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THE NATIONAL CHALLENGES OF SPACE SURVEILLANCE AND TRACKING'S TECHNOLOGICAL SOLUTIONS

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Abstract

Space technology and services represent a major component of the well-functioning societies' infrastructure. At the same time, outer space is being increasingly accessed with many entities sending out multi-use technologies in an attempt to minimize launching and operational costs. Subsequently, as a cross-domain activity, space technologies and services lay in the insufficiently settled area of legislative and institutional measures, leading to a growing ambiguity among the professional community.

Controlling outer space technologies has become increasingly complex in the aftermath of the fundamental changes in international relations which have and continued to occur starting with the 1990s when a "human security" dimension was introduced. Emerging outer space technologies pose the great promise to enrich our lives and therefore there is a significant tension between these ideas, the difficulties of enforcing regulations with the intent to curb dual-use technology brought on by the ubiquitous tools used to develop new technologies, and, at the same time, mitigate the risks and vulnerabilities that come with it.

By highlighting the Romanian SST system architecture and few statistics of results, the paper is expected to contribute to building a better understanding of the controversial nature of space services and technologies, especially concerning delineations among geopolitical groups of interest, as well as interfacing, roles and responsibilities, and impact on interoperable means of communication among nation-states and various institutions. Based on the authors' expertise and activity in several national and international programs and projects, the paper proposes a way to manage these not-so-monolithic concepts for a generic SST architecture, considering its different institutional and legal implications.

Keywords: *Space Surveillance and Tracking, Space Situational Awareness, Space Traffic Management, Multi-use*

1. Introduction

The right of any nation-state to build up outer space technologies - be they launching capabilities, orbiting satellites, planetary probes, or ground-based equipment - is, in principle, unquestionable. In practice, however, problems arise when technology development touches the very blurry line between civil and military applications, largely because most the technologies are of dual, military and civil, purposes. This dichotomy has raised a series of political, military, security, economic, and other concerns that affect the transfer of outer space technologies in different ways, particularly between established and emerging space-competent nation-states. Accordingly, for long periods of time, several nation-states have sought ways and means to restrain the transfer of specific dual-use outer space technologies, e.g. launcher technology, while still permitting some transfer of these technologies for civil use.

However, controlling outer space technologies has become increasingly complex in the aftermath of the fundamental changes in international relations which have and continued to occur starting with the 1990s, when a “human security” dimension was introduced. Emerging outer space technologies pose the great promise to enrich our lives and therefore there is a significant tension between these ideas, the difficulties of enforcing regulations with the intent to curb dual-use technology brought on by the ubiquitous tools used to develop new technologies, and, at the same time, mitigate the risks and vulnerabilities that come with it. Dual-use technologies also mean they can be destructive beyond intended targets. Examples of dual-use space systems include global positioning, telecommunications and reconnaissance, all of which can serve either civilians or militaries. This is different from the technology that is ‘multi-use’, which is a technology that can serve defensive or offensive ends. This type of technology can originate with civilian (including commercial) entities who intend the technology to be used for civilian purposes but can nevertheless be weaponized [1]. Space Surveillance and Tracking technologies fall under the classical dual-use category, being used for both civil and military purposes.

The European Space Agency refers to Space Surveillance and Tracking (SST) as one of the most important components of Space Situational Awareness (SSA), consisting of the ability to identify and anticipate the movement of space objects that are orbiting around the Earth. An SST system develops data that contributes to the protection of space-based infrastructures, preventing in-space collisions, alongside providing analyses of in-orbit fragmentation and re-entry analysis. Moreover, intelligence operators can use SST structures to collect information on space objects, such as detecting unknown satellites or checking the activity and efficiency status of others (Space Object Identification, SOI) [3]. The direction of this action is certainly military-oriented but, some- times, it can help outline satellite maneuvers. For a complete SST system, besides the SST sensors, management structures and the facilities, it is necessary to provide a full SST process line, from the data collection to the information analysis. The SST system offers both tracking and surveillance of artificial space objects. Precisely, the” surveillance” goal is to detect new objects and compute their original orbit. Nowadays, satellites and launch actions depend on US data for collision avoidance alerts, yet the European Union has endorsed a Decision to provide a Space Surveillance and Tracking (SST) Support Framework [4]. Decision No 541/2014/EU of the European Parliament and of the Council of 16 April 2014 [5] is the foundational document of the European Union Space Surveillance and Tracking (EUSST) Consortium. It defines Space Surveillance and Tracking (SST) as one of the three pillars of space situational awareness (SSA), alongside the monitoring of Space Weather and near-Earth Objects. It highlights its contribution to ensuring the long-term availability of European and national space infrastructure facilities and services which are essential for the safety and security of the economies, societies and citizens in Europe. This safety network is being currently built from assets belonging to some EU member states, i.e. France, Germany, Italy, Poland, Portugal, Romania, and Spain, with the support of the European Union Satellite Centre.

Currently, we are on the verge of a new space travel revolution, as programs such as NASA's Artemis and ESA's new astronaut selection are coming to life. In this context, on 1 March 2022, Romania becomes the 16th country to sign the Artemis Accords, committing to taking appropriate steps to ensure that entities (also private operators) acting on its behalf comply with the principles of these Accords. The Artemis Accords contain, reaffirm and develop several principles of space law, in accordance with norms, principles and practices stemming from the Outer Space Treaty of 1967. These include principles such as peaceful exploration, transparency, emergency assistance, release of scientific data and preserving heritage. The principles set out in these Accords are intended to apply to civil space activities conducted by the civil space agencies of each signatory.

Along with this understanding, and as part of this collective international effort of building transparency, in this paper, the authors present the efforts and the results of building a national Space Surveillance and Tracking (SST) architecture. Based on the authors' expertise and activity in several national and international programs and projects, the paper proposes a way to manage these not-so-monolithic concepts for a generic SST architecture, considering its different institutional and legal implications.

2. Romanian contribution to the SSA / SST efforts

2.1. Romanian international activity

Romania, as a Member State within both the European Union and the European Space Agency, became involved in the field of SSA through the Romanian Space Agency and agreed to issue the decision of the European Parliament and the Council on the establishment of the SST Support Framework, also participating in the elaboration of the decisions for its implementation by the European Commission. As previously stated, currently seven EU member states are part of EU SST. Romania contributes to the provision of EUSST services both with valuable data from the national sensors included in the network and through the expertise and knowledge of qualified personnel. At the same time, Romania participates in all major international programs on space security – UN COPUOS, ESA SSA Optional Program, and, as stated above, is a member state of the EU Space Surveillance and Tracking Consortium, NATO space working groups and committees, European Defense Agency's programs, as well as numerous other bilateral and multilateral agreements aiming at the peaceful use of outer space [24]. Within ESA, Romania participates in the "Space Situational Awareness" Program since 2012, the year in which the accession to this program was signed. At the same time, as a participant and financial contributor to this optional program, Romania has explicitly expressed its desire to invest in the SSA domain. In addition, on 25 April 2019, the Romanian Space Agency signed an agreement with USSTRATCOM that fosters openness, predictability of space operations, and transparency in space activities. Effective monitoring and space situational awareness require cooperation, and thus this agreement builds the relationship between the two countries and allows the space community to be more effective in space activities, enhancing the safety of space for all nations.

2.2. National institutional network

Since 1957, in Romania, scientific research activities have been carried out in the fields of space weather, astrophysics and some specific services, such as terrestrial geomagnetic field monitoring, processing of SSA observational data for third parties and consulting. Nowadays, the fruitful collaboration between experts from academia, industry and at decisional level led to the development of a national SSA program with activity in all its segments: space surveillance and tracking, near-Earth objects (NEO) and space weather (SWE) monitoring. The sensor network was developed during recent years; equipped with the latest technology in data acquisition that allows the monitoring of outer space threats coming from different size objects from the solar system, from artificial space objects orbiting the Earth and from those originated by solar activity. Based on data received from all sensors, on national level several programs of space situational awareness were established; this includes a platform where a group of Romanian entities that activate in the space domain gather all the data and provide different specific products and services such as databases, maps, space weather forecast and orbit prediction. In recent years, within the National Research and Development Program and through European funded projects, a potential in the field of space surveillance has begun to emerge. The Romanian efforts are focused on the development and implementation of a national system for analyzing and assessing risk in outer space through integration of the existing infrastructure of optical and radar sensors with national astronomical data processing capabilities in order to build the national catalog of space objects and develop a national space service for re-entry events (RE). In this way, the national SSA system attempts to systematize coherently the research, monitoring and forecasting of the situation in outer space in the field of SSA.

In 2017 the Government of Romania established the Working Group for the coordination of the modification and modernization of two C-band antennas belonging to the Cheia Satellite Communications Center, within the project of the European Space Agency Implementation of a radar technology at Cheia Satellite Communications Center ”GL-CHEIA”. The founding document highlighted the issue of SSA, the steps taken by the Romanian Space Agency to join the EUSST Consortium, as well as the advantages for the national scientific research and the economic environment brought by modernization and the transformation of the equipment from the Cheia Space Center into a radiolocation system. It also underlines the important contribution to the establishment of a national and international warning and intervention framework in case of the fall of natural and artificial bodies.

Currently, GL-CHEIA is carrying out, in its second stage, for implementation of the transformation works of the Cheia Station which is the object of a project under the coordination of the European Space Agency (ESA) and Romanian Space Agency. In addition, the Romanian Space Agency coordinates a series of working groups with institutions from the defense and security realm, on issues of dual-use technologies, managing legislative initiatives, communication between institutions and even financial initiatives [25]. Furthermore, the Romanian Space Agency and Ministry of Defense are in close contact, and their institutional interconnection reflects mutual support on various levels. One of such working groups is represented by the Inter-institutional Working Group for SSA (GLI-SSA), comprising security and defense system and civil institutions, from the Ministry of Research and Innovation, Ministry of Communications and Information Society, Ministry of National Defense, Ministry of Interior, Ministry of Foreign Affairs, the Romanian Intelligence Service, the Special Telecommunications Service, the Protection and Guard Service, and the Romanian Space Agency. GLI-SSA’s main objective is to carry out a voluntary and transparent process between the Group's component institutions, based on the principles of information exchange, consultation and coordination, in order to capitalize on the services offered by space surveillance systems, especially those developed in the context of the European strategic documents, evaluation and establishment of priority directions for action to develop specific expertise, infrastructure.

2.3. National SST architecture

The national SST architecture included in the EUSST network currently consists of sensors located in different areas of the country (Figure 1), i.e. six telescopes + two under integration process; also, plans are in place in order to include in the near future a radar as well. Each sensor, individually or in other configurations, is also part of many other projects and activities related to SSA and its segments. The infrastructure will be briefly described in the following subparagraphs.

2.4. Cluj optical sensors

The Cluj optical sensors AROAC-T30 and BITNET-T30 form a pair of two identical telescopes and CCD cameras, located in two different observing locations (separated by approximately 37 km) which perform synchronously optical sidereal observations in the same region of the sky. This SST system is jointly owned and developed by the Romanian Academy Cluj-Napoca Branch, Astronomical Observatory Cluj (public institution) and by BITNET CCSS (an independent Romanian private company)

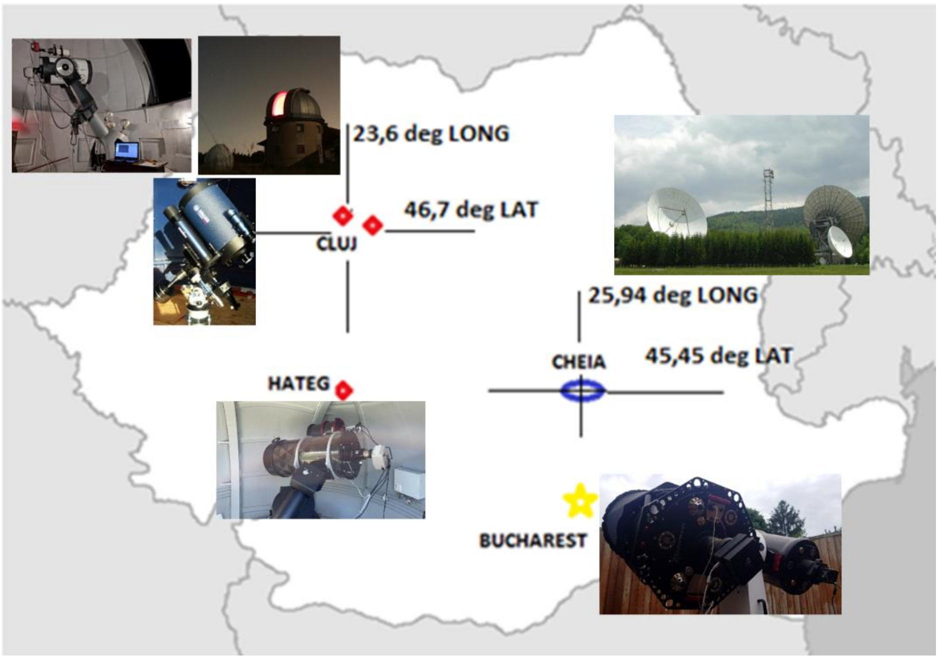

Figure 1: Romanian SST system

2.4.1. *The AROAC sensors*

AROAC-T30 is a semi-automated LX600 12 Schmidt-Cassegrain tracking telescope (D=300 mm, F/D=8) placed on an equatorial fork mount, having a FOV of 0.33° x 0.22°, a CCD camera with a resolution under 1 arcsec/pixel and a maximum angular rate in RA/DEC of 8°/s. It is located at the Feleacu Station and operated by Astronomical Observatory Cluj. These technical specifications make it suitable for MEO/GEO survey and tracking. It works in tandem with the BITNET-T030 facility for tracking, being part of the AMHEOS system (Automatic Medium and High Earth

Orbit Observation System Based on Stereovision). This facility can support SST services (CA and FG) and can contribute to the catalog maintenance.

Figure 2: AROAC-T08 acquisition on 24.07.2020: Low conjunction probability between COSMOS 2543 and COSMOS 2535 satellites. The stars appear as stable points while space objects as tracked (© Romanian Academy Cluj-Napoca Branch, Astronomical Observatory Cluj-AROAC, 2020)

AROAC-T08 is a sensor used for optical observations of LEO objects, based on a refractor telescope Orion ShortTube 80 (D = 80mm F/5; apochromatic refractor; piggyback on a Planewave CDK 24 telescope with equatorial mount with a maximum angular rate of 25°/s) and a CCD SBIG STT 1603 camera (13.8 mm x 9.2 mm; 1536 x 1024 pixels, 9µm x 9µm/pixel). The tracking strategy follows the conditions described in [26] and [27]. This sensor is used for re-entry and collision avoidance observations. An example is depicted in Figure 2: the collision probability between two different COSMOS satellites is low but requires continuous monitoring for risk estimation and analysis. The altitude of the two Cosmos satellites above the Earth's surface was: 614.48 km for COSMOS 2543 (NORAD ID: 44835) and 614.53 km for COSMOS 2535 (NORAD ID: 44421), respectively. The time difference in the directions of travel was less than 1 second, which translates to a distance between the two objects lower than 7 km.

AROAC T61 is a new telescope developed as a part of national effort to increase the SST capabilities. It's configuration of 610 mm diameter with F/6.5 and F/4.3, Direct Drive Planewave L600 equatorial mount and a CMOS FLI Kepler camerainside of a 5.5 m dome makes it suitable for tracking observations on the LEO/MEO/GEO. The fast mount allowed the AROAC-T08 to join AROAC-T61 as piggy-back for LEO observations.

With its tradition of observing the Earth's artificial satellites since the beginning of the space age, in addition to the EUSST program, AROAC has participated in several other international collaborations in the field of artificial satellites dynamics within the programs COSPAR, INTEROBS, INTERCOSMOS and ATMOSPHERE. In addition to the activities of monitoring artificial space objects, the main research directions of the AROAC facility include celestial mechanics, dynamics of artificial satellites and bodies in the solar system, observational astronomy - astrometry, astronomical photometry, stellar astrophysics, extragalactic astronomy, archaeoastronomy, history, education and popularization of astronomy.

2.4.2. The BITNET sensor

The BITNET-T30 tracking telescope is located at the Marisel, Cluj County and operated by BITNET Research Centre on Sensors and Systems. This facility has the same configuration with AROAC-T30, namely a Schmidt-Cassegrain telescope (D=300 mm, F/D=8), an ASA DDM 85 direct drive mount with pointing accuracy less than 12 arcseconds and 1 arcsecond tracking for a 5 minutes exposure time, a CCD camera and a GPS receiver for time synchronization.

The private company BITNET CSS operates mostly in the SST segment of SSA, with expertise in optical and radio space surveillance and tracking techniques and robotic SST prototype instruments integration and operation. It can also contribute to the SWE segment, having experience in the development of passive radio instruments for ionospheric research, thus contributing to Romania, ESA and NATO SSA related projects and activities.

2.5. The BERTHELOT sensors

The BERTHELOT-T04 telescope complies with the survey and tracking requirements for objects located on orbits higher than LEO with an estimated detection greater than 50 objects and an angular accuracy less than 1 arcsecond. The optical telescope is of Ritchey-Chretien type having a 0.37m, f/8 main mirror with a 1 degree non-vignetted field of view. A moving speed of 13 degrees/s allows for a quick re-positioning of the optical set-up between targets. The CCD camera has a large format E2V chip (2k x 2k pixels, 13 microns pixel size). Under the most favorable conditions (no Moon, airmass = 1, unfiltered CCD observations, sky brightness of 22 mag/arcsec, atmospheric extinction of 0.2 mag, 0.8 telescope transmittance) a 0.37 m, f/8 telescope with a 80 % QE CCD camera (13 microns pixel size) can detect, with SNR > 10, objects of magnitudes 11.3, 13.7, and 16 for exposure times of 0.01, 0.1 and 1.0 seconds. The size of objects corresponding to the limiting magnitude attainable in this configuration (assuming a diffuse Lambertian phase function and an albedo of 0.1) at distances of 1 000, 23 000 and 35 800 km are 0.17, 1.21 and 0.59 m respectively[1].

HARET telescope developed under national effort has join BERTHELOT-T04 in 2021 for survey observations by sharing the same mount. His configuration (Officina Stelare Ricardi - Honders RH 200 mm f/3 paired with a Zyla 5.5 sCMOS - Andor camera) is faster and above BERTHELOT-T04's configuration which led as BERTHELOT-T04 to be used for tracking observations. In this view the capabilities of Berthelot Observatory have improved significantly.

The sensors are remotely controlled, located at a moderate altitude (400m) on a protected area belonging to the Romanian Academy. This facility can support SST services (CA and FG) and can contribute to the catalogue maintenance. The surveillance strategy involves tracking objects on both axes (ascension and declination) in order to increase the signal-to-noise ratio. Figure 3 is such an example of space objects surveillance: the telescope is moving from East to West acquiring 3 consecutive frames per each observed sky region within 1.5 s exposure time, at binning 2 x 2.

Besides its important contribution to SST services, Berthelot facility is used in many other projects to observe the outer space activity, such as: international campaigns of monitoring the NEAs in order to provide astrometric measurements, to perform

[1] actual size of detected/observed objects

photometry, or to confirm new discoveries, comet observations for astrometry and coma/tail evolution, monitoring asteroid outburst, imaging phases of planets, conjunctions and occultations [28]. This facility also includes an all-sky camera that is part of the MOROI (Meteorites Orbits Reconstruction by Optical Imaging) national network for meteor monitoring. There are plans regarding the upgrade of this infrastructure, that will include new instruments for Space Weather monitoring (magnetograph and radio spectrometer) that will allow the integration of this facility to international networks and make the Berthelot Observatory a very versatile data provider to all SSA segments.

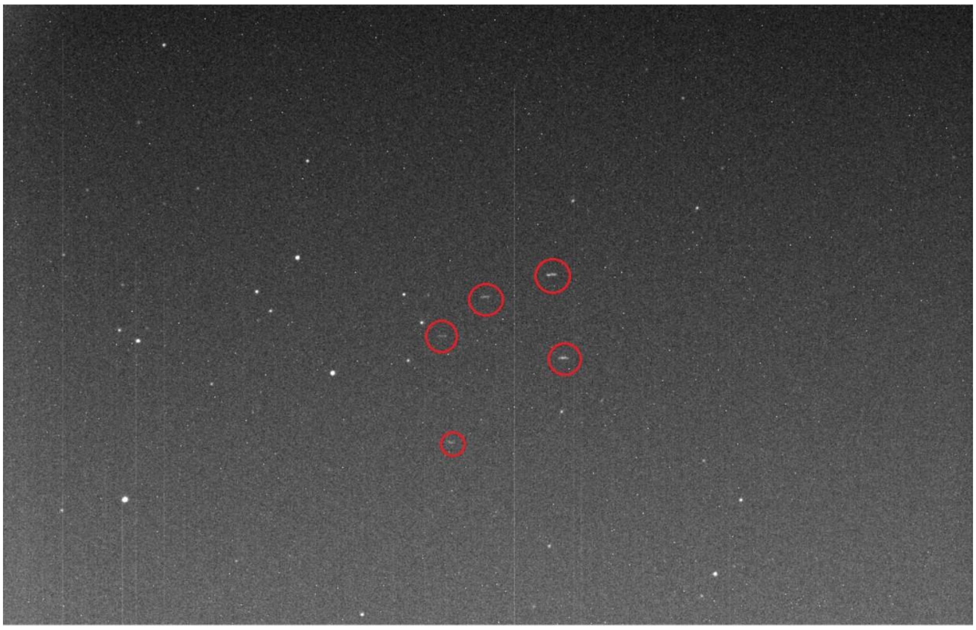

Figure 3: Berthelot acquisition in surveillance mode during the observation campaign from 03.01.2021 (image center RA= 04h29m39s, DEC=-06◦34'18") (©Astronomical Institute of the Romanian Academy, 2021)

2.6. The NEEMO system

The NEEMO system consists of two optical sensors installed on a single mount. The primary telescope is an Officina Stellare RiDK, 500 mm f/7 paired with a FLI–ProLine16803 4k front illuminated CCD camera, while the secondary telescope is an Officina Stelare RH Veloce 350 mm f/2.8 paired with a 4 k CMOS camera–FLI-KEPLER 4040 [29].

With a 0.53 arcsec/pixel resolution and 0.6° x 0.6° field of view, the primary telescope is intended for precise tracking, while the short telescope with a wide field of view of 2.1° x 2.1° with a pixel resolution of 1.89 arcsec will primary be used on SST surveillance applications. The telescopes are installed on an Alt-Az L-600 Mount from PlaneWave, instruments with a maximum angular rate of 15°/s. The direct drive mount is able to point the system with a pointing accuracy less than 2 arcsec and a tracking accuracy of 0.3 arcsec over 5 min. The limiting magnitude is 17.39 for tracking telescope and 15.8 for surveillance telescope.

The NEEMO system is able to perform survey and tracking for objects on all orbital regimes LEO/MEO/GEO. Figure 4 shows astronomical data acquired after India's ASAT test on the Microsat-R satellite (LEO orbit). The astrometric information of the detected fragments could not be extracted due to the orbit constraints.

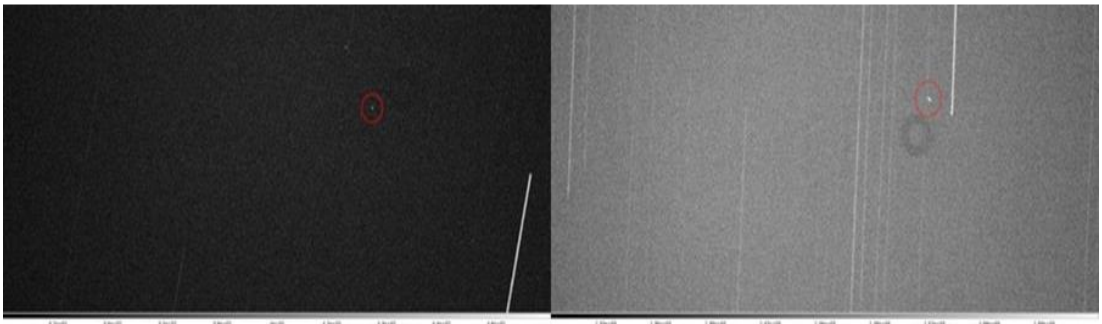

Figure 4: Images of Microsat-R fragments taken by the sensor NEEMO on the 20th of April, 2019
(©Astronomical Institute of the Romanian Academy, 2019)

The acquisition strategy based on non-sidereal tracking considers moving targets as fixed targets on the detector frame during individual exposures, while background sources (stars, galaxies, slower moving Solar System targets, etc.) appear as streaked [30]. In the survey mode, the telescope is scanning the geostationary belt, moving from 20° East to 25° West, covering 90° of sky in 1 hour of observations [31]. For each observed sky region, we acquire 3 consecutive frames, with 2.5 s exposure time, at binning 1 x 1, obtaining around 200 fits data for a session. During a night of observations, we perform several sessions (depending on weather conditions or the schedule) obtaining up to 1 500 fits.

The optical system is mounted inside of a standard fully automated maritime container which acts as a dome for the telescopes. The entire observation process is fully automated and self-powered through the built-in photovoltaic system. These capabilities make it deployable to any region with better coverage of the GEO belt.

This optical system is also a very important asset in the Romanian SSA infrastructure, as it is used to provide various astronomical data, from artificial space objects, asteroids or comets, to observations of occultations phenomena, conjunctions, or deep space objects [29]. The multitude of data that can be obtained with the help of this sensor confirms the national capabilities in the field of SSA, increasing Romania's visibility in this field and facilitating the accession to numerous international projects.

2.7. Cheia Radar Station

The Cheia radar (Figure 5) is located in the Cheia Ground Station, owned by National Radio-communication Society S.A (RADIOCOM), which is a national Romanian infrastructure for space activities since 1978. The station is equipped with all facilities necessary to guarantee high service availability: power supply lines, Uninterruptible Power Supply (batteries and engines), and redundant communication links. The radar infrastructure is based on the retrofit of two existing 32 meters parabolic antennas, used in the past as a C-band telecommunication antennas, into an SST quasi-monostatic radar. The radar is currently in the testing phase.

Possible tasks that can be performed by refurbished antennas (peak simulated values) are: Space Surveillance (SS) in park beam mode for objects on LEO (200-2 000 km altitude orbit) with radar cross section (RCS) greater than 20 cm2 and Space Tracking (ST) for targets on LEO (orbital altitude 800-2 000 km), with RCS greater than 10 cm2. Even for objects for which it is not possible to be tracked by the antenna, it is possible to obtain significant data at each visible pass, to refine the orbit determination. The sensor is foreseen to be fully operational before the end of 2022.

Figure 5: The Cheia radar station

2.8. Romanian Operational Centre for SST (COSST)

The Romanian SST Operational Centre (COSST) was established at the end of 2018 under Romanian Space Agency auspices in the “Developing of monitoring and coordination of space surveillance activity, to forecast the risks related to impacts of natural and artificial objects – acronym ARGOSS” project framework. COSST is operational from the 1st of April 2019, with entry into force of the 1SST18-20 H2020 project (grant number 299/G/GRO/COPE/19/11109). Its main objectives are: sensor network coordination, sensor planning and tasking and astrometric data processing and analysis for orbit determination and refinement. The data workflow is shown in Figure 6.

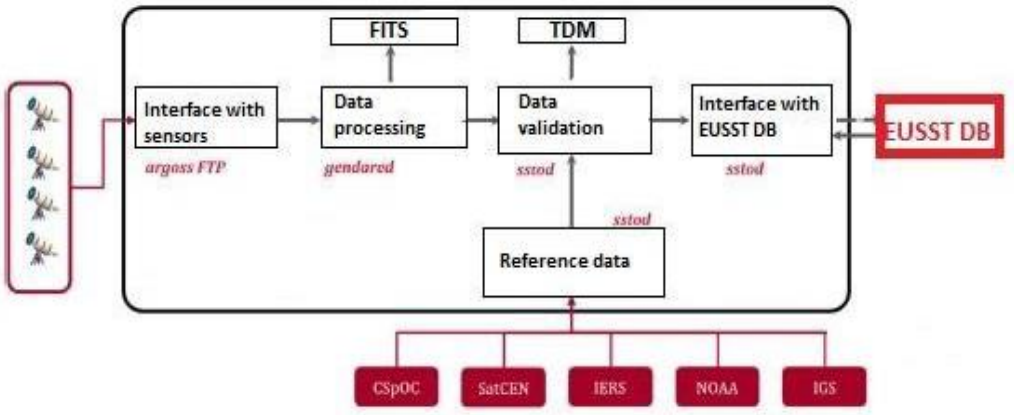

Figure 6: COSST functional architecture (© GMV Romania, 2020)

The sensor measurements in fits format are uploaded via ftp to the AR GOSS server where they are processed using gendered software and validated by the sstod software. During the validation, sstod correlates the obtained astrometric data with reference data provided by other databases like SatCen, NOAA (National Oceanic and Atmospheric Administration) for space weather, CSpOC (Combined Space Operations Center) for predictive ephemeris, IERS (International Earth Rotation and Reference Systems Service) for Earth orientation parameters, IGS (International GNSS Service) for time synchronization, other sources. After validation, data in the

TDM (Tracking Data Message) format are uploaded into the EUSST database for cataloging and EUSST service provision.

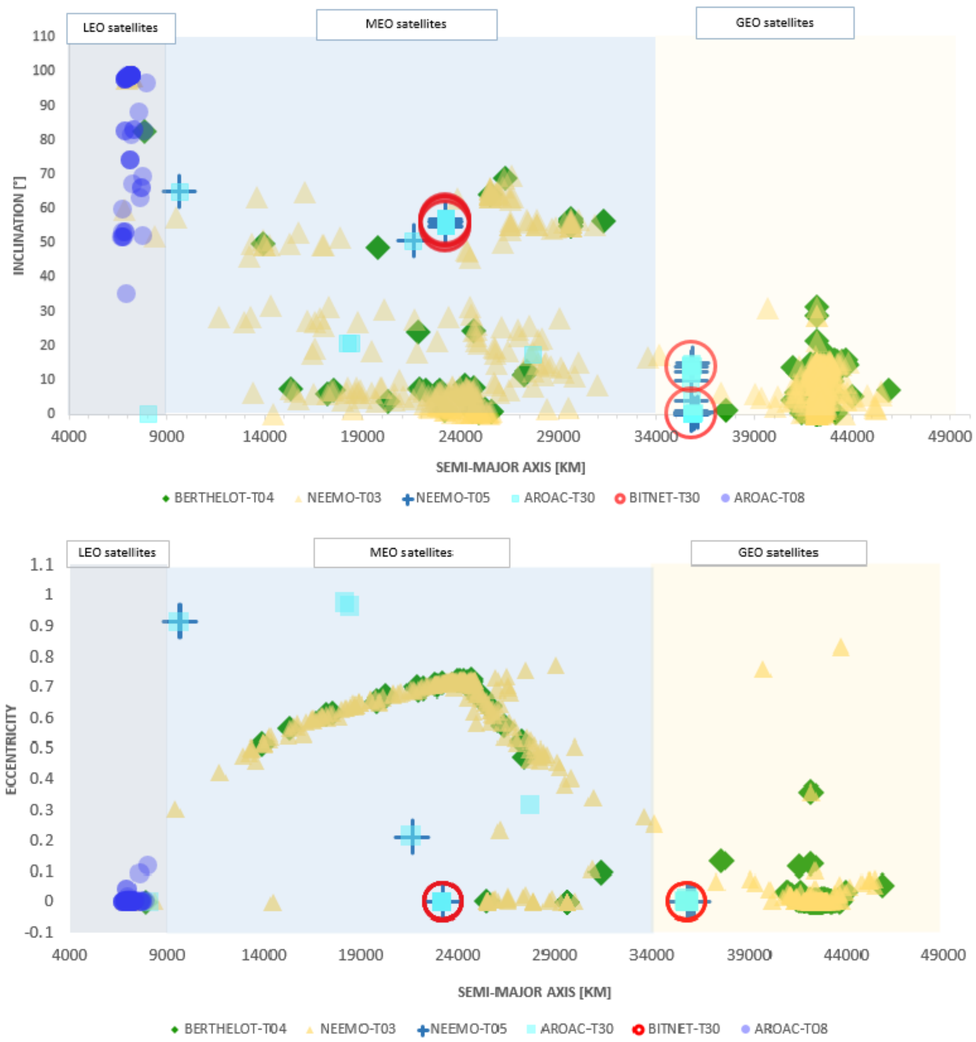

Figure 7: Surveillance and tracking data gathered in the EUSST project framework by AROAC, BITNET, BERTHELOT and NEEMO sensors: up: inclination vs semi-major axis of the space objects detected during April 2019 - January 2021; down: eccentricity vs semi-major axis

Calibration campaigns are periodically conducted to assess the sensor performance. The quality of tracks and contribution to the services are also investigated. Overall assessment of a sensor includes: noise, track noise, track duration, number of tracks, number of measurements, measurement rate, operational reliability, operational robustness to operate, timeliness, responsiveness capability, different objects observed and unique object observed.

A statistic with the sensors measurements is shown in Figure 7. These plots show that with this sensor infrastructure we can perform observations in all orbital regimes. Almost all observations in LEO orbit are performed using AROAC-T08 telescope, while on MEO / GEO orbits, the data are acquired using all the other sensors in the network. The overlapping points in the MEO region corresponds to the space objects on which the sensors were calibrated (Galileo satellites). The overlapping points in the GEO and HLEO region correspond to the tracked objects during tasking request campaigns.

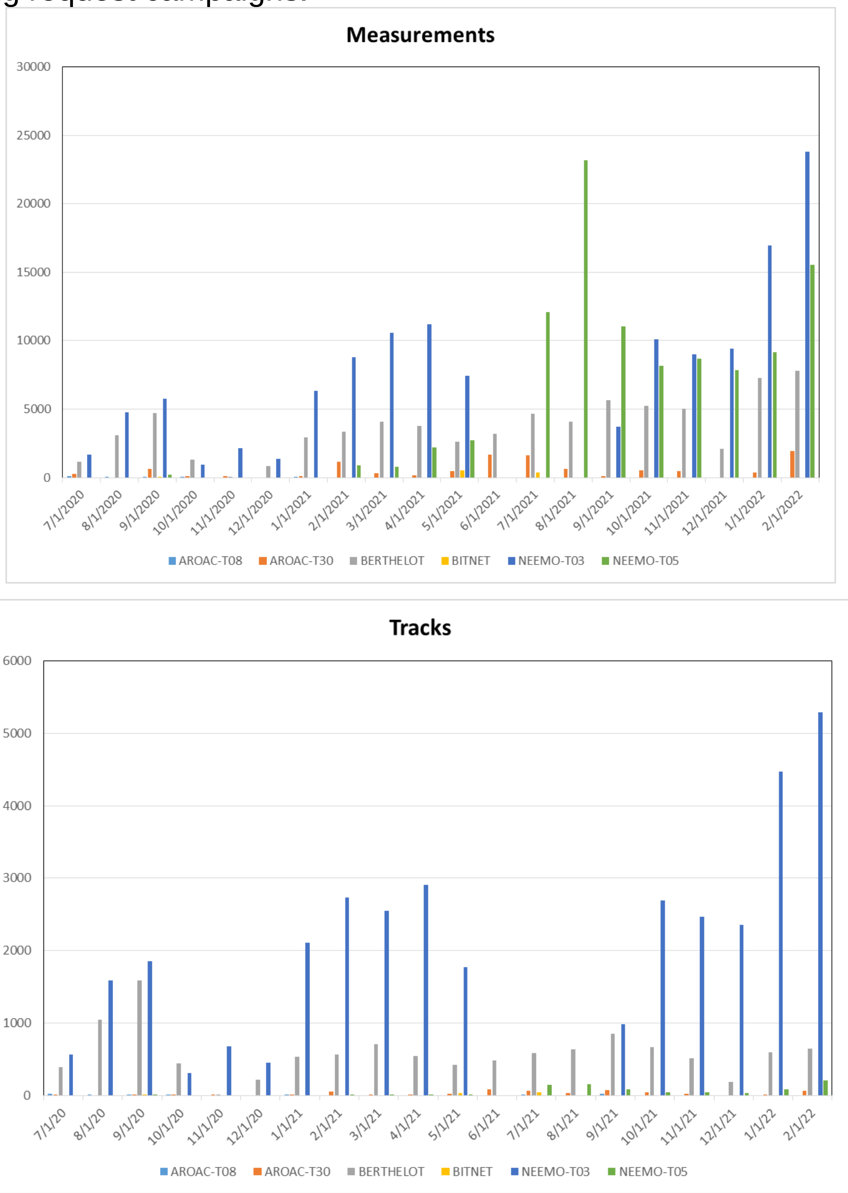

Figure 8: Trend evolution of the measurements (up) and tracks (down)

The number of objects detected has increased significantly with the automation of the data processing (figure 8). The tracking sensors respond to the tracking requests when visibility conditions are suitable for object detection. The most tracked objects are ESA's SENTINEL satellites, monitored in order to reduce the risk of collision with other objects. The surveillance sensors are focused on unique objects detection and the measurements of the European satellites placed on the GEO belt [31], including the rocket bodies and non- functional satellites. Many unknown objects are detected constantly, such sensitive information being kept in COSST for orbit determination.

Current development plans for the network of sensors involve both technical improvement of existing sensor's components with more powerful ones, at the current level of technological development, and building new equipment with different configurations, that shall be placed both in the country and outside its borders [32]. Also, automating the processes of data acquisition and telescope handling will reduce the necessity of human intervention in the loop. Improvement of software programs for the fast and precise processing of the observations is in progress, aiming at increasing the quality of data and services coming from the national sensors network.

3. Conclusions and ways forward

The main focus of this article is to present a general overview of the national SSA/SST architecture. In this sense, the article should be perceived as a programmatic snapshot of the current SST infrastructure in Romania. Special consideration is given to Romania's SST architecture, by overviewing the sensor network, the workflow between the parties involved and briefly mentioning legal and institutional implications.

Significantly increasing number of space debris, space missions and in general of space activity, require coordination, no matter how obsolete it sounds, as the fundamental tool in managing the emerging space aspects. Outreach and transparency between industry, stakeholders and governmental entities is key, as well as the development of a structured relationship with the private sector. Also setting up a dialogue with international partners and seeking communication and collaboration on a global level.

For continuing peaceful activities in outer space in a sustainable manner, stakeholders worldwide need to take into account ways (strategic, operational, legal, institutional, and others) to ensure that all players preserve a safe, secure and sustainable space environment. Thus partnerships are a crucial element in developing such a collaborative approach. Developing only military assets and processing functions is not a feasible way to manage sensitive information, and for this reason, a more straightforward solution is to include civilian assets into this system. This method implies the need to establish, in case-by-case situation, data-sharing agreements regarding the security of information.

Romania's plans to develop the SST capabilities are aligned with international and European objectives, many of them being already ongoing. In our case, establishing a SST network implied the collaboration between entities from different domains, as academia, public institutions, private sector or industry, and the experience showed that this is possible, with promising results.

The SST sensor network in Romania is an example of a dual-use system. It is owned and operated by civilian entities, but is integrated in both military and civilian projects, which means that, from a technical point of view, civilian systems are suitable for the requirements of both fields. Moreover, with the help of implemented data sharing agreements and military-civilian collaboration at national and international level, the challenges of dual-use technologies can be overcome, with sensitive data being handled in a secure way.

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