SPACE DEBRIS LASER RANGING – EVOLUTION TOWARDS ACTIVE SENSOR NETWORKING FOR DEBRIS OBSERVATION INCLUDING THE UPDATE OF THE IZAÑA-1 STATION

Laura Aivar (1), Alberto Águeda (2), Martin Ploner (3), André Kloth (4), Nils Håkansson (5), Linus Heinzl (6), Clemens Heese (7), Tim Flohrer (8), Michael A. Steindorfer (9), Georg Kirchner (10), Nadine Trummer (11)

(1) GMV AD., Isaac Newton 11, 28760 Tres Cantos, Spain, laivar@gmv.com
(2) GMV AD., Isaac Newton 11, 28760 Tres Cantos, Spain, aagueda@gmv.com
(3) DiGOS Potsdam GmbH: Telegrafenberg D-14473 Potsdam Germany, martin.ploner@digos.eu
(4) DiGOS Potsdam GmbH: Telegrafenberg D-14473 Potsdam Germany, andre.kloth@digos.eu
(5) DiGOS Potsdam GmbH: Telegrafenberg D-14473 Potsdam Germany, nils.hakansson@digos.eu
(6) DiGOS Potsdam GmbH: Telegrafenberg D-14473 Potsdam Germany, linus.heinzl@digos.eu
(7) ESA/ESOC, Robert-Bosch Strasse 5, 64293 Darmstadt, Germany, Clemens.Heese@esa.int
(8) ESA/ESOC, Robert-Bosch Strasse 5, 64293 Darmstadt, Germany, Tim.Flohrer@esa.int
(9) Space Research Institute, Austrian Academy of Sciences, 8042 Graz, Austria Michael.Steindorfer@oeaw.ac.at
(10) Space Research Institute, Austrian Academy of Sciences, 8042 Graz, Austria Franz.Koidl@oeaw.ac.at
(11) Space Research Institute, Austrian Academy of Sciences, 8042 Graz, Austria NadineMaria.Trummer@oeaw.ac.at

ABSTRACT

Satellite Laser Ranging (SLR) of orbital targets is a well-established technology in the scientific community with precision ranging to operational satellites equipped with retroreflectors.

After introducing more sensitive receivers, more powerful transmission systems and improvement of track initialisation techniques, it became possible to receive and process echoes from uncooperative targets. However, to assure the success of these observations, an accurate a-priori pointing information is required and tight constraints on the observation's conditions must be met. These challenges are the motivation drivers for establishing a "proof-of-concept" for fully automatized SLR stations, the Debris Laser Tracking Network (DLTN), integrating the upgraded ESA's Izaña-1 (IZN-1) station.

This activity has started in summer 2022 and it will finish at the end of 2024, performing validation campaign using actual observations in the first semester of 2024. This paper is provided to introduce the project to the community and describe the activities intended to be done.

1 INTRODUCTION

The activity described by this paper is a project organized in two main parts.

1. Upgrading of the IZN-1 station for fully autonomous daylight space debris ranging and preparation for network integration of the station.
2. Implementation and validation via an observation campaign of an active space debris tracking network based on laser ranging stations.

The first part is detailed in section 2 and the second part in section 3.

This is an activity funded by ESA and developed by a consortium led by GMV (in charge of second part and project management) with the participation of DiGOS, IWF (in charge of the first part) and LSF (consultancy for the second part).

2 UPGRADED ESA'S IZN-1 STATION

The IZN-1 is located at the Observatorio de Teide on the Spanish island of Tenerife. It is a multi-purpose optical ground station for satellite observation, position measurements and communication. The telescope carries the SLR (Satellite Laser Ranging) package for ranging to cooperative targets equipped with retro reflectors. Currently on the two Nasmyth foci the laser ranging detector package and the laser communication terminal is installed. Additionally on one of the 2 optical ports a space debris observation camera is installed for passive optical space debris observations.

As part of the upgrade of the IZN-1, we will extend the functionality of the system with a space debris laser ranging transmitter for ranging during night-time as well as daytime to uncooperative targets up to 3000 km range orbits. The space debris laser system will be installed in a separate structure (IZN-2), on its own mount. Such a system can be installed adjacent to any SLR station, enabling it to perform Space Debris Laser Ranging

(SDLR) without modifying the main SLR system.

The space debris laser tracking module will be added to the IZN-1 system using a so-called split configuration (Figure 2-1). In the split configuration, the new space debris laser package will be mounted onto its own new mount, which will be installed in a separate structure (separate transmitter section). The SDLR mount will be installed into a new dome, which will be set up adjacent to the existing IZN-station. This bistatic configuration uses two mounts for the laser ranging measurements synchronized such that both are tracking the same target. The laser pulses will be emitted from the transmitter system (Tx), and the returns will be received by the existing main telescope (Rx), with the existing laser ranging detector package.

An additional stare & chase functionality will allow the ranging to targets with less precise predictions. Based on passive optical observations an orbit improvement will be carried out for increasing the accuracy of the orbit predictions and for assisting the space debris laser ranging system.

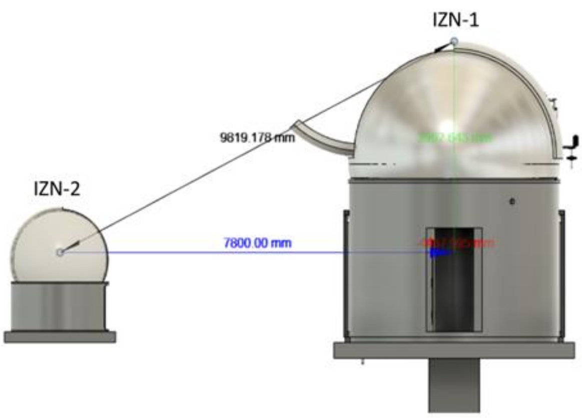

Figure 2-1: Spilt configuration of the IZN-2 station

2.1 Space Debris Laser Tracking Module

The space debris laser ranging station concept is based on capable off-the-shelf hardware to the widest extent possible with the following key characteristics:

- The ELRS (ESA Laser Ranging Station) will fully maintain the original performance in tracking cooperative targets
- The IZN-1 station will fully maintain the original operational specifications.
- Range measurements to non-cooperative targets during night-time up to 3000 km, during daytime up to 1400 km.
- Range measurements using the primary wavelength of a pulsed Nd:YAG laser (1064nm)
- Automatic operation for space debris tracking, stare & chase, light curve measurements

The upgrade is based on state-of-the-art technology and uses proven designs wherever possible.

2.1.1 Dome subsystem

The dome is a slit type dome of about 2 m in diameter with a cylindrical base. It is extremely rigid against harsh environmental conditions.

2.1.2 Space Debris Laser Ranging subsystem

The main components of the space debris laser ranging subsystem are:

- the pulsed laser source for laser ranging to noncooperative targets,
- the transmitting refractor telescope
- a camera used for guiding purposes.

The space debris laser package (Figure 2-2) is mounted on an alt-azimuth direct drive mount.

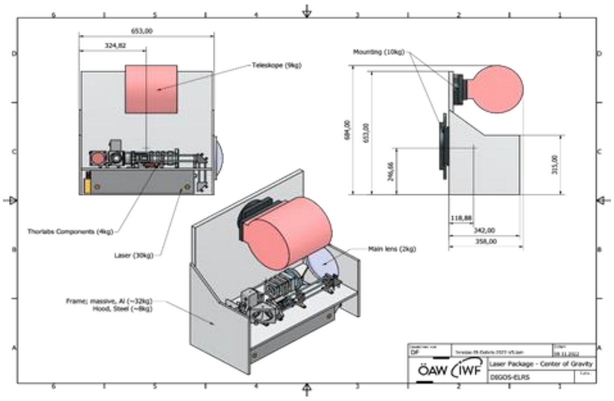

Figure 2-2: Space Debris Laser Package

Space debris laser package

The space debris laser package mainly contains the laser head, the transmit telescope and the guiding camera. An additional telescope for the stare & chase mode will be installed on top of the SD laser package.

For the space debris laser, a high-power laser with a wavelength of 1064nm, a repetition rate of 200Hz, a pulse energy >180mJ and a pulse width of 5-9ns is used for ranging.

To estimate the system specifications, a link budget is calculated based on works by [1,2]. The simulated expected performance in Figure 2-3 shows the minimum optical cross section using detection limits of 3% and 10% for night-time and daytime ranging under good sky conditions.

At night-time, 10 cm objects may be observable at ranges below 600 km and 50 cm objects may be observable at ranges below 1400 km. Larger objects (e.g. rocket bodies) may be observable up to a distance of 3000 km. At daytime, 50 cm objects may be observable at ranges below 1000 km. At daytime, ranging will generally be restricted to shorter ranges and larger objects.

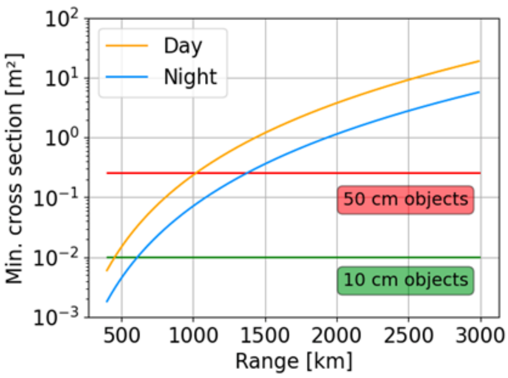

Figure 2-3: Minimum cross section vs range for day and night

An already integrated laser ranging detector package (Figure 2-4) in the IZN-1 station contains the optical components in order to receive the returning laser light and to perform the ranging measurement. The detector package will be updated by a single-photon detector as a light curve detector (Figure 2-7) to enable high temporal resolution light curve recording simultaneously to the ranging measurements.

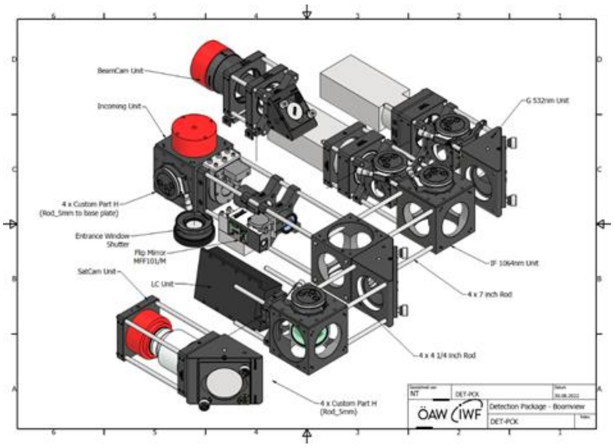

Figure 2-4: Schematic layout of the detector package

Guiding system

Since available space debris predictions are often rather inaccurate, a visual guiding system would offer a great benefit for successful ranging to targets with inaccurate predictions. Visual tracking will be possible as long as the target is not passing into the earth shadow. The most limiting factor for the visualisation is always the contrast to the sky background [3]. It is obvious that the contrast is much weaker for the same object during daytime than during twilight. The minimum target size which can be visualised should correspond to the minimum target size which can be ranged with the new space debris ranging system.

The visualisation during night-time requires a telescope with an aperture of 20 to 30cm. As the exit aperture of the space debris laser package with a diameter of 20cm fulfils the specification related to the aperture, guiding during the night can be performed with the satellite camera mounted in the space debris laser package. For the visualisation of targets with larger angular offsets than the FOV (Field Of View) of the satellite camera, the Stare & Chase telescope can be used. Even the smallest objects which can be ranged during night-time with the space debris laser system can be visualised in both cameras. A spherical object with 10cm diameter in a distance of 600km will have a brightness of 11mag assuming 20% reflectivity. A similar brightness will have a spherical object with a diameter of 50cm in a distance of 1400km. For the faintest objects the integration time has to be increased to a few tenths of a second.

Completely different is the situation during daylight [4]. As the contrast to the sky background is the limiting factor for the visualisation, it has to be maximised by selecting the hardware components carefully, especially the telescope aperture in conjunction with the sensor of the camera. Link budget calculation (Figure 2-3) for the SD laser ranging system show that the limiting object size for ranging during the day will be approximately 50cm in a distance of 1000km. This corresponds to a brightness of 10mag. As shown in Figure 2-5, only objects brighter than 8mag can be visualised by a properly designed guiding system with the given telescope aperture.

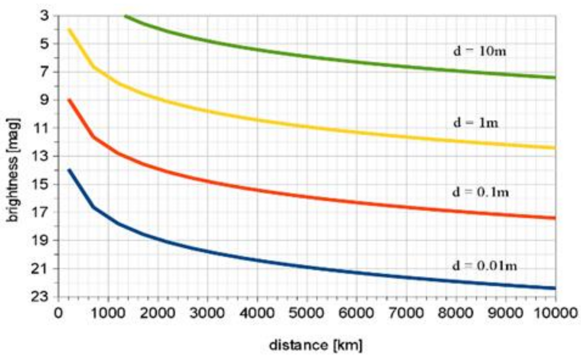

Figure 2-5: Estimated magnitudes of four spherical satellites from 1cm to 10m diameter with albedo of 0.2

Objects brighter than 8 mag can be visualised in day light under perfect atmospheric conditions using the cameras installed on the main telescope. Additional band pass filters will be used for reducing the sky background. The SD laser ranging system allows successful ranging during the day to objects fainter than 8 mag. As a consequence, ranging to the smallest objects during the day has to be carried out without any guiding system (blind tracking). Successful ranging observations will only be possible if the predictions have only little uncertainty and proper search strategies are available.

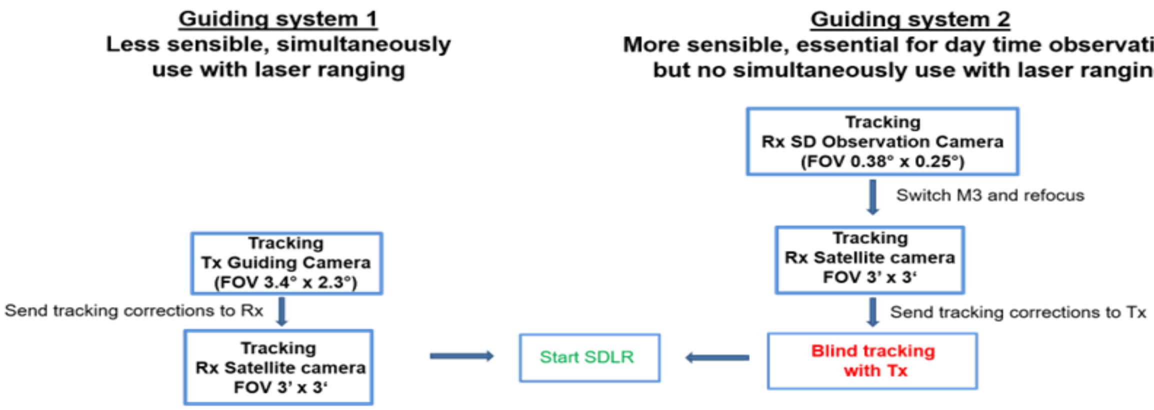

Figure 2-6: Procedure overview for two different guiding systems

The transmit telescope and the Stare & Chase telescope are for various mostly programmatical reasons not too well suited for day light visualisation of objects. Due to the small aperture of 20cm only objects brighter than 6 mag might be visualised (see Figure 2-5).

The use of the already integrated space debris observation camera on the main telescope as a guiding camera suffers from the situation that it cannot be used in parallel to the laser ranging measurements.

Summarising, different guiding systems are available (Figure 2-6). For night-time observations the transmit telescope as well as the Stare & Chase camera system are most suited (Tx Guiding System). The only difference between both systems is the larger FOV of the Stare & Chase telescope. But it should be noted that the optical axis of the Stare & Chase telescope deviates by a small amount from the optical axis of the transmit telescope. In both cases tracking corrections calculated by the Tx Guiding System will be sent to the main telescope (Rx) to ensure that the object is within the FOV of the Rx Satellite Camera.

During day light operation the cameras of the IZN-1 main telescope (with an aperture of 80cm) will be mainly used as guiding system. First the object will be visualised with the Rx SD Observation Camera located on an additional Nasmyth port and the angular offsets will be calculated on a sequence of images. After correcting the predictions with help of these angular offsets, the tertiary mirror will be switched back from the additional Nasmyth port to initial Nasmyth port. This will take roughly 5 seconds including the time for the required refocusing. Subsequently the closed loop tracking will be started using the Rx Satellite Camera of the detector package. The calculated angular offsets will be permanently sent to the Tx telescope.

2.1.3 Stare & Chase subsystem

The new stare & chase operation mode will allow tracking and laser ranging of orbital objects whose orbital parameters are only known with large uncertainty. As this mode requires good image quality and low background noise, it can only be conducted at night-time. The objects must be illuminated by the sun. The Stare & Chase telescope will start tracking on the basis of the rather inaccurate orbital parameters. The wide FoV camera continuously records and analyses images of the sky. In case the object is not within the FoV, a sky survey will be started around the predicted position. As soon as the object is within the FoV, its astrometric coordinates will be determined on a few subsequent images by comparison with background stars. Subsequently, an automated processing chain is started to generate improved orbital parameters of the object. Due to the short observation period and the relatively large uncertainties in the measured coordinates, these orbital parameters will be still rather inaccurate, but usually accurate enough to immediately initiate object tracking, starting the search loop and ranging with the space debris laser system (“chase”). The results of these tracking and ranging measurements can be used to obtain accurate orbital parameters.

For the staring mode a telescope of 20cm aperture and a focal ratio f/2.4 is used. As a space debris observation camera, a CMOS camera with sensor size of 36 x 24mm (resp. a FOV of 4.3° x 2.9°), and a pixel size of 3.76µm (corresponds to a pixel scale of 1.6”/pixel).

2.1.4 Light curve subsystem

In astronomy Light Curves (LC) is a common method to extract physical and dynamical characters of space objects. The application of LC on satellites or space debris is to collect the solar radiation reflected by the surface of the object, and LC shows the brightness variation of an object over a period of time. The signal density is firmly connected to the geometry relations between observer, object and sun, cross-section and the reflectivity of object. The light curve package installed at IZN-2 focuses on dynamic properties of space objects, such attitude, attitude motion, using a single photon avalanche diode (SPAD) and a field programmable gate array (FPGA). In Figure 2-7, the incoming light gathered by a receiving telescope is guided by the mirror M1 to the detection package. The two ranging wavelengths (532nm and 1064nm) are directed to their individual detectors. The remaining light is divided further into 2 portions: < 800 nm is used to visualize space object, and all above 800 nm light is collected by LC SPAD detector [5, 6].

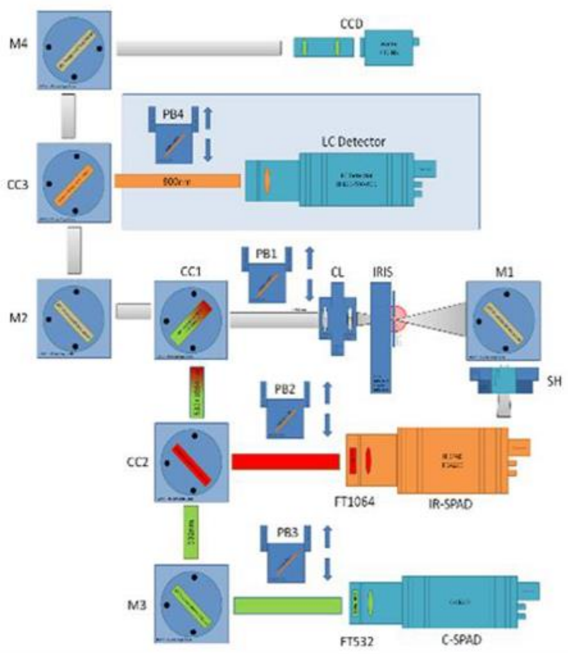

Figure 2-7: Optical layout of the detector package

2.1.5 Computer and software subsystem

The computer hardware and software, which controls the space debris laser station in addition to its previous functionality, are mainly already integrated into the IZN-1 station.

The existing network subsystem of the IZN-1 station provides communication links between the different station components for time synchronisation, data exchange, command & control, backup as well as an uplink to the internet. The new infrastructure of IZN-2 also has two additional computers installed. The station, as already done in IZN-1, will be operated by the off-the-shelf SCOPE command and control SW. All laser functionality can be accessed by the operating software of the used laser. The data filtering is an off the shelf software whose interfaces will be modified in order to directly interface with SCOPE.

2.2 Station protection and laser safety

A station protection function is already available at the existing IZN-1 station and this function will be used to protect the space debris station (IZN-2) as well.

The Laser Safety functionality that is already integrated in IZN-station ensures that persons inside and outside the station, as well as airplanes and other “flying objects” in the local airspace, are not exposed to hazardous laser light emitted by the system. It will also take care of the space debris system laser safety. Any risks to humans in case of motor control errors will be avoided. The system is also responsible to minimise interference with other observation systems on ground and in space.

In addition to existing laser safety unit, a thermal infrared camera is integrated to ensure detection of objects without ADS-B (Automatic Dependent Surveillance - Broadcast).

In order to survey the station at day and night-time consistently, two surveillance cameras are installed.

3 DEBRIS LASER TRACKING NETWORK

The goal of the second task of the activity is developing a Debris Laser Tracking Network (DLTN) connecting user and contributing SLR stations that could be operated commercially.

The main capabilities offered by the DLTN system are:

- Requests for tracking SLR observations among all the SLR station network
- Requests for orbital information, CDM (Conjunction Data Message) and RDM (Re-entry Data Message) improvement based on the tracking data collected by the SLR station network
- Request for chasing SLR ranging immediately after stare observation
- GEO, MEO and LEO objects catalogue maintenance with a certain pre-defined level of accuracy based on SLR observations
- SLR sensors calibration

The following types of actors that will be interacting with the DLTN system are identified.

- Observation Requestors (OR): satellite owners, satellite operators, ESA, individuals interested in refining orbits, research institutes, students, national entities, defence entities, etc. In general, they will be entities interested in the collection of laser data and, potentially, derived products from the SLR stations in the DLTN.
- Platform Administrators (PA): ESA, GMV, Expert Centre, etc. They would be allowed to perform additional activities with the DLTN such as tasking specific SLR stations, performing calibration campaigns, managing users, including new stations in the network, etc.
- Supporting Observatories (SO): Optical or radar station which are supporting in staring phase of the stare and chase campaigns.

Figure 3-1 shows the two major components of the DLTN system: SLR stations network (DLTN-SN) and the DLTN online platform (DLNT-OP)

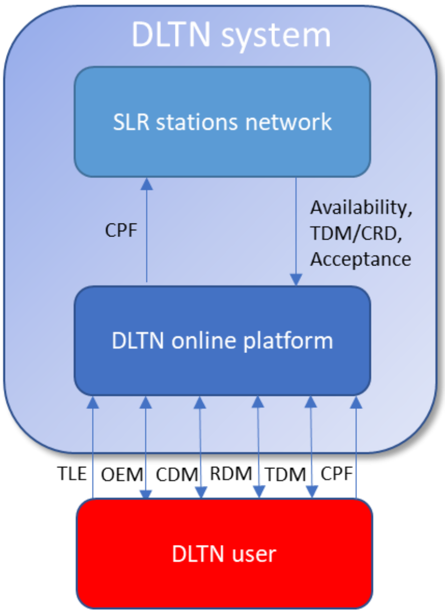

Figure 3-1: DLTN system diagram

3.1 SLR stations network

These are the SLR stations within the network participating to observation collection.

The networking approach is essential to achieve a quality of orbit information that will add significant value as compared to traditional tracking.

ESA's updated IZN-1 station shall be integrated into this SLR stations network along with several other active SLR stations in Europe and beyond.

Dedicated Service Level Agreement (SLA) will be agreed with the participating SLR sensors in the stations network.

Several SLR stations have already expressed their willingness to participate in the observation validation campaign that will take place the first semester 2024.

3.2 DLTN online platform

The DLTN-OP is an online sensor network platform for near-real time requesting, scheduling, analysing, displaying and providing Space Surveillance & Tracking (SST) data products for the end users.

The DLTN online platform shall allow the coordination of a network of SLR stations for the acquisition of tracking data for space objects (including debris) in LEO, MEO and GEO and provide derived services (refined orbits, refined CDMs, refined RDMs, catalogue maintenance) based on the tracking data provided by the SLR stations.

3.2.1 Use cases

Several uses cases have been derived from these required functionalities as explained in the next sections.

Observation request

This use case (Figure 3-2) is intended to obtain observations acquired with the SLR sensors.

The user (OR) will provide the orbital information for the considered object and select the candidate sensors to be scheduled. DLTN-OP will calculate the observations opportunities considering the information provided by the user and will generate the observation scheduling request to be sent to the sensors, usually in CPF (Consolidated Prediction Format) format, the standard used by the SLR sensors. Once the SLR sensor accepts the request and the observations are acquired, these observations will be uploaded to the system in the predefined format in SLAs. Finally, DLTN-OP will store these observations and provide them to the user.

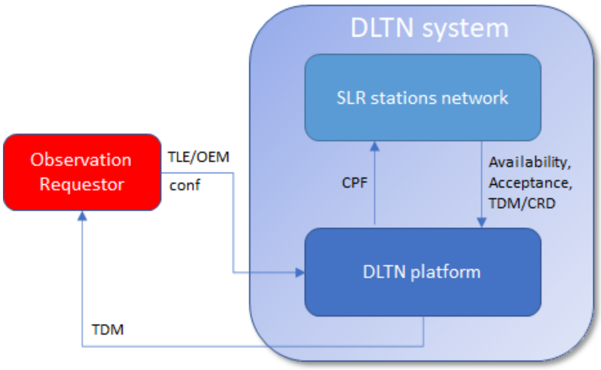

Figure 3-2: Observation request flux diagram

This is the simplest use case and it will be used as foundation for the rest.

Orbit refinement request

The goal of this use case is to refine an input orbit, i.e., obtain a more precise orbit based on the acquired observations.

The flux of this use case is totally based in the observation request case and includes an additional step (orbit determination) after DLTN-OP acquires and stores the SLR observations. The outputs of this use cases are the observations and the refined orbit.

CDM refinement request

The objective of the CDM refinement request use case is to obtain a refined CDM based on the acquired SLR observations.

Taking the orbit refinement use case as foundation for this use case, it is only needed to add the conjunction analysis calculation based on the refined orbit. The user will obtain the observations, the refined orbit and CDM as output.

RDM refinement request

This use case is intended to obtain more precise information of a re-entry event.

This use case is also based on the orbit refinement use case. Re-entry calculation is done with the refined orbit and the calculated refined RDM, refined orbit and observations are given as output.

Stare and chase request

This use case (Figure 3-3) can be thought as an orbit refinement but with a poorer orbital information to start with. In that case it is needed to do a first stare stage with the telescopes in order to obtain better orbit information and assure that the SLR observations will be finding and pointing the object.

It is assumed that stare and chase use case in the DLTN is done to known objects with an (probably coarse) a-priori orbital information.

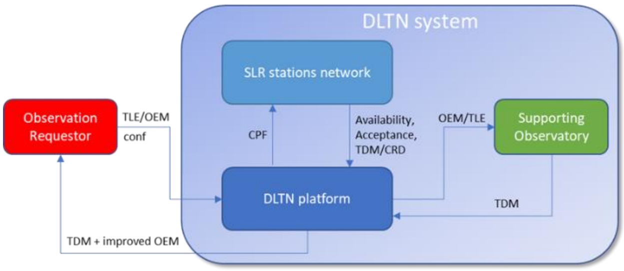

Figure 3-3: Stare and chase flux diagram

The user (OR) will provide the initial orbital information for the considered object and select the candidate sensors (telescopes for stare and SLR stations for chasing) to be scheduled. DLTN-OP will calculate the observation optical opportunities and generate the observation scheduling request to be sent to the telescopes. An OEM or TLE will be sent to the telescope (supporting observatory) to do the stare phase. Once the DLTN-OP receives the acquired optical observations, a first orbit refinement using an IOD (Initial Orbit Determination) and the optical observations is done. The validity of the IOD is quite short in time (orbit precision degrades fast), so this procedure needs to be done automatically as soon as the optical observations are available in the platform.

This first refined orbit is used to calculate the observation opportunities from the SLR sensors. The generated CPF is sent to the SLR sensors to perform the tracking (chase phase). Once the SLR sensor accepts the request and the observations are acquired, these observations will be uploaded to the system in the predefined format in SLAs. Finally, DLTN-OP will store these observations and use them to obtain a more refined orbit. The user will obtain the observations and the improved orbit information.

Catalogue maintenance

Catalogue maintenance use case goal is to preserve a defined precision level of the stored orbits in the catalogue.

The user will define the configuration (precision envelope) that the catalogued orbits need to fulfil. These catalogued orbits will be evaluated periodically and when one of these orbits does not satisfy the precision levels, an orbit refinement request will be launched. An orbit determination will be done with the acquired SLR observations and this improved orbit will be stored in the catalogue. If this orbit does not reach the required precision level, the procedure will be repeated until the precision criteria is satisfied.

SLR sensor calibration

The purpose of this use case is to assure that SLR sensors used in the DLTN-OP are well calibrated.

This use case is only available for the platform administrator.

Calibration will be done based on precise orbit information of well-known satellites (calibration targets) whose orbital information is publicly available. DLTN-OP shall maintain updated precise orbit information of the calibration targets as part of the platform database.

SLR stations are required to upload an observational arc for any one of the calibration targets at regular events. Once the SLR observations are available at the DLTN-OP, they will be used to calculate the sensor calibration: calculate the sensor bias, if any, or observation biases based on the calibration target observations and precise orbit information. The sensor is considered “calibrated” and can be used for further observations if the deviation between the precise orbit and SLR sensor measurements is less than a prescribed value defined in the SLA. If the calibration is not successful, the sensor status will be set into “quarantine” and the SLR sensor needs to provide more calibration target observations for further calibrations. Once this calibration will be successful, the status of the sensor will be switched to “calibrated”.

3.2.2 Design

The DLN-OP has been designed to fulfil all the defined use cases and considering that operations shall be as automated as possible.

Moreover, it is intended to reuse experience from other networks like SatNOGS, developed by LSF (part of the consortium)

In order to reduce implementation efforts for the software and maximize re-usability of the software, it is highly recommended to re-use existing software packages implementing orbital mechanics, observation opportunities computation, collision risk and re-entry events algorithms.

The GMV's COTS (Commercial-Off-the-Shelf) software proposed to be used for the development of the backend of the DLTN online platform are the following:

- ***Sstod***: Implementing orbit propagation, orbit determination and initial orbit determination algorithms.
- ***Senplanner***: Implementing observation opportunities computation for SST sensors tasking purposes.
- ***Closeap***: Supporting the analysis conjunction events including the assessment of collision risk.
- ***Reenpred***: Supporting the analysis of re-entry events including estimation of re-entry prediction.

These existing COTS software solutions make use of CCSDS-based (Consultative Committee for Space Data Systems) standard interfaces. This is very convenient for the DLTN-OP, as its design make use of the established navigation standards from the CCSDS for the promotion of international standards to be used for the exchange of information between the platform and user. These systems information ensures the inter-operability between different entities participating within the DLTN. In the area of space systems, several standards already exist such as the Orbit Data Messages (ODM: OPM, OMM, OEM) for orbital information of a space object and Tracking Data Message (TDM) for tracking observation. In the field of SST, aside from the ODM, another standard promoted by the CCSDS is the so-called Conjunction Data Message (CDM) that provides all information about a conjunction at the time of closest approach (TCA). In a similar manner, the Re-entry Data Message (RDM) supports the exchange of information related to upcoming re-entries.

As a summary, the characteristics that had driven the DLTN-OP design have been automation, reuse experience of SatNOGS, use of GMV's COTS and use of well-established international standards (CCSDS).

Figure 3-4 depicts the main component of the System. It is worth to identify the two most important pieces, the frontend, which is a Web application providing a User Interface to the three types of users (final users, station operators and administrators), and the backend that provides the necessary business logic through a well-defined REST API (Representational State Transfer Application Program Interface). The backend relies, in turn, on a relational DB (DataBase) to persist any kind of data associated to the implemented functionality, like for instance the user requests, the observation data coming from the SLR stations, or the orbits generated from them.

SLR stations can upload their observations through two different interfaces, the REST API or by uploading the observation data files to an FTP (File Transfer Protocol) store exposed by the System. This store is constantly monitored by the System to get and ingest the observations as soon as they are made available by the stations. This is also used to command the stations with the tasking requests calculated by the System. The SLR stations are requested to get the tasking requests from there.

The SATCAT form and TLEs (Two Lines Elements) catalogue will be routinely download from Space-Track

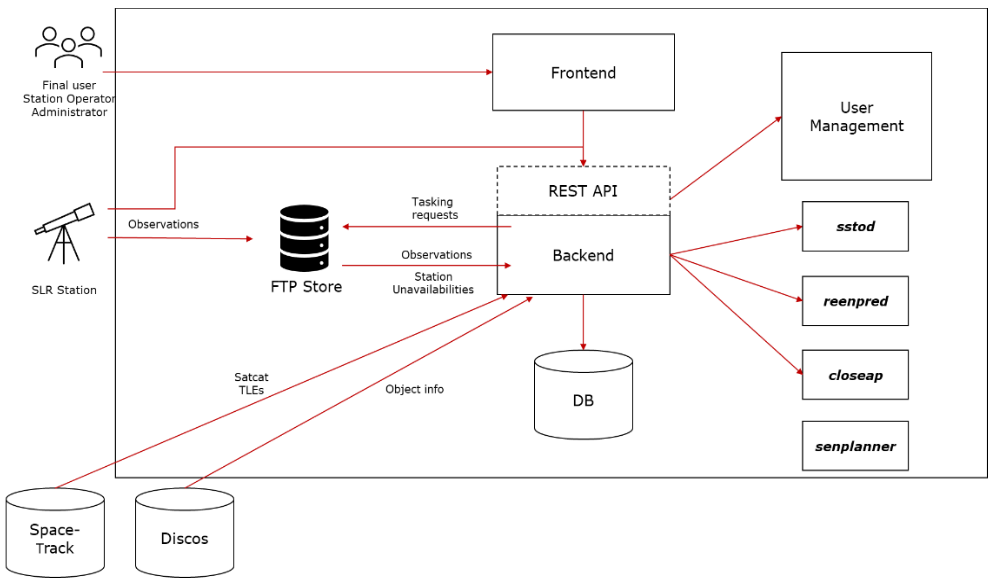

Figure 3-4: DLTN-OP overall architecture

(https://www.space-track.org) to get an updated catalogue of objects in the System. This information will be complemented with data coming from DISCOS (https://discosweb.esoc.esa.int/) to get more accurate information about the mass and area of every object. Although not depicted in the figure for the sake of clarity, solar activity, earth orientation parameters (EOPs) and leap seconds will be routinely downloaded from external sources to be used in the computations.

The User Management is a functional component in charge of maintaining the users database and to implement the necessary logic to guarantee that any access to the REST API is properly authenticated and authorised depending on the user role. It has been identified as a separate module and not within the Backend to implement it through an open-source solution, Keycloack.

Sstod, ***Reenpred***, ***Closeap*** and ***Senplanner*** are the before mentioned GMV COTS in charge of implementing the computational layer in every use case. ***Closeap*** provides conjunction analysis capabilities and will be used for CDM refinement. ***Reenpred*** is intended to be used for re-entry refinement, ***Senplanner*** is to be used to calculate the plans to command the sensors network and ***Sstod*** will be used in the other use cases (orbit refinement, calibration, etc.)

Every component of the Figure 3-4 is deployed in a separate container. ***Sstod***, ***Reenpred***, ***Closeap*** and ***Senplanner*** are volatile containers, meaning that the container is run when the COTS is called and disposed when the call ends and the results is returned by the corresponding output files. The other containers are never stopped, they are always running as services.

4 NEXT STEPS

Some months after the beginning of the activity, the project is finishing the design phase, which corresponds to the advancements described in this paper.

Although the global design of the upgraded ESA's IZN-1 station is not completely fixed yet, some of the required items have been identified as a clear need. The procurement of these parts has already been started in order to avoid project delays caused by the long delivery times needed for these items. The hardware items will be integrated and tested before being installed at Observatorio de Teide in Tenerife (tentatively before Christmas 2023).

DLTN Online Platform development has started early January 2023. Its release is expected for last trimester of the year.

Both parts will be tested in an observation validation campaign that will take place first semester 2024.

5 CONCLUSIONS

This paper has shown the main objectives of the activity and the current status of the two main tasks.

As part of the upgrade of the IZN-1, it is planned to extend the functionality of the system with a space debris laser ranging transmitter for ranging during night-time as well as daytime to uncooperative targets. The space debris laser system will be installed in a separate structure, on its own mount. Such a system can be installed adjacent to any SLR station, enabling it to perform Space Debris Laser Ranging (SDLR) without modifying the main SLR system.

The Debris Laser Tracking Network (DLTN) will connect users and contributing SLR stations and it could be operated commercially.

The DLTN-OP is an online sensor network platform for near-real time requesting, scheduling, analysing, displaying and providing Space Surveillance & Tracking (SST) data products for the end users. This platform has been designed taking into account automation, reuse experience of SatNOGS, use of GMV's COTS and use of well-established international standards (CCSDS).

At the time of writing this paper, the activity is close to finishing the design phase. Development period is planned for this year and observation validation campaigns for first semester 2024.

6 REFERENCES

1. Degnan, J. (1993). *AGU Geodynamics Series*, 25, 133

2. Zhang, Z.-P., Yang, F.-M., Zhang, H.-F., Wu, Z.-B., Chen, J.-P., Li, P. & Meng, W.-D. (2012) The use of laser ranging to measure space debris. *Research in Astron. Astrophys.*, 12 (2), 212–218.

3. Steindorfer, M. A., Kirchner, G., Koidl, F., Wang, P., Antón, A., Sánchez, J. M. & Merz, K. (2017) Stare and chase of space debris targets using real-time derived pointing data. *Advances in Space Research*, 60, 6, 1201-1209.

4. Steindorfer, M.A., Kirchner, G., Koidl, F. *et al.* (2020). Daylight space debris laser ranging. *Nat Commun* 11, 3735.

5. ISSN 0273-1177,Šilha, J., Zigo, M., Hrobár, T., Jevčák, P. & Verešvárska, M. (2021). Light Curves Application to Space Debris. *8th Eur. Conf. Sp. Debris*, 20–23.

6. Steindorfer, M.A., Kirchner, G., Koidl, F. & Wang, P. (2015). Light Curve Measurements with Single Photon Counters at Graz SLR. *In Proceedings of 2015 ILRS Technical Workshop.*