APPLICATION OF USE CASE SCENARIOS TO SUPPORT THE DEVELOPMENT OF A FUTURE SSA GOVERNANCE AND DATA POLICY IN EUROPE

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ABSTRACT

Space Situational Awareness (SSA) refers to the knowledge of location and function of space objects and of the space environment, including operational satellites, space debris, near Earth objects and space weather. The development of a European SSA system will underpin the exploitation of European space assets, representing a key capability contributing to the autonomous access to space for Europe. [1]

The European Union Satellite Centre (EU SatCen), through the "Support to Precursor space situational Awareness services" (SPA) project, has backed SSA activities in Europe by providing a set of suggestions and recommendations to support decision-making regarding the development of SSA Governance and Data Policy. [10]

1 INTRODUCTION

Any disturbance to space assets could disrupt essential services affecting the security and well-being of European Union (EU) citizens as well as reducing the associated benefits of space. In this context, the need for a capability of Space Situational Awareness (SSA) in Europe has been underlined by Space Council resolutions as a safeguard to ensure the exploitation of and access to space. [1][2]

The European SSA is expected to address three main areas [3]:

- Space Surveillance and Tracking (SST).
- Space WEather (SWE) monitoring and forecast.
- Near-Earth Objects (NEO) monitoring.

The EU SatCen has been contributing to the current European SSA activities through the "Support to Precursor space situational Awareness services" (SPA) project. The SPA project was a Support Action under the Seventh Framework Program (FP7) of the European Commission (Grant Agreement No. 262930, theme SPA.2013.2.3-2: Security of space assets from on-orbit collisions), managed by the EU SatCen and started the 1st of March 2011 with a duration of twenty months.

Under the full control of EU Member States (MS), SPA has studied and evaluated aspects of SSA Governance and key elements of Data Policy in the EU SatCen secure environment [7]. The SPA project has focused on the SSA-SST segment and services which, being sensitive and dual use (civil and military) in nature, represent the greatest challenges from a governance and data policy development perspective.

The overarching principle of a future SSA governance and data policy is to protect the interests of the EU, its MS and allies while maximize the exploitation of SSA capabilities.

This paper is organised as follows: Section 2 describes the methodology used for the performed technical analysis of the data policy and governance needs. Section 3 introduces the importance of space. Section 4, 5 and 6 describe the SSA-SST services, models and requirements. Section 7 summarizes the analysed Data Policy topics. Section 8 and 9 introduce the project demonstrator and the use cases and scenario assessment. Section 10 summarizes the findings on Governance and Data Policy. Finally, Section 11 and 12 present the conclusions and acknowledgments.

2 METHODOLOGY

The SPA project has followed an analysis methodology based on use cases and scenarios suitable to perform an analytical and technical evaluation.

A use case based analysis is commonly used in different domains such as software systems engineering. This type of analysis identifies a certain goal of a system, allowing the modelling as interactions between different system components and actors, focusing specifically on how it is done rather than what has to be done. Each use case also includes scenarios that analyse instances of how the system is used in specific circumstances. [11]

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[*] *The content within this publication is solely of the authors. This publication does not constitute any endorsement on behalf of the European Union Satellite Centre. At the time of writing, the engineering architecture, governance and data policy of a future European SSA system have not been defined by the appropriate decision making bodies. This publication in no way prejudges any decisions or specifies any design aspects of a future SSA system in Europe.*

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The methodology used for the technical analysis of the data policy and governance needs aimed to:

- Provide a systematic and pragmatic approach.
- Develop an increased understanding of the problem for analysing data policy and governance needs.
- Offer a tool to communicate and discuss with stakeholders.
- Provide a clear analysis roadmap to perform the SPA analysis work.

Fig. 1 depicts an overview of the SPA methodology.

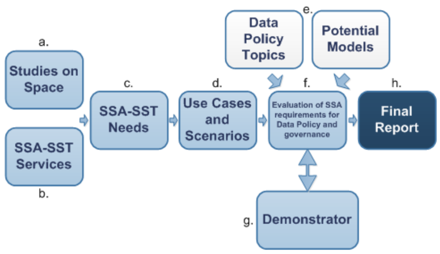

Figure 1. SPA Project overall methodology.

The methodology of the SPA project is described as follows:

a. At the beginning of the SPA project, the importance of space from an economic and strategic point of view has been analysed.
b. Concurrently, a number of SSA-SST experimental services related to the protection of space infrastructure have been described and characterized in cooperation with relevant SSA stakeholders in Europe.
c. Starting from the studies performed on the importance of space (a) and on the preliminary SSA-SST services (b), an analysis on existing SSA requirements has been performed and preliminary SSA-SST needs and requirements have been derived.
d. Then high level use cases and detailed use case scenarios have been defined as a tool to better understand and analyse data policy and governance needs in cooperation with relevant SSA stakeholders in Europe.
e. In a parallel way, main Data Policy topics and potential architecture models with relation to the Governance of a future SSA-SST capability in Europe have been derived.
f. Finally, the EU SatCen has performed an evaluation of SSA-SST use case scenarios in order to outline SSA-SST Data Policy and Governance technical inputs as well as additional functional needs.
g. To perform this evaluation, the EU SatCen has hosted within its already existing secure premises demonstrator software for the above SSA-SST services (cooperating with the European Space Agency (ESA) and using EU SatCen experience on the area of the analysis and integration of heterogeneous data sources with multiple security levels).
h. A final report has been produced summarising knowledge gained, lessons learned and the achievements of the SPA project with recommendations in view of further developments of SSA in Europe, particularly on the technical aspects of its Governance and Data Policy.

3 IMPORTANCE OF SPACE

Space is a key strategic sector for European competitiveness and economic growth. The size of the worldwide public space budget (allocated funds for space expenditures) in 2010 was approximately 76B€, from which an 8% (worth 6B€) represents the EU's MS contribution. As shown in Fig.2, Europe is the second largest contributor to the space industry after United States (US) and its budget is distributed mainly in five areas of applications [5]: communications and launchers (31% each), science (17%), Earth observation (15%) and navigation (6%).

According to the Union of Concerned Scientist information (public satellite database), in January 2011 there were over 960 catalogued operational satellites in orbit, together with approximately 2400 inactive and uncontrolled satellites and 15000 catalogued debris. [6]

Presently, Europe has indicatively ~14% (representing 160) of the total operational satellites in orbit and is the fourth largest contributor to the debris population with 4% (representing ~605) of catalogued debris.

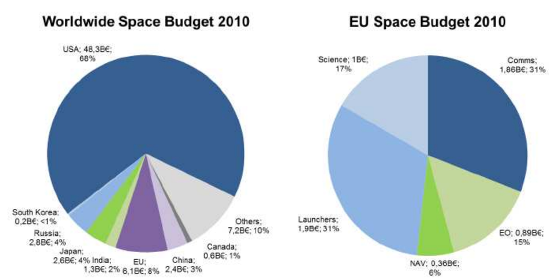

Figure 2. Worldwide and EU Space budget.

The quantity of space objects is growing constantly and consequently the probability of collision between a satellite and debris is rising rapidly.

A European SSA capability would help to reduce the loss or disturbance of assets due to collision with space debris and space weather. According with the analysis performed, the estimated economic impact for a loss of a European satellite due to a collision in LEO is approximately 19M€ per year and due to space weather is approximately 206M€ per year.

This estimated economic impact could be negatively affected due to non-quantified consequences and costs that may outcome from the omission of a European SSA capability. A clear example could be the loss of a critical communication service during an emergency situation causing loss of lives.

The consequences of a NEO's impact are difficult to estimate because of the intrinsic variables of the object (size, velocity, and composition) and the area of impact but, in the worst case, a NEO's impact could cause loss of lives and serious disruption of the global economy.

4 SSA-SST SERVICES

Three indicative services of an SSA-SST segment have been identified as Satellite Over-flight, Satellite Conjunction Alert and Space Re-entry Prediction. These services have been confirmed by SSA stakeholders as relevant for the SPA project, for any future SSA capability and for Common Foreign and Security Policy (CFSP) challenges related to data policy and governance

4.1 Satellite Over-flight service

The Satellite Over-flight service offers an estimation of when a particular space object/satellite will be visible from a particular location on Earth (and vice-versa). The Over-flight service and calculation chain permits historical, real-time and predictive estimation (by computer simulation) of the evolution of the orbital parameter values with time of a satellite/object and its orbit. This allows the prediction of line of sight opportunities between a satellite and a particular location on the Earth’s surface; this could be for observation or communication purposes. From both points of view, satellite or ground location, typically, time windows of availability are predicted for a given satellite and location.

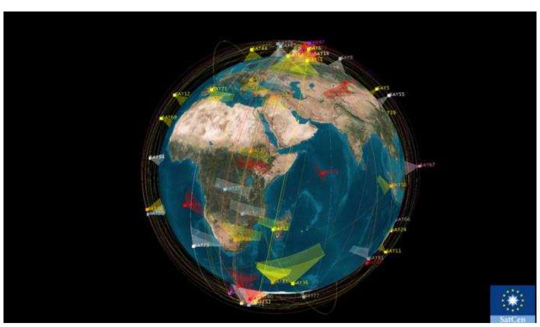

Figure 3. 3D Representation of Over-flight service for multiple LEO satellites.

4.2 Satellite Conjunction Alert service

The Satellite Conjunction Alert service is intended to greatly reduce the probability of conjunction between operational space assets and all other man-made objects in orbit.

The conjunction probability estimation involves inputting of the parameters for a particular satellite and all other objects to be checked against and evaluating the probability of collision. A communication may be sent in a timely manner to the identified satellite’s operators; after the final result of the service has been produced and a message sent to the operator, a collision avoidance manoeuvre may be done.

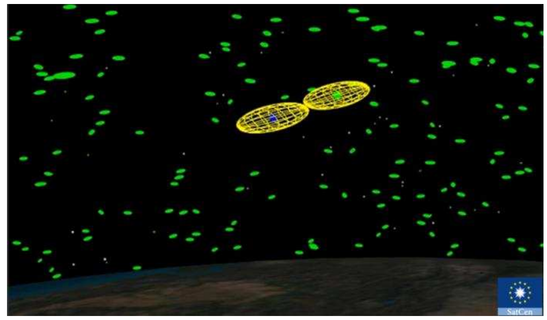

Figure 4. Illustration of Conjunction Probability analysis.

4.3 Space Re-Entry Prediction service

The Space Re-entry Prediction service is concerned with maintaining a list of objects of high probability of re-entry to the atmosphere and reaching the Earth’s surface. Also, it is used to make a prediction of the trajectory and debris cloud impact zone location on Earth.

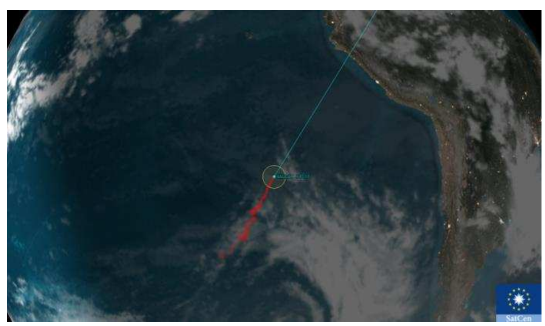

Figure 5. Simulation of Re-entry of ANUSAT.

5 POTENTIAL SSA-SST MODELS

During the course of the SPA project, three hypothetical architecture models have arisen as generic models called Federated, Unified and Joint models. Two of these, the Federated and the Joint, were understood (from stakeholders’ feedback)[2] to be front-runners as possible models for a future SSA-SST in the EU.

[2] As part of the discussions during the second SPA project workshop held the 19th of January 2012, it was agreed to focus the SPA analysis on the Federated and the Joint models.

The following characteristics are common to all potential architecture models:

- All are hypothetical engineering architecture corresponding to an intergovernmental SSA-SST governance scheme in Europe.
- An autonomous European SSA-SST capability is offered.
- A strong data policy is in place (compliant with national security needs) for each national or EU/ESA type entity participating.
- Other third parties might have offered access by dedicated agreements as well as external interfacing with allied nations at all processing levels.
- The input/use of external data at any level from international entities is subject to a data policy. External interfacing with allied nations at all processing levels may be present.
- Cooperation between SSA capability providers is in place.
- The elements are multi-layered and could be distributed in Europe.
- Users' access privileges are based on Commercial, Governmental (Civil/Military) status.
- Protected facilities are available, especially a space object database/catalogue.

Particular characteristics of the Federated Model are:

- It is composed by two or more autonomous (yet complementary and compatible) SSA-SST national systems with agreements and management structures (governance).
- The boundary of the federated system is at the property limit of the member nation's resources and assets.
- This model could offer a capability to users upon agreements along with suitable service enforcement instruments. A wider capability, extending consortium member states, may be provided with an additional interface offering services to a wider range of users, including commercial, national and European entities.

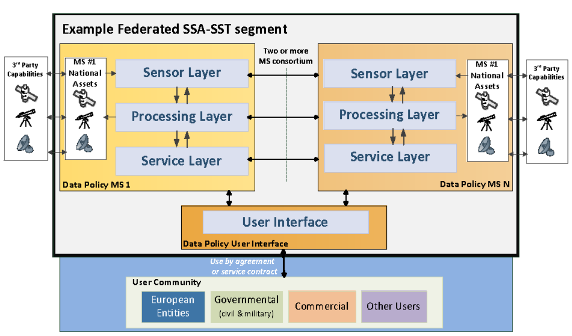

Figure 6. Example of a possible Federated model

Particular characteristics of the Joint Model are:

- It is a coordinated compatible fusion of existing capabilities and resources in Europe into a system of systems.
- Member states of the EU/ESA contribute any type of resource, including catalogue information into a European SSA-SST system.
- The potential interface or incorporation or use of national or federated resources could be done through a comprehensively consulted agreement.
- MS of the EU/ESA contribute essentially assets or capabilities into one SSA-SST system in the EU.

6 HIGH LEVEL SSA-SST NEEDS & REQUIREMENTS

The SPA project has studied and documented a synthesis on the initial needs and requirements for a future SSA capability in Europe and has considered inputs from various sources. These include high-level requirements from international and European treaties and existing requirements on SSA. On the later, the following texts have been key for SPA:

- The EDA SSA PT Common Staff Target, (CST). [8]
- The ESA SSA PP Mission requirements Document (MRD). [9]
- European SSA High Level Civil-Military User Requirements. [3]

The following data policy and governance themes have been identified: member state national security, verification of treaties, European and International co-operation, standardisation, civil-military synergy, provision of services, protection of life and space infrastructure, autonomous access to space, architectures aspects, interoperability, nonrepudiation and data classification and downgrading/declassification.

7 SUMMARY OF DATA POLICY TOPICS ANALYSED

A scenario-based analysis has been performed considering core data policy topics, summarized below:

- Identification and data classification and declassification rules, considering aspects related with detected objects identification and classification, including different types of data associated (i.e. orbital data, object characteristics, etc.).
- Information and Facility Protection, covering core data security policy aspects (i.e. confidentiality, integrity, authorisation,

availability and non-repudiation) for data-at-rest[3] (e.g. catalogue data) and data-in-motion[4] (e.g. services products delivery) across the SSA processing chain.

- Administrative aspects, mainly covering sensor tasking, specific sensor policies, liability, security agreements, IPR/licensing issues and exchanges with third states.
- Interoperability and Standardisation, secure and standardised exchanges within the system and with external entities, including catalogue data, service products and sensor tasking/data.

8 DEMONSTRATOR

The SPA project has implemented (in its secure area) a demonstrator platform that has supported the core study analysis, providing means for identifying relevant technical findings and recommendations for the implementation of the data policy and governance models of a future European SSA capability.

The SPA demonstrator has been delivered by simulating a complete as possible SSA-SST capability processing chain, starting with the data acquisition in the sensors and the production and management of object catalogue/s, up to the distribution of the final service level information to the end users.

An overview of the functional description and data flow of the SPA demonstrator is provided in Fig. 7.

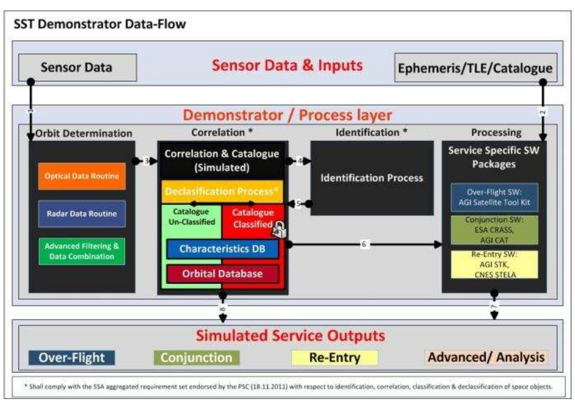

Figure 7. SPA Demonstrator Data-flow.

The SPA demonstrator follows a three-layer structure with a sensor layer, processing layer and service layer. The sensor layer mimics radar, optical telescopes and infrequently space based instruments. The processing layer contains essentially the treatment of sensor data, sensor tasking management and the production of specific orbits related to satellites. The service layer collects the data stored in a database to offer different SSA-SST services.

The SPA demonstrator infrastructure supporting the analysis and scenario evaluation process has been defined and installed considering available SSA related software in order to ensure the achievements of the SPA project goals. The set of selected and installed software is comprised by COTS products (i.e. AGI STK) and specific ESA SSA SST Preparatory Programme (PP) software.

8.1 Demonstrator data

In any given SSA system, the three indicative services of Satellite Over-Flight, Satellite Conjunction Alert and Space Re-Entry require prior availability of surveillance and tracking data of space objects. Since the start of the SPA project, a set of representative observation data has been sought and obtained. The data have been then processed to determine the characteristics of the orbit.

The following entities have kindly provided sample tracking or orbital data:

- France, CDAOA, GRAVES (Grand Réseau Adapté à la Veille Spatiale).
- Spain, The Real Instituto y Observatorio de la Armada (Spanish Navy Observatory).
- Spain, Observatorio Astronómico de Mallorca. (Mallorca Observatory).
- United Kingdom, Rutherford Appleton Laboratory, Chilbolton Observatory.
- United States, Joint Space Operations Center (JSpOC) through public data on the internet.

The data collection contains a source of example orbits along with being an exercise in European co-operation, in the context of the SPA project. Diverse surveillance and tracking data has been resolved into the different types of orbits (GEO, MEO and LEO); producing inputs for the simulated SSA-SST services.

9 USE CASES AND SCENARIO ASSESSMENT

A scenario based analysis has served to provide technical inputs to support the definition of governance and data policy by competent bodies and to identify additional functional needs for the further development and definition of a European SSA system.

9.1 Overview of Use Case Scenarios

The defined use case scenarios of the analysis methodology cover the SSA-SST services and extend to the processing layer, the catalogue and sensor management SST functionality. Representative

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[3] Data-at-rest: Refer to the data stored on any kind of media.

[4] Data-in-motion: Refers to the transfer of data from a stored location to a different location using any communication means, which can be physical copy or move, internal network, internet, dedicated communication lines, etc.

information flows have been identified for each of the scenario families to drive the analysis, considering identified SSA-SST models and main data policy topics to be investigated.

A total of thirty-seven scenarios have been defined, identifying a separation criterion which aims to highlight the analysis of data policy and governance needs. The following criterion areas have been used:

- Catalogue and Sensor Management scenarios analyse the sensing and processing functionality of a SSA-SST segment. Twenty scenarios have been defined separating the analysis by system functionality (i.e. surveillance, tracking and additional catalogue management functions, such as declassification, manoeuvre detection and injection of external data), sensor ownership/classification and space object ownership/classification.
- Conjunction Warning Service scenarios have been defined, nine in total, these have been separated based on object ownership, object classification and their status/manoeuvrability.
- Overflight Service scenarios, three in total, have been defined and separated based on different types of overflight requests to be received and the classified nature of the satellite capabilities.
- Re-entry Service scenarios have been defined, five in total, separating them based on ownership and classification level of the object re-entering, risk of the object considering the nature, content and payload and potential re-entry location of the object.

The individual assessment of each scenario has raised a set of data policy and governance issues and suggestions which complements initial findings and completes the core results of the project.

Fig. 8 shows an example of detailed assessment that has been performed using sample information flows for Conjunction Warning service.

Relevant scenarios, fourteen in total, have been also evaluated using the SPA demonstrator as simulation platform.

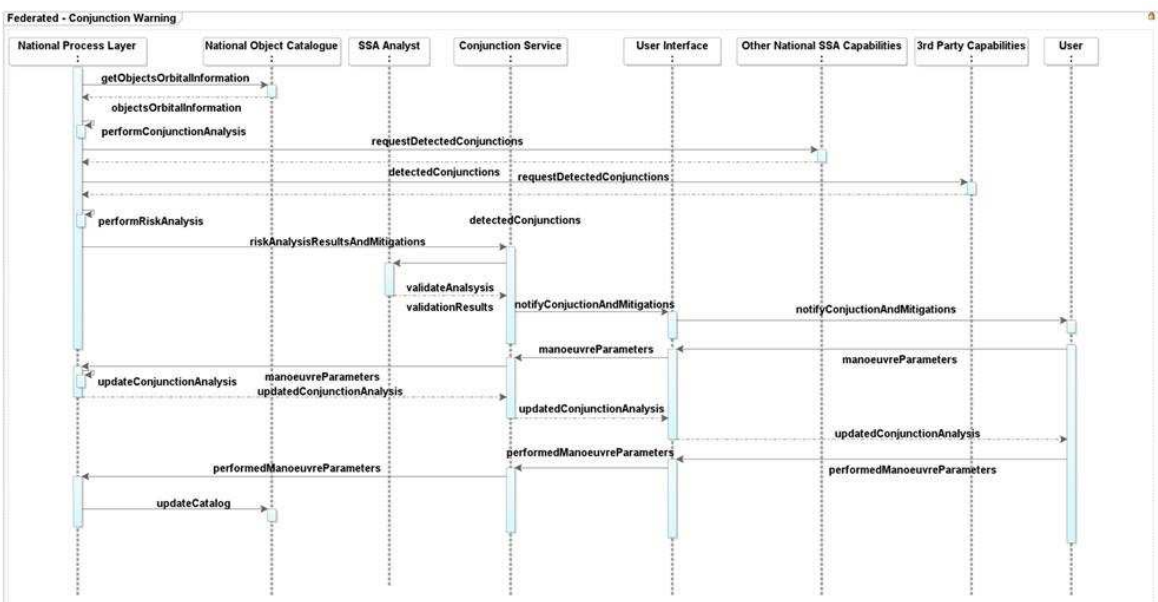

Figure 8. Sample of Conjunction Warning Use Case, Federated Model.

10 RECOMMENDATIONS ON GOVERNANCE AND DATA POLICY

10.1 Space object catalogue management

Access to a comprehensive catalogue will be required to achieve a proper SST function. This catalogue must contain all objects, classified and unclassified, with minimum associated information suitable to provide services while protecting sensitive information and EU MS interests. It is recommended to define the rules governing catalogue information merge within Europe assets as well as externally. An execution of a detailed risk analysis is recommended considering the potential harmful effects of catalogue contamination, addressing aspects such as quarantine/validation rules and day-to-day updates.

10.2 Information classification/declassification governing rules and properties

It is recommended to define concrete rules governing the classification of the information and their properties (i.e. originator, declassification properties, need-to-know) in different areas such as sensor information, classified space objects correlation and derived services products (e.g. Over-Flight, Conjunction and Re-Entry products). Particularly, responsibility definition and agreements required on rules for certain scenarios involving EU, EU MS or potentially third parties should be addressed for delivering services in timely manner while preserving information security.

10.3 Dual Nature of the SSA capability, definition of security domains and information exchanges

The dual nature of a future European SSA capability and separation between classified and unclassified information handling is one of the drivers of the data policy and architecture, affecting all SSA-SST layers (sensors, processing and services). Considering applicable security regulations [4], the data policy needs to identify the different security domains, their mode of operation and how data exchanges are performed, both internally and externally to users and third parties.

10.4 SSA-SST Sensor network definition and required agreements

A critical source of information will be national sensors partially or totally devoted to SST. Collaboration mechanism(s) would allow a balance between the protection of sensitive material and the provision of suitable information, maximising their use. There is a need for the identification of proper surveillance and tracking strategies and sensor selection priorities considering available assets, classified and unclassified. A risk analysis must support the potential use of unclassified sensors for surveillance achieving the required coverage and performance at all orbital regimes.

10.5 SSA capability dependency on defence services and interfacing definition

The Civil/Military user requirement document [3] has established that the provision of specific defence services would not be addressed in a potential European SSA dual-use capability, including in particular those that fulfil a critical “internal” function performing an autonomous identification of detected objects. It is suggested, respecting the need-to-know and applicable security principles, to deepen into the needs of the interfacing mechanisms between these specific defence services and a European SSA capability addressing challenges, such as unidentified object handling and classification responsibility, impact on services, identification process responsibility, involved data exchanges and required timeliness.

10.6 Definition of Third party information exchanges areas, dissemination and IPR needs

A future European SSA capability is expected to interface and share information with external third parties as part of collaboration agreements, including catalogue information, conjunction or re-entry events information, with the objective to achieve a better protection of assets in space while maintaining autonomy of the European SSA capability. It is recommended to establish the rules governing the exchanges, the regulation aspects and associated data policy, including security agreements for classified information handling, nature and content of the exchanges, data standardisation, traceability of the information, further dissemination and associated intellectual property rights requirements.

10.7 Maximize interoperability via standardisation

It is recommended to identify and develop a set of common provisions to facilitate the interoperability and thus the incorporation of contributing capabilities as well as third party information exchanges. The identified scope of these provisions, respecting national prerogatives, covers aspects such as security of classified information, confidentiality, service provision rules, resource contribution, intellectual property rights, liability, governance and finance, etc.

10.8 Identification of user communities, rules governing access and service delivery

A future European SSA capability is expected to provide services, of unclassified and classified nature, potentially to a variety of users (National, European, governmental, commercial and third parties). It is recommended that the data policy and governance elaborate on the expected user community that can access a particular SST service, the eligibility criteria, the governance structure required to provide access, and the service tasking and delivery rules and technical mechanisms to be followed.

10.9 Role of the European SSA capability and liability

In the context of conjunction event mitigation, considering the variety of potential scenarios involving objects from EU, EU MS or third states, it is recommended to define the concrete role of a European SSA capability. Independently of the potential advisory vs. regulatory role for conjunction events, it is foreseen at least the need of a coordination role between involved parties. The liability or responsibility for an event/act could be established if the associated data is guaranteed to be correct and if a formal notification process has been applied. In this context, data integrity and non-repudiation mechanisms are suggested to be further detailed in terms of data policy.

10.10 Identification of proper notification chains at National and EU level

Taking into account the potential harmful effects (infrastructure and environment) during confirmed cases of space object collision or re-entry, it is recommended to determine within an EU context a coordinated and efficient notification chain for timely reaction to relevant parties, which might benefit from already established mechanisms in place.

10.11 Data policy supervisory mechanism and continuous assessment

It is recommended that the future governance contains a supervisory mechanism to facilitate and monitor the implementation of data policy, including the investigation of incidents. That might include elements such as risk assessment, mitigation measures, requirement development, etc.

11 CONCLUSIONS

The EU SatCen, through the FP7 support action project SPA, has contributed to the current European SSA activities providing a set of focused and pragmatic suggestions and recommendations. SPA has concluded that an optimized cooperation between SSA capability providers is a common key element for any future SSA development in Europe.

SPA project has benefited a diverse range of European arenas where SSA is a key element and the EU SatCen is participating directly or indirectly. SPA has facilitated a technical dialogue to bridge the gap between decision makers and technical audiences on SSA matters.

12 ACKNOWLEDGMENTS

The EU SatCen wish to thank the invaluable support to develop the SPA FP7 support action kindly provided by SSA key stakeholders in Europe.

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