Star Sensor and Gyro in order to achieve sufficient attitude knowledge stability for payload operations.

The architecture of the platform related AOCS modes are derived from the standard SGEO platform design, yet enhanced by a superior attitude determination system in order to fulfil the more challenging payload needs in terms of attitude knowledge and stability thereof.

In GEO, 3-axis attitude stabilization is performed through momentum exchange with a set of Reaction Wheels (RW). Their orientation provides a volume for the overall angular momentum capability, which is adapted to the averaged external disturbance torques. The wheels arrangement provide the full operational capability, including the "over-determination" (4 directions for 3 axes) that allows zero wheel speed transitions to be avoided. The attitude reference and the required pointing knowledge are provided by two high-performance Star Trackers (STS) supported by operating high performance Gyro. For sun pointing modes, the attitude reference is given by sun sensors

On the EDRS-C platform, a high performance gyro is needed to fulfil the very demanding attitude uncertainty drift requirement for the operation of the LCT. As a consequence, as opposed to platform standard design, the gyro is needed as a nominal sensor in Normal Mode and the Station Keeping Modes and is thus switched on during the complete mission time. This fact causes in turn the need for an excellent gyro reliability performance. Data fusion between Star Tracker and Gyro will be performed on basis of a carefully chosen filter algorithm. Besides performance enhancement in nominal operation, the gyro ensures independence from the star sensor, which could be blinded or not able to deliver data because of high rotation rates.

The thermo-elastic distortions between the attitude reference and the critical payload are minimized, accommodating the STS next to the LCT with a dedicated radiator and the Gyro head underneath the earth deck inside the S/C at the closest possible location to the LCT.

Fig. 5 shows the Star Trackers and Gyro accommodation.

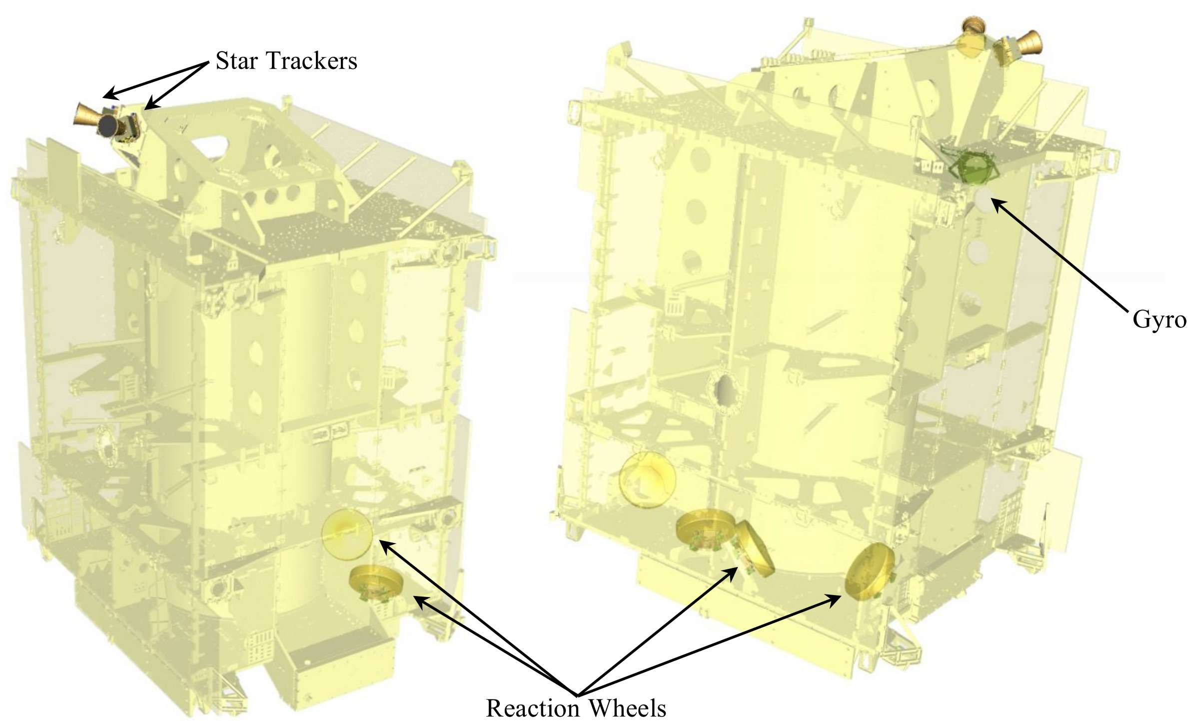

Fig. 5. Start Trackers, Gyro and Reaction Wheels Accommodation

C. Pointing Stability

The fine pointing stability needed by the LCT is ensured from one side at design level by mitigating the unavoidable continuous µvibration sources (RW, SADM).

Micro-vibrations are low amplitude disturbances which may impair the pointing performance of the LCT. These disturbances predominately originate as parasitic vibrations from rotary mechanical devices. Micro-vibrations occur at frequencies and amplitudes which cannot be measured or controlled by the AOCS and thus, cannot be compensated as conventional pointing errors. Typical micro-vibration disturbances have amplitudes in the range of 10ug to 10mg over the frequency range 1Hz-1kHz. The LCT supplier has determined a micro-vibration requirement which specifies the maximum disturbance allowable at the LCT interface.

The main sources of micro-vibration for EDRS-C are the reaction wheels and SADM although the reaction wheels are dominant. The RW have speed dependent disturbance characteristics whereas the fixed rotation rate of the SADM provides a constant disturbance signature.

The SGEO platform was originally designed to purely serve conventional telecom payloads, however the presence of the LCT (optical instrument) requires adaptation to the conventional telecom satellites design. The EDRS-C design has evolved to minimize contributions from micro-vibration sources and a characterization test campaign in order to understand the S/C response to such excitations was deemed necessary and carried out on some key units and on the S/C itself.

As an example, the reaction wheel mounting points were moved from the central tube to the platform radiator panel ensuring that the stiff central tube did not provide a direct transmission path to the LCT. Passive reaction wheel dampers were added to attenuate disturbances in the most critical wheel speed ranges. The current reaction wheels accommodation is shown in **Fig. 5**.

The focus of EDRS-C micro-vibration activities was to provide analytical proof that the micro-vibration disturbances did not exceed the requirement set by the LCT supplier. Given that the micro-vibration levels are dependent on gravity, air pressure and the spacecraft configuration, it is impossible to conduct a flight representative measurement on ground. As a consequence, a detailed analysis was necessary to predict the in-flight levels.

The analysis approach combined characterization of micro-vibration sources and analysis of the micro-vibration propagation through the spacecraft structure (Ref [2]). Measured disturbances from the reaction wheels and SADM were combined with structural transfer functions to determine the total disturbance at the LCT. The validity of this analysis was supported by a test on the SGEO structural model (STM) and will be further validated by measurements on EDRS-C. These tests are intended to demonstrate the conservatism of the micro-vibration analysis and thus, the validity of the flight prediction.

Fig. 6. shows the SGEO STM suspended during the micro-vibration test. The suspension system isolates the spacecraft from facility disturbances and allows the spacecraft structure to resonant more naturally and the reaction wheel brackets instrumented with a shaker and accelerometers. The resulting micro-vibrations were measured at the location of the LCT interface.

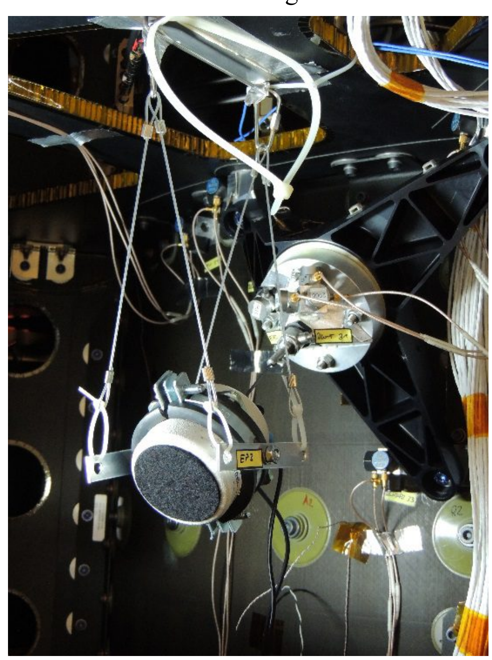

Fig. 6. Microvibration Characterization Test

From a mission perspective the fine pointing stability is ensured by carefully combining the needed programmable events that may generate pointing degradation like, for example: station keeping with the operations of the laser terminal.

The goal is to maintain the nominal Earth pointing attitude as long as possible and to maximize the overall service availability.

Station-keeping maneuvers in GEO rely on the 10N thrusters of the chemical propulsion subsystem, being fired simultaneously. A subset of the Reaction Control Thrusters (RCT) is also used for momentum dumping of the reaction wheels, performed in combined maneuvers with Station Keeping.

Station keeping, eccentricity corrections and momentum dumping are performed periodically controlling the RCT on the north and on the south side. The station keeping, eccentricity correction and momentum dumping are accomplished in combined maneuvers, thereby minimizing propellant need, total maneuver time and the LCT operational restriction. Two such combined maneuvers are performed on one “station keeping day”, one in each orbital node in order to optimize efficiency for inclination (north-south) correction.

During station keeping maneuvers the LCT is commanded to return park position because, the thrust firing could cause plume contamination on the LCT optics. In addition, these maneuvers inevitably cause fine pointing degradation that would prevent operation of the LCT.

In addition to taking into account the station keeping maneuvers and other programmable events as described above, a special feature has been incorporated within the Nominal Mode of the AOCS to actively compensate the (estimated) disturbances torques resulting from large angular maneuvers of the LCT’s Coarse Pointing Assembly. This is being implemented by directly adding the estimated torques based on the current CPA position to the regular torque commands on the Reaction Wheel Assembly (RWA). This feed-forward approach enables an improved disturbance rejection than would normally be possible by pure feedback control of attitude error measurements.

D. Contamination Control

The Laser Communication Terminal as with all optical instruments, is sensitive to contamination, and imposes stringent cleanliness requirements on the spacecraft mission. The contamination aspects and the subsequent possible performance degradation of the optical instruments have to be considered and controlled at all phases in the spacecraft design, manufacturing and operative life.

As described in Ref. [1], in response to the EDRS beginning and end of life contamination requirements, OHB System has established an on-ground contamination control plan and performed an in-orbit outgassing analysis in order to predict and control the cleanliness and contamination level for the EDRS-C flight hardware during the manufacturing, assembly, integration, test (MAIT) and life mission.

The on-ground contamination budget estimates the expected molecular and particulate contamination levels generated during the MAIT activities and launch phase.

The in-orbit outgassing analysis demonstrates that for 15 years orbit the LCT will not experience performance degradation due to the molecular contamination. The in-orbit contamination analysis provided confirmation to the satellite design identifying the major contaminants during the operative life and inputs to the On-Ground Contamination Control (Ref. [1]).

The LCT supplier supports OHB System in the estimation of the LCT on ground contamination budget from the LCT delivery up to the launch pad. Tesat-Spacecom provides very detailed handling and storage procedures to prevent contamination issues. Dedicated procedures have been established upon Tesat-Spacecom recommendations.

PAC (Particulate Contamination) and MOC (Molecular Contamination) predictions are supported by measurements and constant monitoring by witness samples inside the specific integration and test areas.

As an outcome of the on ground contamination prediction, a cleanliness control flow chart has been established by OHB System. The aim of this Flow is to identify check points, the so called Cleanliness Inspection Point (C.I.) to reconcile the predicted budget and allocation with the measured levels of PAC and MOC.

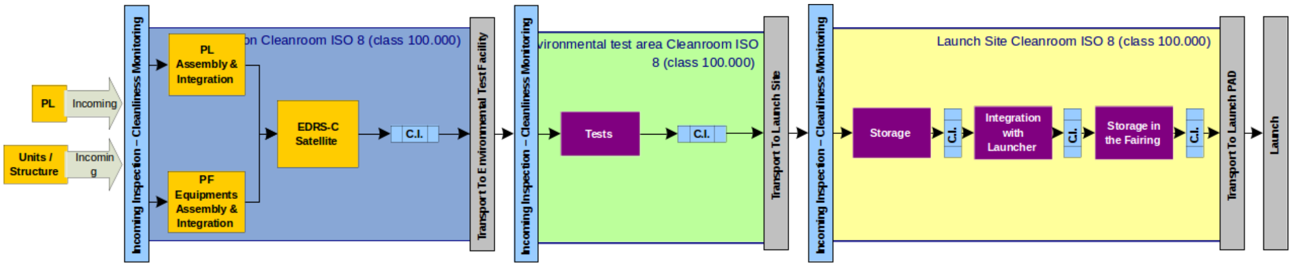

Fig. 7. Cleanliness Control Flow Chart

The monitoring will start as soon as the LCT will reach the OHB facilities September 2016.

V. INTEGRATION STATUS

Currently the two main modules: the platform module and the repeater module, are in the finalization phases and soon ready to be mechanically and electrically mated. The LCT delivery at OHB is planned by mid of September 2016. LCT integration is planned for October 2016.

Fig. 8 shows the platform and repeater module during the integration at OHB premises.

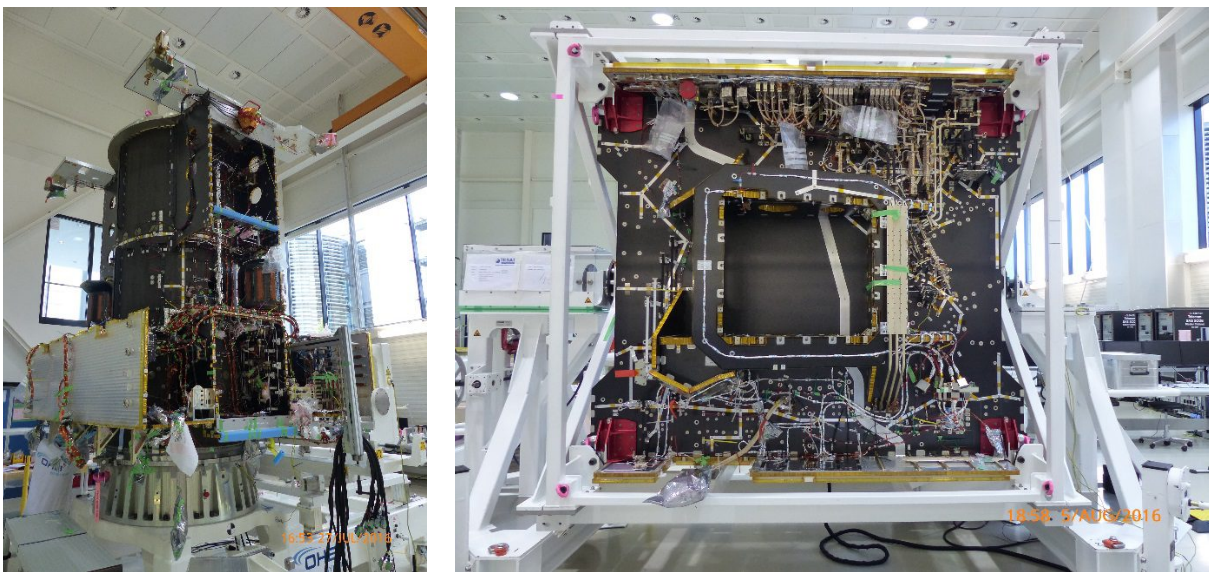
Fig. 8. EDRS-C Integration Status

VI. CONCLUSION

Presenting the EDRS-C design adaptations performed on the existing SmallGEO platform design, to provide the LCT with an environment that guarantee its full performances, this paper has provided an insight about the Small GEO platform flexibility and has demonstrated its ability to hoist both standard telecom payloads and optical payloads with very few engineering adaptations (i.e. accommodation flexibility, wide catalogue of compatible units) and optimizations and with no modification of the payload design.

Furthermore, the adaptations and optimizations implied not only a better knowledge of the platform performances (i.e.: micro-vibration characterization and contamination analysis) and consolidation of the existing platform design but also an extension of the platform competitiveness with reference to optical payloads.

EDRS-C represents, therefore, an important milestone for OHB System in the development and industrialization of the generic SmallGeo platform product line.

VII. AKNOLEDGMENTS

OHB Bremen would like to thank ESA, Tesat-Spacecom and Airbus Defence and Space for their contribution and support.

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