IAC-22, A6,IP,71,x70911

How will COPLA work within EU SST?

Ms. Katia Caceres [a]*, Mr. David Moreno[b], Mr. Francisco Ayuga García[b], Mr. Alfredo Anton[b], Mr. Mihai Ghita[c], Ms. Mirela Bivolaru[d], Mr. Daniel Stelmecke[e], Mr. Pascal Richard[f], Mr. Albino Carbognani[g], Mr. Tomasz Zubowicz[h], Mr. Bruno Coelho[i]

a) CDTI (Centre for the development of Industrial Technology), Spain, b) GMV Aerospace & Defence SAU, Spain, Spain; c) European Union Satellite Centre (SatCen), Spain; d) Romanian Space Agency (ROSA), Romania; e) DLR (German Aerospace Center), Germany, f) CNES, France; g) INAF, Italy; g) Polish Space Agency (POLSA), Poland; i) Portugal MoD, Portugal; *Corresponding Authors

Abstract

The "Decision of the European Parliament and the Council Establishing a Space Surveillance and Tracking Support Framework" was adopted on April 16, 2014. It established the European Space Surveillance and Tracking (EU SST) Support Framework at European level, which evolved into a fully-fledged component of the European Union Space Programme adopted on 28 April 2021. EU SST contributes to the global burden sharing of ensuring the sustainable and guaranteed access to and use of space for all.

Its primary objective is the provision of space-safety services, namely, to protect spacecraft from the risk of collision, to monitor uncontrolled re-entries, and to survey the in-orbit fragmentation of space objects. CDTI, as participating entity in the EU SST programme, is developing the Coordinated Planner (COPLA). COPLA's objective is to coordinate the observation schedule for all contributing sensors (while sensor control remains under the responsibility of the Member States) with the ultimate goal of improving the quality of the SST services. This paper presents the processes of COPLA within the EU SST system and answers the most relevant functional questions. How will COPLA manage availability and scheduling in EU SST? How will COPLA coordinate the tasking requests? How are the observations for services, calibration campaigns and particular exercises to be scheduled? How will COPLA and the EU SST Catalogue interact? These questions arise facing the coordination of the EU SST sensor network with heterogeneous capabilities, programmatic constraints, and technical characteristics.

Functionally, COPLA is composed of two differentiated computational chains, survey and tracking, which require to be executed sequentially to obtain the maximum benefit from the observation resources. While the survey chain is in charge of optimizing the survey operations to gain the best possible accuracy of orbit covariances during the survey activities, the tracking chain is in charge of managing the tasking requests for objects of interest. Priorization and object weighting are described in this paper.

Finally, understanding timeliness for COPLA is understanding the "rhythm" of the EU SST sensor network. As changes in the operation of sensors occur on a daily basis, e.g. due to maintenance periods and calibration campaigns, COPLA will update the sensor schedule using a configurable frequency, considering an extended temporal horizon and updating dynamically the planned slots in order to consider the latest available orbital information of the objects and tasking requests from the catalogue and services.

Keywords:
EUSST, Planner, Scheduling, Survey, Tracking

Acronyms/Abbreviations
Coordinated Planner (COPLA)
European Space Surveillance and Tracking (EU SST)
Operations Centre (OC)
National Operation Centre (NOC)
Tasking Request (TR)
Member State (MS)

1. Introduction

Within the Space Surveillance and Tracking systems, a **key element** is the **sensor planning** system. The **quality of the catalogue and the SST services** generated by the system will largely depend on its **effectiveness** in planning the available sensors. The planning system must take into account various inputs, such as the quality of orbit data within the catalogue and request from the cataloguer for objects to be maintained, the follow-up requests from the different services, for example collision avoidance, fragmentation and re-entries analysis, the capacities of each sensor and the characteristics and orbits of the objects to be planned. From these inputs, the planning system must generate proposals for the observation strategies of the surveillance sensors and the tracking plans of the sensors that allow optimizing the use of the sensor network based on predefined weighing functions. Good planning will allow any SST system to make optimal use of the capabilities of the sensor network, obtaining its greatest benefit from the catalogue and service point of view, and enable the SST system improving the precision of the orbit based on the specific needs for each object.

For instance, within a sensor network, among others, there are coexisting sensors that use different technologies: passive optics (telescopes), active optics (lasers), active radio frequency (radar) and passive radio frequency (passive ranging). Likewise, they are usually sub classified into surveillance (survey) sensors or tracking sensors, operating complementary within a network of SST sensors. Some can operate either ways or even mixed ways. Similarly, each sensor can observe one or more orbital regimes. The different combinations of technology, operating mode, capacity, quality, orbital regime, etc. will greatly affect the scheduling algorithms and the data flow followed by the system.

Optimal Sensor network operation is only achieved through centralized planning, considering all sensors together, with their capabilities and characteristics, and generating a common plan that truly optimizes resources globally and maximizes the results.

COPLA is the centralized planning tool for the EUSST network.

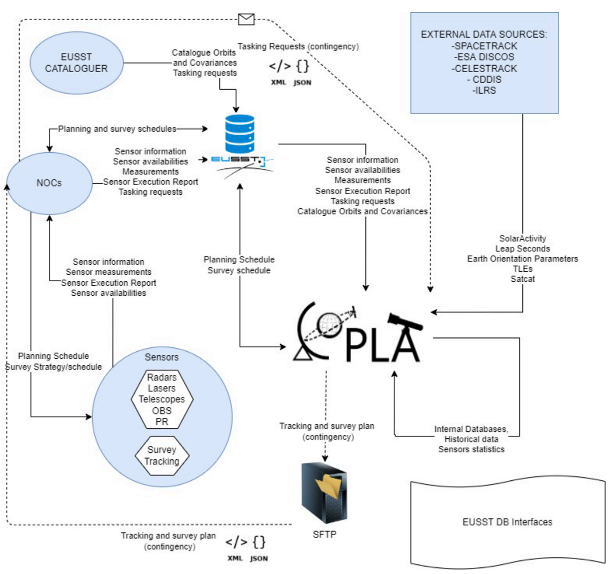

Fig. 1. COPLA schema within EU SST

Fig. 1 shows the COPLA within EU SST. It will be an element interacting with the EU SST Database to provide and receive information to the NOCs for and from the sensors contributing to EU SST and as well as the EUSST cataloguer.

This paper presents the processes of COPLA within the EU SST system and answers the most relevant functional questions.

2. COPLA Processes within the EU SST

<u>*2.1 Tasking request integration process*</u>

In the EU SST the requests to sensors for events, observations, exercises etc is carried out by the Taskin Request (TR) process prioritising services. This process is in constant evolution given the needs of the network, specific requirements by OCs and the evolution of the EU SST DB. In order to optimise and efficiently integrate TRs, COPLA will optimise the performance of TR within the network creating plans that maximizes the efficiency and results.

The nominal process consists in the TR being read by the COPLA, producing a plan to be sent to the EUSST DB. The plan may contain or not one or several slots for the TRs depending on its priority and the other slots. COPLA, based upon observability and detectability conditions will accept or reject the TR in the EU SST DB, and depending on its global optimization COPLA may lead to the case that not all the TR slots will be scheduled by all the declared sensors declared as accepted for the TR, as COPLA will know which contributions optimise the network and the observations. Even if a sensor is declared as contributing there will be situations when it is not going to be able to participate in the TR (weather, inability to observe) in this way the sensors will not be penalize and the best opportunities are going to be scheduled for events given their priorities

,

Next figure shows this dataflow:

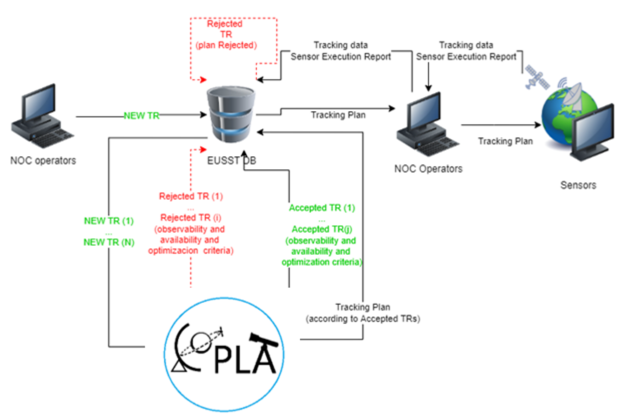

Fig. 2 COPLA schema TR

<u>*2.1.1 COPLA and Catalogue TR processes*</u>

As part of the natural integration within the system the catalogue planification will interact with the COPLA.

In a nominal way of functioning one of the priorities of the coordinated scheduling activities is prioritising services and catalogue quality.

Catalogue implements its own quality control methodology and as part of this it will be able to create tasking requests that will be ingested by the COPLA to improve the quality of particular orbits that require extra observations.

By its own functioning schema COPLA prioritises the quality of the catalogue meaning the number of the TRs generated by catalogue should be low in a nominal operation environment. This scenario will be analysed in operations analysing the number of TRs, the efficiency of the system, and fine-tuning taking into account TRs generated by catalogue versus improvement of the covariance generated by the tool.

2.1.2 COPLA and Calibration TR processes

COPLA will improve the organization of the calibration campaigns, by scheduling observations depending on sensors for each member state, calibration objects (nominal objects for calibration or customised objects) and priorities, depending in the criticality and timing of the campaign. These options will be customised by the MS originator of the TR having by default values in case only calibration is defined.

Observation opportunities will be computed for the given sensors-objects giving flexibility to the network and optimising the resources in the whole calibration period.

In a next phase the COPLA preview to include an evolution in calibration pointings improving the process.

2.2 Survey, Tracking, Monitoring Chains

Once COPLA has downloaded the required inputs from the EU SST DB the tool can starts its execution. For a nominal execution, the workflow should be understood as sequentially, starting from the Survey Chain, then the Tracking Chain and finally the Monitoring Chain (see Fig. **3**). At the same time, each of the chains encompasses a set of modules that works also in a sequential way.

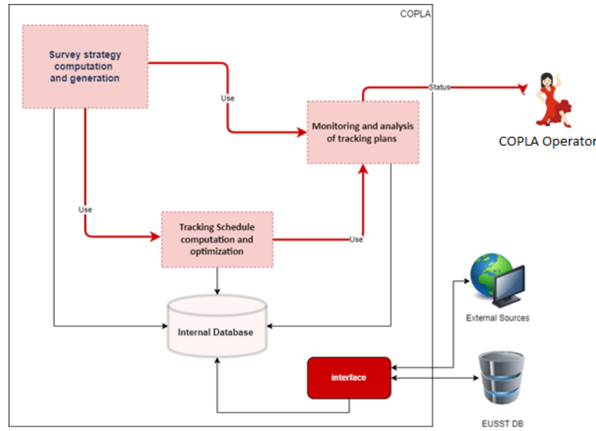

Fig. 3. COPLA Chains flowchart

Survey Chain is the starting point of the COPLA once the different inputs from the EUSST DB and external sources such as orbits, sensor availability, Earth orientation parameters, solar and geophysical activity, object properties, etc… have been retrieved. It has the following modules ordered sequentially.

Survey Strategy module is only used for optical sensors since in the case of surveillance radars, there is no possibility of any kind of surveillance strategy as the field of view for the radar is generally fixed by design.. The selection of the surveillance strategy, therefore, consists of two parts: selection of the declination band and subsequent selection of the right ascension. For the selection of the declination band, the process starts from a complete set of objects from which the objects that meet certain criteria are filtered, i.e. minimum and maximum apogee, maximum eccentricity, inclination ... etc. The filtered set is propagated in order to locate the region of object concentration, and the declination band is calculated. Once the size of the band to be observed is known, the number of visual fields in the same band is calculated considering the sensor's own field of view. Once the declination band to be observed has been calculated, the next step is to find the location of the bands to be observed that maximizes the conditions of observability, considering effects such as the separation of the moon, the galactic plane, the shadow of the earth, etc. To do this, a simple optimization is carried out where the observation time of the region outside these restrictions is maximized. In other words, the tool optimizes an observation strategy where the effective surveillance time, as well as the brightness of objects, are maximized (see Appendix A). The tool is in a preoperational phase these strategies will be under study and finally, the MS will decide to follow the survey strategy or to provide the tool with its own survey strategy.

Survey visibilities module will evaluate the visibilities obtained with both, the survey strategy for optical sensors and the fixed pointing for radar sensors against the complete EU SST Catalogue. For this evaluation, the observability and detectability constraints for each sensor type will be used.

Survey accuracy gain module is in charge of obtaining the main objective of the survey chain, that is, computing the covariance improvement produce by each of the survey visibilities (represented as a set of measurements depending on the visibility extension). This improvement will be later used in the **Tracking Chain**.

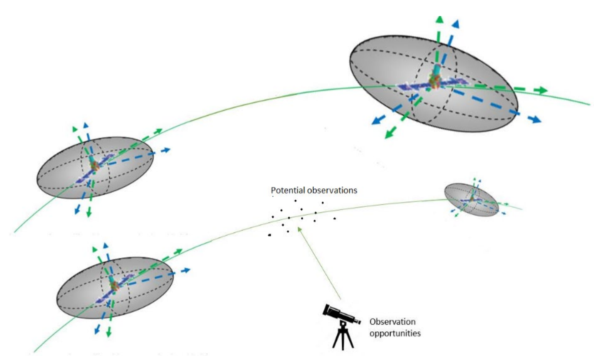

Fig. 4. Accuracy gain obtained with potential observations from a survey sensor

Tracking chain is used by telescope, radar and laser stations under tracking activity. This chain is mainly dedicated to objects under tasking requests from the SST services, high degraded accuracy objects from the Catalogue, calibration campaigns and dedicated exercises. In order to extract optimal schedule of the sensor network, this chain should be executed after the **Survey Chain** considering the observations likely be provided by the survey sensors and their effect on the objects. It has the following modules ordered sequentially.

Object characterization module main functions are the classification of the objects in different groups, known as “population groups” and the establishment of the priorities for the full object’s set that will be used later for the optimizer (see Section 1.3 for further details).

Tracking opportunities are computed in a similar approach as **Survey visibilities**. The only difference is that for the case of opportunities the condition of having the object inside the FoV is changed by the Field of Regard (FoR). FoR can be defined as the total area a sensor can cover by changing its pointing. This condition is implicitly met with the observability constraints. This opportunities computation phase will allow constraint relaxation, so that its main objective is just to obtain a set of pre-filtered opportunities with the most restrictive or physical conditions. Then, in a second phase, a probabilistic approach will be applied on those filtered opportunities. The probabilistic approach allows considering the uncertainty in external or environmental factors, and relationships between the different constraints, simply giving a value of the joint *observation probability* of a given object for each moment. For this approach, machine learning algorithms will be used since they can implement simple neural networks that can represent the effect on the *observation probability* as a function of the observation parameters, elevation, separation and phase of the moon, brightness, etc ...

Sensor performance weighting module will also provide an additional contribution to the schedule optimisation given the sensor performance indicator. A model based on the history of previous plans and the characteristics of the sensor, and the objects are used to estimate the success probability that a given slot will be actually observed by the sensor. This success probability is used by the planning algorithm as an additional contribution to the cost function of each slot. Two kinds of models are available for computing the sensor weight: one is a simple statistics-based model, based on the success rate of previously planned slots to that sensor in the past; the second model is a machine learning methodology which used more information about the object.

Tracking accuracy gain module works in the same way as the Survey accuracy gain module with the only difference that in this case the initial covariance to which they are added the slot improvement will be the updated one after the survey campaign.

Tracking plan optimizer module makes use of a generic discrete optimizer that, based on the previously calculated observation opportunities, selects from those opportunities already divided into slots that obtain the best result by means of a predefined cost function (see Appendix B). This cost function will include the expected improvement in the covariance of the objects, their priority, the probability of observation, and sensor performance indicator. The solver optimization process has the following phases:

- The Construction Heuristic (CH) initializes the values of the planning variables according to the score (hard/soft constraints) and the selected strategy.
- The Local Search (LS) works from an initialized solution that evolves during the

search according to the score and the chosen search algorithm.

A full description of the algorithms implemented by each of these modules can be seen in [1].

Object pointing generator is the last module of the **Tracking Chain**. For the optimal slots (scheduled slots), the corresponding OEM/TLE and/or CPF (in case of laser) and pointing coordinates (Azimuth-Elevation and Right Ascension-Declination) are computed.

Final part of COPLA is the **Monitoring chain** used for the analysis of the results of the survey and tracking campaigns. This chain is composed of two different modules: monitoring and visualization.

Monitoring module performs a cross-check between the commanded tracking plan and/or the survey visibilities, the sensors execution reports, and the measurements received from the sensors. In this way, it is possible to know for each commanded slot or for each track of measurements received in the case of surveillance sensors, the observation conditions reported by the sensor (meteorological or technical) and if the planning of said slot has been satisfactory, allowing the operator immediate analysis of the result of planning. In this way, the COPLA Operator knows immediately if the observation request has been satisfied or, if not, the reason why the slot has not been able to be executed. On the other hand, as described in the calculation of opportunities and weighing of sensor performance, the monitoring of the tracking and surveillance plans will allow the feedback of the automatic learning modules in charge to obtain the observation probabilities and the figure of merit weight of the sensor.

Visualization module will use Grafana technology to allow the Users explore and visualize all the outputs of COPLA. For example it allows to visualize complete schedules of a tracking campaign, to Gannt chart for slot visibilities, observation conditions heatmaps, sensor availability and distribution worldwide, etc.

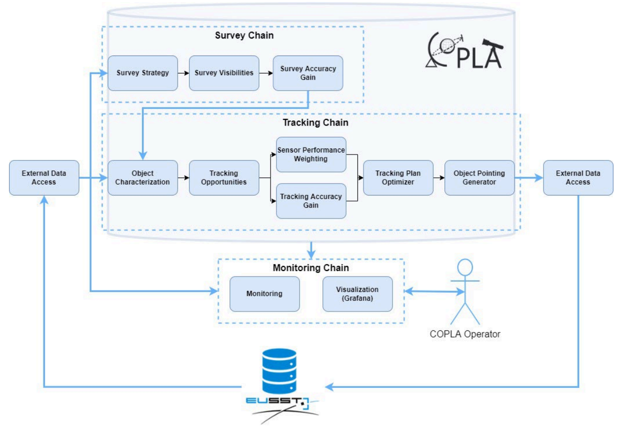

Fig. 5 COPLA Chains flowchart

2.3 Priorization and object weighting

One of the key points of COPLA workflow is the **Object characterization** mentioned before. This characterization is mainly based in three different aspects: **orbital regime, population group and object priority**.

For the orbital regime, COPLA classify the complete set of objects based on their lower and upper limits for the Semi-Major Axis, Eccentricity and Inclination.

Population Groups are defined by the COPLA Operator according to object properties or identifier such as:

- Status of the object (Debris, Active, Decayed or Unknown).
- Event type in which the object is involved, if applicable (Conjunction, Re-entry, Fragmentation, Calibration or Other).
- Risk level of the event in which the object is involved, if applicable (Info, Warning or Alert).
- Orbital regime of the object, as explained before.
- Object International Designator

Each of the *Population Groups* have an associated priority multiplier which can be also tunned by the COPLA Operator.

Object priority is computed by a set algorithm mainly based in the following aspects:

- Priority multiplier, as described before, for each of the *Population Groups.*
- Accuracy factor that depends on the covariance of the object (main diagonal) after the survey campaign and the time since last observation of the object.

- Size factor that depends on the area of the object.

In that way, as the greater is the multiplier, object's covariance, time since last observation or size the greater will be the computed priority. Additionally, on top of this priority there exists an extra factor that accounts for the EU SST Tasking Requests. Tasking Requests explained in Section 1.1 can be classified according to the following criticality (stablished at EU SST Consortium level):

Table 1. Tasking Requests criticality

EU SST Criticality	COPLA Priority extra factor
Top priority defined by the EU SST	1
Services High Interest Events	2
Services Interest Events	3
Large debris vs large debris event	4
Catalogue	5
Campaigns & Experiments	6
Default TR	10

Table 1 shows the different possible criticalities values of Tasking Requests together with their associated priority for COPLA, being Task Force the most important event in the EU SST. Therefore, the internal COPLA priority of an object will be always higher for Tasking Requests than for nominal objects. For example, the same catalogued object can have a higher priority in case a Tasking Request of Catalogue criticality is opened for a period of time than if the object follows its nominal flow (without being triggered by a Tasking Request).

2.4 Timeliness

In this section the schematic nominal timeline for the COPLA is presented. With this schematic timeline it is possible to understand how the whole dataflow works with time, taking into account that the sensors can work in very different ways depending on the sensor type, the tracking or survey mode or even among similar sensors.

First, **COPLA** connects to database to retrieve information to generate the plan (tasking request, catalogue and sensor status…). Then an optimum plan is obtained and uploaded to the database (survey and tracking plans for all sensors). This task is executed as many times as required, with a configurable period of execution (e.g. one day) covering a certain delta time (e.g.one week). This is depicted in Figure 6 in different colours (blue, yellow, red, green) to indicate every of the updates.

Then the **Sensors** behaviour depends on the kind of sensor or even each sensor. The interaction is not done directly but through the NOCs, which connect to the database to download and upload the data. In the Figure 6 two extremes have been presented:

- Sensor in blue horizontal bar (tracking sensor) download slots and acknowledge the plan. After observation campaign, data requested to sensors (observations and execution report files) are uploaded.
- Sensor in green horizontal bar (survey sensor) operates continuously and connects to EUSST DB asynchronously, retrieving the requested time span of slots and acknowledging that time span, and uploading previously executed period tracks.

In this scheme, EUSST DB operates continuously receiving information from both sides, plus tasking requests from OCs and EU SST cataloguer.

With this way to operate, the Coordinated Scheduler can be executed anytime, and the sensors can request plans anytime, covering the required time span for any case (the required time span can be requested from the database). If the sensor acknowledges any amount of slots, those will not be considered for re-planning into the next Scheduler execution.

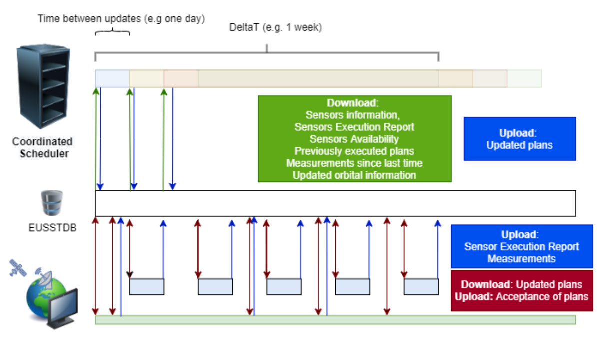

Figure 6: Schematic timeline with nominal interactions Sensors-OC-EUSST DB-Coordinated Scheduler

This schema of a timeline allows the execution of the COPLA several times a day to consider sensors located at different local time areas. In this way, The COPLA could be launched 4 times a day to allow enough reactivity to the sensors at different locations, and at the same time, consider updates in terms of accepted slots for reprograming of tasked objects due to TRs, etc.

In a next phase of the project real time planning will be consider. Adaptation to the timeliness of the overall EU SST network is a priority of the tool to be demonstrated at the operational phase.

3. Results (Execution process plans)

This section presents the main results obtained for a recent campaign within EU SST. This campaign was an EU SST Task Force request for observing the core stage of the rocket that launched the second module of the Chinese modular space station (Wentian). The properties of this object after launchare:

Table 2. Orbital characteristics of 2022-085B

Feature	Value
NORAD ID	53240
COSPAR ID	2022-085B
Satellite Name	CZ-5B R/B
Type	Rocket Body
Inclination	41.45º
Apogee	306.90 km
Perigee	189.22 km
Size	Large

The main objective of this campaign was to obtain as much measurements as possible from the EU SST sensors in order to compute the re-entry window and location of the object for re-entry risk assessment analysis.

The workflow of the campaign starts by opening a Tasking Request with Re-entry type and Task Force priority. After this, COPLA can start working by downloading all the needed information from the EU SST DB, such as, orbital information, sensor information, sensor availability and obviously Tasking Request information.

A first interesting picture for COPLA Operator is the one shown below, in which a prelaminar insight of the available sensors can be extracted in order to know what the sensor activity during the campaign will be.

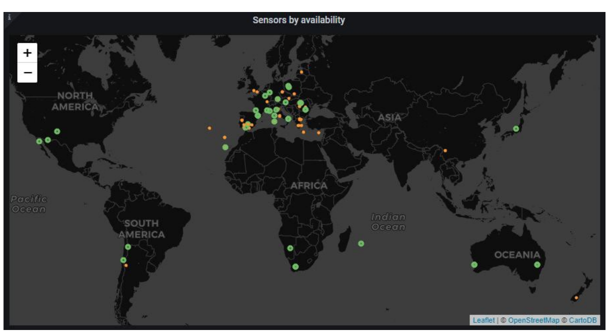

Fig. 7. EU SST Sensor availability

Having this in mind, COPLA main software is executed for all the EU SST sensor network and for an analysis period between 2022/07/24T00:00:00 to 2022/07/27T00:00:00, obtaining the following slots of visibilities:

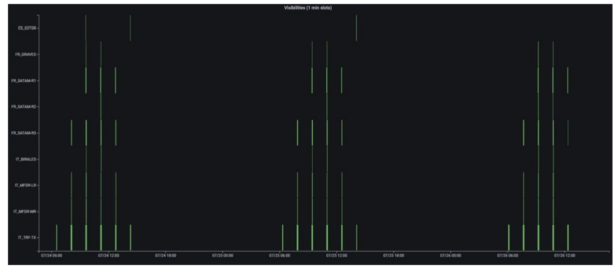
Fig. 8. Visibilities for EU SST Sensors

It is also interesting for COPLA Operator and other Users to see how the distribution of these passes will be in angular rate and elevation of the object.

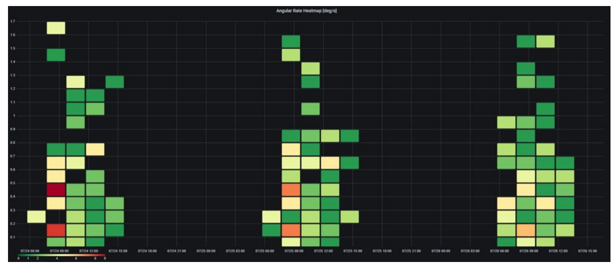
Fig. 9. Angular rate Heatmap

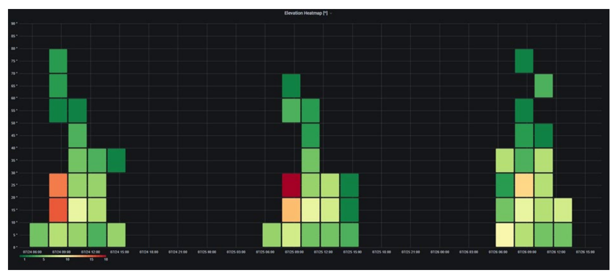
Fig. 10. Elevation Heatmap

In 9 it is possible to see that the greater concentration of visibilities is in the low-velocity region which is favorable for obtaining longer measurements. On the other hand, in 10 it is possible to see that the elevation of most of the visibilities is very low, which is consistent with the geographical location of the sensor used for the illustration.

5. Discussion

This paper shows the future of the EU SST sensor planning with the integration of COPLA tool. When comparing this situation with the current EU SST, that is, without a coordinated planner some highlights or improvements can be extracted as specified below.

First of all, the feedback obtained from the covariance improvement during a survey campaign or period will be inserted in the Tracking Chain thus avoiding the excess or defect of measurements for the same object over the same period. This is something that cannot be achieved with the current EU SST situation, in which the survey campaigns cannot be quantified and transmitted to other OCs for considering them in their tracking plans.

The main advantage, however, is the possibility of optimization the sensor network. With the current EU SST situation each OC is responsible of selecting the tracking tasks for its own sensors (decentralized scenario) without knowing the tasks of other sensors and prioritizing the Tasking Requests. By doing this, the system works in a suboptimal scenario. With COPLA (centralized scenario), all the needs are optimized at the same time, so that, not only the Tasking Requests are covered but also catalogue maintenance is improved. And what is more important, the potential tasks of one sensor affect to the rest of the sensors and therefore objects in Tasking Requests are not overloaded with measurements but optimized between them.

Finally, there is one additional advantage of the centralized scenario, which is the possibility of monitoring the performance of all the sensors together and even use these results to feed the chain later.. In addition, a global picture of the EU SST could be also extracted from this centralized scenario with COPLA.

6. Conclusions

COPLA is a new tool within the EU SST network that will implement an optimization and maximize network performance. Operation is a key part of the implementation of the tool that will require adaptations for a network nonhomogeneous and with different peculiarities. Tasking request optimization and responsiveness, sensor observations, sensor efficiency, increase of performance of sensors with different configurations, integration processes, all these different casuistries will be improved by the COPLA.

The COPLA in this moment is in a first version that will be fine-tuned into operations within EUSST processes. The tool needs operations for a perfect adaptation and iterations with the different MS, OC, sensors and actors, being a non-heterogenic network and initiating an exciting next phase for the project.

The evolution of the tool is already envisioned as a real time configuration and planning, as also data timeliness, having the most updated information for the most critical events. The real time planning evolution opens the door to also consider sudden changes of meteorological conditions for reassigning high-priority tasks among sensors or fast actuations to new high interest events in which the response time is very limited. In addition, it will be very useful for capturing unforeseen problems in sensors and be able to reconduct the tasks of a non-operative sensor to other sensors.

Acknowledgements

This project has received funding from the Horizon 2020 research and innovation programme under grant agreements No 952852. The content of this presentation reflects only the view of the SST Cooperation and the European Commission, and the Research Executive Agency are not responsible for any use that may be made of the information it contains.

Appendix A (Survey strategy optimization)

Survey strategy optimization function:

(1)

$$\underset{\alpha_j,\,\delta_j}{\text{maximize}} \sum_{i}^{N_b}\sum_{j}^{N}\frac{1}{2}\left[1+\cos\left(\theta_{i,j}\right)\right]\Delta t_{i,j}$$

$$\text{subject to}\ \begin{cases} el_j > el_{min} \\ SZD_j > SZD_{min} \\ GDP_j < GDP_{max} \\ MD_j > MD_{min,NM}\ \text{if}\ (\alpha,\delta)\in \text{New Moon} \\ MD_j > MD_{min,FM}\ \text{if}\ (\alpha,\delta)\in \text{Full Moon} \\ \beta_j > VA_{Sun,j} + VA_{Earth,j} \end{cases}$$

Where:

* NB is the number of vertical barriers and N is the total number of epochs under analysis

* Δti,j is the survey field time for the ith barrier at jth epoch

* βj is the angular difference between observations taken from the centers of the Sun and the Earth and VABody,j is the view angle (half of the angular extent of the object w.r.t. certain body, also known as semi-diameter) jth epoch

Appendix B (Tracking plan optimizer)

Tracking plan cost function:

$$minimize \sum_{j=0}^{obj} F_{obj}\cdot\frac{1}{Acc_T}\cdot w_1 + \sum_{s=1}^{sens}\sum_{m=0}^{mov}\alpha_m\cdot w_s \quad (2)$$

$$\hat{P}_{fT}^{-1} = Trace(\hat{P}_{fS}^{-1}) + \sum_{i=0}^{obs\ T} Trace(H_i^T W H_i)\cdot F_{obs}(1-F_{cc})\cdot F_{sw} \quad (3)$$

Where:

* $Fobj$ represents the priority of the object, the objects with the highest priority weigh have preference to be observed.

* $P̃fT$ represents the final orbital accuracy gain with respect to the updated covariance from survey operations ($P̃fS$) considering all the observations of the selected slots of the same object for tracking $\sum HiTWHi\cdot Fobs(1-Fcc)\cdot obs\ Ti=0Fsw$.

* $Fobs$ represents the probability of success of the slot according to the probability estimated by the opportunity calculation.

* Fcc represents the forecasted probability of cloud cover.

* Fsw represents the figure of merit calculated based on the historical performance of the sensor, i.e. sensor weight.

* αm represents the angle of by the sensor for the movement from slot m to slot m+1.

* $w1$ and ws correspond to configurable weights by the COPLA operator that will allow adjusting the relative weight of the observation quality and the movement of the sensors.

References

[1] D. Moreno, A. Domínguez, F. Ayuga, A.M. Antón, D. Lubián, I. Grande, K. Cáceres, Coordinate Planner Algorithms, 3rd IAA Conference on Space Situational Awareness (ICSSA), 2022.
[2]2-3SST2018-20 Proposal- Second funding line in Work Programme 2018-2020 for the further development of a European SST Service provision function
[3] Decision No 541/2014/EU of the European Parliament and the Council Establishing a Space Surveillance and Tracking Support Framework" (2014).
[4] Regulation (Eu) 2021/696 of the European Parliament and of the Council of 28 April 2021.