Steps Towards a European SST System for Objects Beyond LEO Altitudes – Romanian Insights

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ABSTRACT

In this paper we present a short overview of space surveillance and tracking (SST) technologies and requirements, ongoing European programs and Romanian projects that could potentially contribute to a more comprehensive and resilient NATO space situational awareness.

1.0 INTRODUCTION

Space-based systems have become indispensable to many services critical to Europe's economies and government functions, including those related to security. This dependency will increase in the future. See for instance [1,2,3]. Space Surveillance and Tracking (SST) is the ability to detect and predict the movement of satellites and space debris in orbit around the Earth.

From a civilian perspective, data generated through a SST system can be used to actively protect space-based infrastructure, such as Earth observation satellites or navigation systems, from colliding with the ever-increasing cloud of man-made space debris.

From a military perspective, should be noticed that SST activities are classified. For instance, detection of an unknown space object and its orbital parameters is classified by default. Detected objects undergo the following (typical) identification process:

- The object will remain classified until identified
- When correlated with a classified object, it remains classified
- In other cases, it is declassified and orbital data might be made available to third parties.

2.0 EUROPEAN PERSPECTIVE ON SST

The high-level users' needs for the European SST system can be summarized as follows. See for instance

[4,5]:

- support safe and secured operation of space assets and related applications
- support risk management and liability assessment
- assess the status and basic characteristics of space objects
- detect non-compliance with applicable international treaties and recommendations
- enable the allocation of responsibility for space objects (to launching State) or Organisations (ESA, Member States, etc.), and support confidence building measures (identification of owner and/or operator).

The core of any SST system is the catalogue; this contains information on everything that has been detected in orbit. In order to produce this catalogue, it is necessary to:

- Reconstruct object orbits from the data that are produced by the sensors (orbit determination). Please see Fig.1.
- Check to see if this object has already been seen and is already in the catalogue (correlation). This is a very challenging issue. If we are speaking about a catalogue produced by the same sensor/sensor network it is easy. But, if we want to correlate the catalogues produced by sensors in Europe and US we have to find a way to correlate catalogues. Are we speaking about the same object? Technically speaking, it is possible. For instance, it is about setting up international SST campaigns in the NATO framework. Same space object observed from different NATO countries, each of them using some owned sensor. The next step should be the interoperability of national SST assets (the capability to exchange information and data using specific and agreed protocol). To some extent, we already know how to do it. Please think to Space Weather and NEO (Near Earth Objects) monitoring. In these cases global cooperation is really working since we are facing common threats. But, regarding SST, there are many sensitive problems, especially regarding the detection of classified satellites. The main question is: are NATO countries really open to share SST data for building a common space objects catalogue?
- Monitor the data in the catalogue so that sensors can be tasked to update the information when needed.

One of the critical issues in developing a catalogue of space objects is orbit determination which is obviously dependent on sensor precision/accuracy. Looking to the diagram in Fig.1, what we really can measure is: ranging, rate ranging, angular position, speed. Fig.2 illustrates the definition of a typical SST sensor "precision" [6].

To be noticed that in all cases (such as ranging or angular position measurement) orbit determination involves some mathematical models which can be more or less accurate. In some cases (such as avoiding collision between an operational satellite and space debris), small errors might be critical.

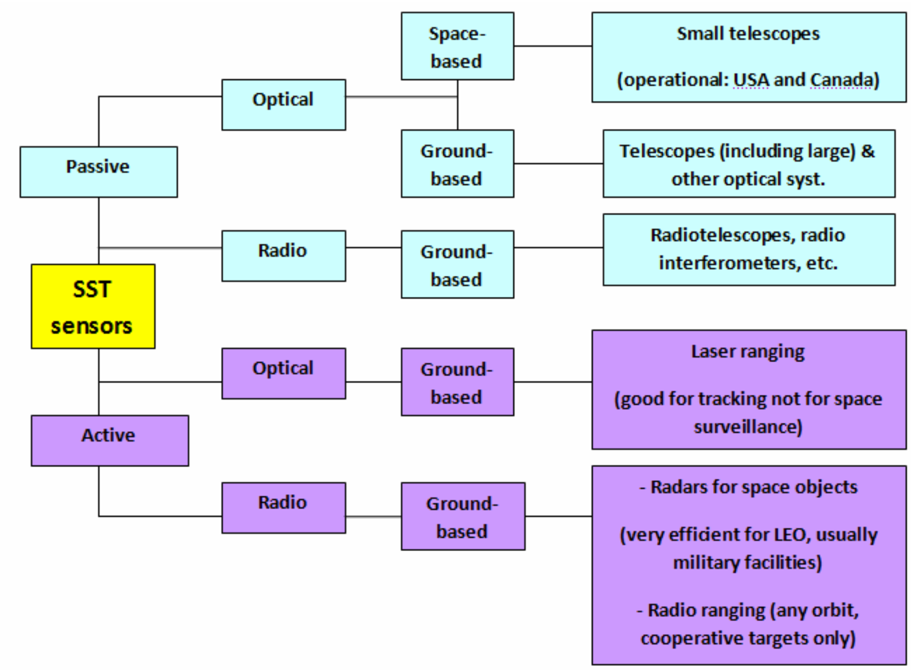

Figure 1: A personal view on typical SST sensors and short comments. This is not an exhaustive list.

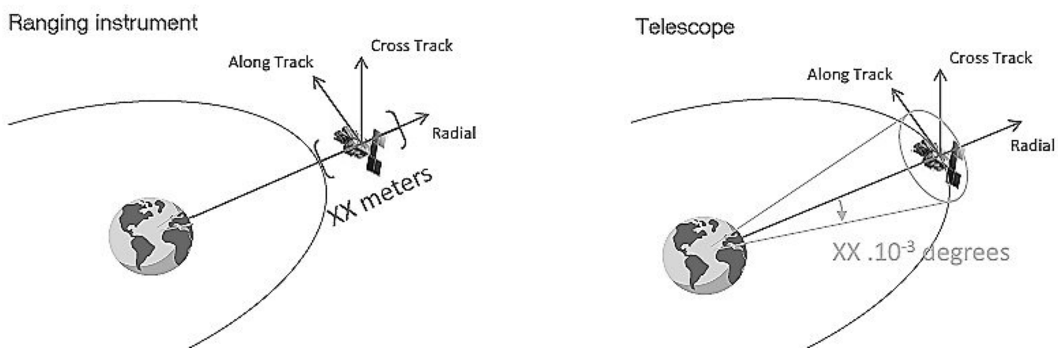

Figure 2: Definition of the precision in the estimation of the location of a satellite using a ranging instrument or a telescope [6].

Performance requirements of adequate SST sensors (as defined by EC):

- The number of objects detectable (>500 LEO objects detectable by a survey sensor and >3000 LEO objects detectable by a tracking sensor; >50 objects for survey sensors and >100 objects for tracking sensor, on any other than LEO). A space object is detectable by an SST sensor system if the operator of the sensor can demonstrate that he can correlate its physical parameters measurements with an already catalogued space object.
- The precision in the estimation of the location of the objects:
  - radial for LEO objects survey sensors (<100 m)
  - angular for all other cases (< 0.1 degrees for LEO objects tracking, < $2x10^{-3}$ degrees beyond LEO using a surveillance sensor and $<10^{-3}$ degrees for tracking sensors).

- Reactivity:
  - In the case of an SST survey sensor system, the time between the acquisition of the physical parameters of all detectable space objects and their detection and location shall not exceed one week.
  - In the case of an SST tracking sensor system, the time between the assignation of the space objects to the SST sensor system and their detection and location shall not exceed 48 hours in 90% of the cases.

It is obvious that a network of sensors (especially if they are geographically dispersed) highly increase the accuracy of orbit determination. For instance, the former statement is equivalent with increasing the visibility window of a space object. It is why NATO countries should cooperate.

With so much at stake, it is not surprising that Europe has decided to acquire a comprehensive SST system. Actually there are two significant ongoing SST programs at European level (other than bilateral or multilateral agreements between nations possessing SST assets, including cooperation with US):

- The ESA SSA program (including SST). The ESA SSA Programme has been on-going since 2009, first as a Preparatory Programme and, after the 2012 Ministerial Council meeting, as a full Programme (Phase-2) in which Romania is participating. A number of activities, many in the form of industrial contracts, have been initiated and some already completed since the start of the programme. Please see, for instance [7]. In Period 3 (2017 ‐ 2020) of the programme, ESA will look towards the implementation of an operational system while continuing to develop new capabilities and implementing more services in the currently ‐ and forecast domain to enhance the awareness of the space environment.
- The EC SST European Support Program [6,8,9]. The European Space Surveillance and Tracking (SST) support program consist in networking and in using national SST assets to provide SST services. During an initial/first implementation phase of the SST Support Framework, five Member States (Germany, France, UK, Italy and Spain) have been deemed compliant with the criteria laid down and have designated national entities which constituted the SST Consortium and signed on 16 June 2015 an SST agreement laying down the rules and mechanisms for their cooperation as well as on 14 September 2015 implementing arrangements with the EU SATCEN. Other nations, such as Poland and Romania, expressed their interest for joining the European SST consortium.

3.0 EUROPEAN PERSPECTIVE ON SST CRITICAL ISSUES REGARDING SPACE SURVEILLANCE AND TRACKING OF OBJECTS BEYOND LEO ALTITUDES

This is a huge volume of space (more than 10^{14} Km^3) containing critical space infrastructures which must be protected: GNSS satellites, Telecom satellites, remote sensing satellites, other surveillance satellites.

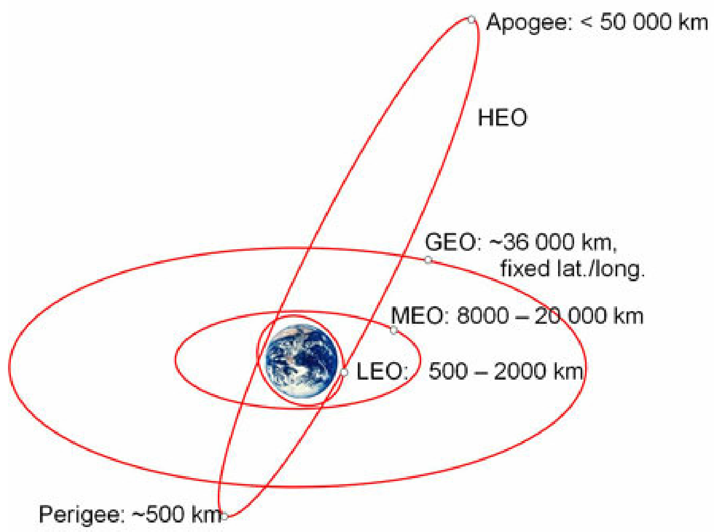

Figure 3: Satellite orbits

The general high orbit regime is caught between the excellent radar coverage at LEO [1] and the simplicity at GEO/quasi-GEO detection using telescopes [2].
When we are speaking about an unknown space object beyond LEO and which is not on GEO/quasi-GEO we can barely rely on a radar (with questionable accuracy for orbit determination) or alternatively use specially adapted optical observations techniques (very small probability for detecting an object with unknown orbit).

Regarding the recommended SST sensors for objects beyond LEO, as stated in the EC SST European Support Program documents, their performance is defined in terms of angular accuracy (meaning telescopes observables) [6].

Several ESA funded studies regarding the architectural design for a future European SST system report on the existing gaps in the observability of this kind of orbits and recommend the deployment of additional telescopes. See for instance [10].

4.0 ROMANIAN INITIATIVES AND PROJECTS REGARDING SPACE SURVEILLANCE AND TRACKING OF OBJECTS BEYOND LEO ALTITUDES

Actually, Romanian organizations are involved in several SST related projects:

4.1 Examples of undergoing ESA industrial contracts with Romanian involvement

- Development of the ESA “fly-eyed” survey telescope (see Fig. 4) which will have performance equivalent to a 1 m-diameter telescope, and providing a very large field of view: 6.7° x 6.7° or about 45 square degrees; 6.7° is about 13 times the diameter of the Moon as seen from the Earth. The new telescope would provide the resolution necessary to determine the orbits of any detected objects. The main idea is to build a telescope that splits the image into 16 smaller sub-images to expand the field of view, similar to the technique exploited by a fly’s compound eye.

[1] There are radars that can detect space objects beyond LEO but their accuracy for orbit determination purposes is questionable.

[2] This is simple because the objects co-rotate with the Earth, making their images almost static on an Earth-fixed sensor’s focal plane.

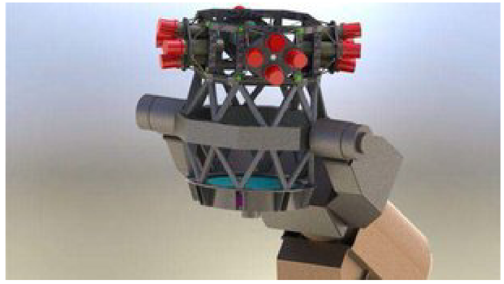

Figure 4: ESA's fly-eye telescope

- Development of a space objects radar in Romania (feasibility study). The main objective of the present project is to deliver a study related to the possible reutilization of the 32-meters antennas presently available at the Cheia Satellite ground station (see Fig. 5), in the context of the European SSA programme.

Figure 5: Cheia antennas for a space radar.

- Assessing the GNSS satellites orbit accuracy and repeatability, comparing observed satellite angular positions on the sky from given points on Earth (using telescopes) with the angular positions predicted by the global ranging network.
- Development of software tools for SST applications. Project example: "GENERIC DATA REDUCTION FRAMEWORK FOR SPACE SURVEILLANCE". The Data Reduction Facility implements the data processing algorithms and sub-processing steps required to process input raw CCD images from SST telescopes, and generate a list of potential Earth Orbiting objects including accurate position, brightness and other measured data.

4.2 Examples of national funded projects

The development of an experimental passive optical SST instrument, which can provide orbital information regarding space objects using long base-line stereovision (see Fig. 6). There are two versions of this system: surveillance of LEO objects (using very large FOV instruments) – see Fig. 7 and surveillance and tracking of objects beyond LEO (using telescopes) – see Fig. 8 [11].

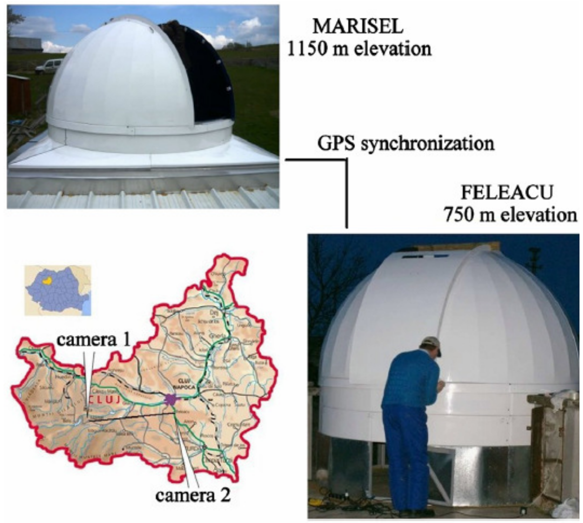

Figure 6: Romanian SST optical asset infrastructure. Pair of optical instruments for stereovision and other experiments.

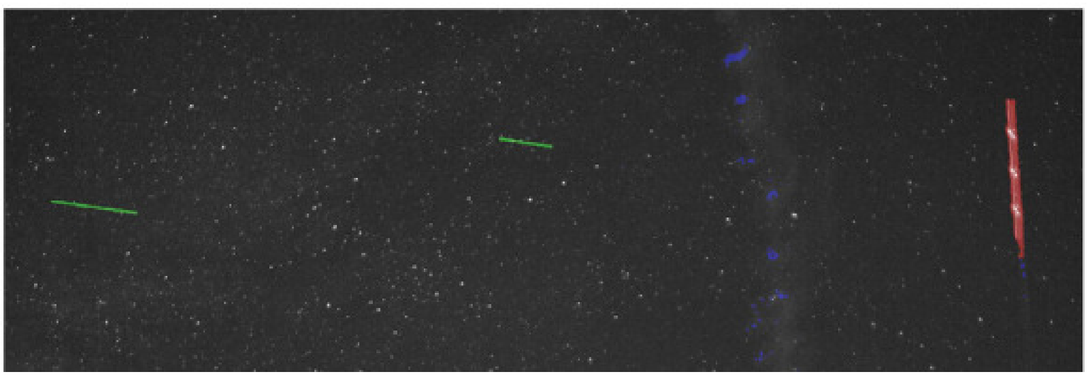

Figure 7: LEO objects detection. Sample result. Objects detection and automatic classification: two LEO objects (left) identified by the green colour, irrelevant objects identified by blue (right) and an airplane identified by red (right).

Figure 8: MEO objects detection. Sample result. Pass of Cosmos 2459 GLONASS satellite.

4.3 European Commission

Romanian optical surveillance asset (for objects beyond LEO) within the future European SST System. Actually developing a proposal for the EC SST European Support Program.

Reasons to develop a Romanian high orbit objects surveillance sensor, from the European SST system perspective. A network of European telescopes increases:

- The window of visibility of a space object
- The detection probability
- The accuracy of orbit determination.

5.0 CONCLUSIONS

- Developing a SST system with global coverage (in terms of objects observability) is a very serious challenge.
- Cooperation between NATO countries is mandatory, with mutual benefits.
- NATO is the only existing framework in which such cooperation can be setup.
- NATO can and should facilitate trans-Atlantic cooperation on Space security and defence issues, including SST. Bring NATO/EU/ESA/EDA and others together for common space security and defence matters
- A question to be answered: what should NATO's involvement be with a European Space Surveillance Network? [12].
- Romania is actually involved in European SST projects and it is open to cooperation with other nations in the NATO framework.

6.0 REFERENCES

[1] ESA (2015), "**ABOUT SSA – SPACE SITUATIONAL AWARENESS**", [Online]. Available: http://www.esa.int/Our_Activities/Operations/Space_Situational_Awareness/About_SSA

[2] NATO Supreme Allied Commanders (2013), "**NATO BI-SC Space Working Group Report on NATO's Approach to Space**", Ref. Paper: SH/J3SPOPS/13-301321 [Online]. Available: http://www.act.nato.int/images/stories/events/2012/nato_space/progress_report.pdf

[3] IAA, **2nd IAA Conference on Space Systems as Critical Infrastructure**, Mamaia (Romania), 29-30 August 2013, [Online]. Available: http://events.rosa-rc.ro/indico/conferenceDisplay.py?confId=28

[4] COUNCIL OF THE EUROPEAN UNION, "**EUROPEAN SPACE SITUATIONAL AWARENESS HIGH LEVEL CIVIL-MILITARY USER REQUIREMENTS DOCUMENT**", 24.10.2011.

[5] ESA, "**Space Situational Awareness - Space Surveillance and Tracking System Requirements Document**", Ref. Doc: SSA-SST-RS-RD-0001, 13.10.2013.

[6] EC2014b "**ANNEXES to the Commission Implementing Decision on the Procedure for Participation of the Member States in the Space Surveillance and Tracking Support Framework**", 12.9.2014

[7] ESA (2015), "**SSA PROGRAMME OVERVIEW**", [Online]. Available:

http://www.esa.int/Our_Activities/Operations/Space_Situational_Awareness/SSA_Programme_overview

[8] EC2014, "**COMMISSION IMPLEMENTING DECISION of 12.9.2014 on the procedure for participation of the Member States in the Space Surveillance and Tracking Support Framework**", 12.9.2014

[9] European Union, "**DECISION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing a Framework for Space Surveillance and Tracking Support**", 4.04.2014

[10] J. Utzmann, et. al., "**ARCHITECTURAL DESIGN FOR A EUROPEAN SST SYSTEM**", Proc. 6th European Conference on Space Debris, Darmstadt, Germany, 22-25 April, 2013.

[11] AMHEOS Project (2015), "Automatic Medium and High Earth Orbit Observation System Based on Stereovision", [Online]. Available: http://cv.utcluj.ro/amheos

[12] Tom "Solo" Single, "**NATO SSA Requirements**", SCI-229-ET on NATO Space Situational Awareness, Paris, France, 2-4 Sep 2009.