European Space Policy Institute

EUROPE'S WAY TO SPACE SITUATIONAL AWARENESS (SSA)

Report 10, January 2008

Wolfgang Rathgeber, ESPI

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Executive Summary

This report deals with important implications of setting up a European system for Space Situational Awareness (SSA). It aims at contributing to the successful implementation of such a system by discussing issues of data policy and operational questions. Thus, the intent is to foster debate within and beyond the community. The addressees of the report are ESA, which is currently taking the lead in SSA matters, its Member States, the EU, and policy makers, who have already discussed the topic on platforms like the European Inter-parliamentary Space Conference (EISC), as well as the general public.

Background

According to the definition of a potential SSA user group gathered by ESA, Space Situational Awareness consists of understanding and maintaining awareness of the Earth's orbital population, the space environment, and possible threats. Space Surveillance is considered the first stage of SSA.

Europe has come to depend heavily on space technology and its applications. Against this backdrop, SSA capability is increasingly being recognized as a key requirement. Currently, Europe relies heavily on SSA data from the US. However, European efforts to establish a SSA system are underway, being led by ESA. The system is to be set up for multiple use, implying that it has been developed to serve different user communities (e.g. civilian and military) right from the beginning.

Several open issues have to be settled as a condition for the successful implementation, proper functioning, and efficient operation of a European SSA system. Most of the questions that arise are interdependent and a balance needs to be found for two or more potentially contradicting requirements and concepts. Critical aspects include, among other things, data policy, the business model, and operational questions.

Data Policy

The data policy sets out the rules and procedures for handling and distributing information collected by sensors (raw data) and manipulated or refined in subsequent system stages (processed data) as well as the mechanisms to control and enforce compliance with these rules and procedures. Numerous data policies exist for different sensor systems. They have to be accounted for when setting up an umbrella data policy for a system of systems.

Data flow is an important element of data policy. This analysis looks at various implemented examples: The US CFE Support Pilot Programme, which is currently distributing space surveillance data; the German TerraSAR-X programme, which is being realized in a PPP as the first of its kind; and the French/Italian ORFEO system, which is a genuine multiple use programme.
Legal aspects are another building block of the data policy. National law will play an important role when distributing SSA data. This is especially true in the context of Freedom of Information Acts (FOIA) that govern the use of public data. The recently adopted German law on satellite data security constitutes a piece of legislation to ensure national security, while preserving business opportunities for private stakeholders selling satellite-based imagery. European and international conventions on information handling exist as well.

Implementation Issues

Regarding the business model of a future European SSA system, a decision has to be taken on how commercial the system should be, i.e., to what degree profit orientation should be allowed or even targeted. If profit orientation is wanted, sufficient business opportunities for commercial stakeholders have to be ensured. It will be crucial for the European SSA system to offer products and services with added value compared to SSA data that is freely available from other sources.

Operational and institutional aspects include the question of who will be in charge of system operation, maintenance and updates, who controls the overall system performance technically and financially, as well as who oversees compliance with rules and procedures. Existing or newly created entities could be charged with these tasks. Different hardware and system architecture options have been suggested in various studies. A strongly centralized approach will facilitate global SSA data sharing between regional SSA systems in the long run.

Perspectives

There is a link between a European SSA system and the global Space Traffic Management (STM) regime that is to be set up. SSA information is needed to check and enforce compliance with the rules and procedures of such an STM regime. This stresses the need for cooperation among the various regional SSA systems, because STM is inherently global. Since STM also deals with access to space and return from space, air traffic must be accounted for in a SSA system as well.

The role of ESA in a future European SSA system may take on various forms. Being heavily involved and currently taking the lead in the associated efforts, ESA could be charged with implementation and initial operation of a European SSA centre. System procurement is another possible task. In any case, ESA's vast knowledge in the SSA domain, incorporated, for example, in its Space Debris Office, needs to be integrated into the planned European system.

As a synthesis, this report gives some general observations and suggestions for further action with a view to contributing to the swift settlement of open questions as well as to an efficient implementation and operation of a future European SSA system. The observations made relate to public outreach, political support, the system's added value, the structure of motivation, international cooperation issues, a common basis of understanding, the multiple use nature, the initial design approach, a precursor solution and support for an STM regime.

1. Introduction

Modern societies have become increasingly dependent on space technology and its applications. The European Space Policy[1] of 2007 acknowledges that space is a strategic tool for independence, prosperity, industrial development, technological and scientific progress. These benefits, however, imply a high vulnerability. To protect space assets and to ensure their smooth operation, it is important to establish a state of space situational awareness (SSA). This, in short, refers to knowing the location and function of relevant space objects and to realizing different kinds of space-related threats like space debris. SSA also allows the monitoring of compliance with international treaties and mitigation measures.

Currently, Europe does not have an autonomous capability for SSA. Some sensors for Space Surveillance exist at the national level, but they just provide part of the necessary information. For the time being, a bigger SSA system can only be sketched with data t provided from abroad, mainly from the United States. However, efforts to set up a European SSA system are underway. The European Space Agency (ESA) has been conducting an associated preparatory action. A major decision upon whether and how to embark on a full SSA programme is expected to be taken at the ESA Ministerial Council Meeting in 2008.

These endeavours are politically backed by the fact that the European Space Policy[2] explicitly states that Europe should protect its space-based capabilities against disruption, and by the fact that the establishment of an independent SSA system is considered a key requirement by important political stakeholders[3]. In addition, various advisory bodies have asserted the need for a European SSA capability such as in the report by the "panel of experts in space and security" (SPASEC) gathered by the European Commission[4].

Against this backdrop, ESPI has conducted a project on implications of a future European SSA system. This report, based on desktop studies and interviews, is the result of the project. It aims at exploring different existing strategies and schools of thought with regard to selected topics crucial to implementation. Special attention is being given to the issue of data policy and associated questions. Within the framework of the project, ESPI also held an expert meeting in Vienna on 6 September 2007 to discuss data policy, institutional issues, and political boundary conditions of a European SSA system[5]. Elements of the presentations and the discussions of the meeting have been used for this report as well.

[1] Resolution on European Space Policy, Space Council on 22 May 2007; ESA/C-M (2007) 1; Communication of the Commission to the Council and the European Parliament: European Space Policy, 26 April 2007; COM (2007) 212 and ESA/C-M (2007) 2.
[2] Ibid.
[3] Conclusions of the Workshop on Space Security and the Role of the EU, Berlin, June 2007.
[4] SPASEC Report, March 2005, ec.europa.eu/comm/space/doc_pdf/article_2262.pdf.

[5] Presentations were given by Luca del Monte (ESA), Lesley Jane Smith (University of Bremen), Ludger Leushacke (FGAN), Laurence Nardon (IFRI) and Tomaz Lovrencic (EUSC).

2. Definition of Terms and Scope

2.1. Space Situational Awareness and Space Surveillance

Within the framework of this study, *Space Situational Awareness (SSA)* is understood to consist of *understanding and maintaining awareness of the Earth orbital population, the space environment, and possible threats*. This definition was prepared by a group of potential SSA users gathered by ESA in the course of various sessions.

In this context, *Earth orbital population* refers to detection and /or tracking of man-made objects, the identification (and characterization) of detected objects and of spacecraft manoeuvres, as well as the determination of orbit state, covariance information, spacecraft attitude, and antenna/instrument pointing.

Space environment refers to detection and/or the tracking of natural objects; detecting and understanding interferences; man-made, induced environments; forecasting space weather and its effects as well as predicting the natural particulate environment and its effects (meteoroids).

The *possible threat* refers to predicting and assessing the risk to humans and property on ground and in air space due to uncontrolled re-entries, detecting and assessing adversary use or preparations for adversary use of or upon space systems, detecting on-orbit explosions and release events, predicting and/or detecting on-orbit collisions, as well as permanent or temporary disruption of mission and/or service capabilities.

A first stage of Space Situational Awareness is *Space Surveillance*, understood to comprise the *routine operational service of timely detection, correlation, characterization, and orbit determination of space objects.* In this sense, SSA, compared to Space Surveillance, covers additional and more detailed aspects, and allows for planning over an extended time. Table 1 lists the definitions for the sake of clarity.

Space Situational Awareness (SSA)	Understanding and maintaining awareness of the Earth orbital population, the space environment, and possible threats
Space Surveillance	Routine operational service of timely detection, correlation, characterization, and orbit determination of space objects

Table 1: Definitions of Space Situational Awareness and Space Surveillance

The Space Situational Awareness (SSA) initiative pursued by ESA is not meant to duplicate or compete with existing intelligence systems. In particular, the system is not planned to feature Ballistic Missile Defence (BMD) or early-warning capabilities. The new facilities planned are intended to complement current ones, forming a system of systems, and to fill existing gaps in data availability, thus resulting in better coverage for users in Europe and the rest of the world.

2.2. Dual and multiple use

An important distinction to be made is the one between *dual and multiple use* devices or systems. In the further course of this study, the following terminology will be used:

Dual use implies that the device or the system has been specifically designed for one actor (e.g. the military) and then has been used by other communities as well, regardless whether this was intended by the originally targeted user or not.

Multiple use, on the other hand, implies that the system has been developed to serve different communities right from the beginning. As will be shown, this is how the future European SSA system should be set up. It should be noted that multiple use does not have to be more expensive or complicated, since it may be considered the optimum utilization of existing assets.

3. Key Aspects of a European SSA System

In the following, selected aspects crucial to the successful implementation, proper functioning, and efficient operation of a European SSA System will be discussed. As will be seen, most of the questions that arise require the balancing of two or even more potentially contradicting requirements and concepts. This report does not aim at specifying the correct amount of trade-off. Rather, it will highlight the rationale of the underlying competing ideas. The issues at stake include among others:

- A data policy answering the question of who accesses what data, when and under which conditions, thus achieving a balance of the need for sufficient information flows with the necessity of respecting security and privacy needs.

- A business model representing attractive revenue opportunities for private entities at different system levels, establishing a trade-off between a purely private and an exclusively public set up in balancing commercial interests with state or supra-national control.

- Operational questions regarding the structural and procedural set up of a European SSA system as well as the institutional framework, balancing a centralized approach with a distributed configuration and civilian utilization with military requirements.

3.1. Data Policy

One critical prerequisite for efficient SSA system operation is a suitable data policy, which in the context of this study is understood to comprise the rules and procedures for handling and distributing information collected by sensors (raw data) and manipulated or refined in subsequent system stages (processed data) as well as the mechanisms to control and enforce compliance with these rules and procedures. Data policy is the answer to the question of who accesses what data, when and under which conditions. Its task is to ensure sufficient information flows, while respecting the need for partial confidentiality and allowing for commercial exploitation. It is worth adding that up to now, many data policies have not been codified, but are based on gentlemen's agreements. Nevertheless, they exist for each sensor and they have to be accounted for when setting up an umbrella data policy for a system of sensors, since they will not be changed according to the wishes of the system operator. In order to design a data policy for the future European SSA system, it is instructive to look at data flows in current dual/multiple use applications. One obvious example is the US Commercial and Foreign Entities (CFE) Support Pilot Programme, since this programme currently distributes Space Surveillance data. Other examples are the German TerraSAR-X programme and the French/Italian ORFEO system, both belonging to the area of Earth Observation.

CFE Support Pilot Programme

The Commercial and Foreign Entity (CFE) Support Pilot Programme is a mechanism to provide US non-public or non-US space operators with space surveillance support through a web-based portal[6]. The available data are an unclassified subset of the observations and analyses made by the US Space Surveillance Network (SSN). This network is run by the US Air Force Space Command (AFSPC) at the Cheyenne Mountain Air Force Base, Colorado. However, it will soon be transferred to the US Strategic Command's Joint Functional Component Command for Space at Vandenberg Air Force Base, California.

SSN consists of more than 20 military and civilian sensors, both radar and optical, ground-based (worldwide) and space-based. The observations and measurements of the network are used to calculate future trajectories of the located objects. The sensors are either dedicated, collateral or of the contributing type. The primary mission of dedicated sensors is Space Surveillance. They can be operated by entities outside the AFSPC or even outside the US. Collateral sensors belong to the AFSPC, but have a primary mission other than space

[6] www.space-track.org

surveillance. Contributing sensors either report to another USAF Major Command or are under contract to AFSPC to provide space surveillance information[7].

The information on the CFE website are satellite orbital data in the form of two line elements, satellite catalogue messages, project tip messages, satellite decay messages, predicted decay forecasts, satellite box scores and satellite reports, updated at irregular intervals. The same information has been provided by the NASA Orbital Information Group (OIG) for many years. Both real-time and historical data can be requested and acquired [www.space-track.org]. The basic services are for free, but advanced services like launch support, conjunction assessment, end-of-life/re-entry support or anomaly resolution are provided for a fee (the amount has apparently not yet been determined).

To gain access, CFE users have to register online. By doing so, they agree "not to transfer any data", including "the analysis of tracking data … to any third party without the prior express approval of the U.S. Secretary of Defense or his delegatee"[8]. Users must also acknowledge that the requested data might not be available, accurate or exhaustive. In addition, they agree to use the data at their own risk and expense, and not to hold the US government liable for consequential damages of any kind. To redistribute data, registered CFE users have to fill the "US Strategic Command Form 1". In the process, they have to detail to whom they transfer the data and why they want to do so. Users have to specify the further utilization of the data and the number of times they want to share the data. They must also state the means of redistribution (written, oral, electronic, etc). Figure 1 shows the data flow of the CFE Support Pilot Programme.

TerraSAR-X

TerraSAR-X is a German Radar remote sensing satellite for Earth Observation. It has been implemented under a public-private-partnership (PPP) between the German Aerospace Centre (DLR) and EADS Astrium GmbH as the first of its kind. The total costs for building and constructing the satellite amount to 130 million Euros. Roughly 100 million Euros come from DLR and the remaining 30 million Euros from EADS. The setting up of the ground segment and the satellite operation over the projected lifespan of five years will cost another 55 million Euros. 45 million Euros of this sum are covered by DLR and 10 million Euros by Infoterra, a 100% subsidiary of EADS Astrium, which is in charge of commercially marketing the data. The fact that industry is investing in this field shows that Earth Observation data are of growing interest to the private market. Maybe this will result in a brisker commercialization of Earth

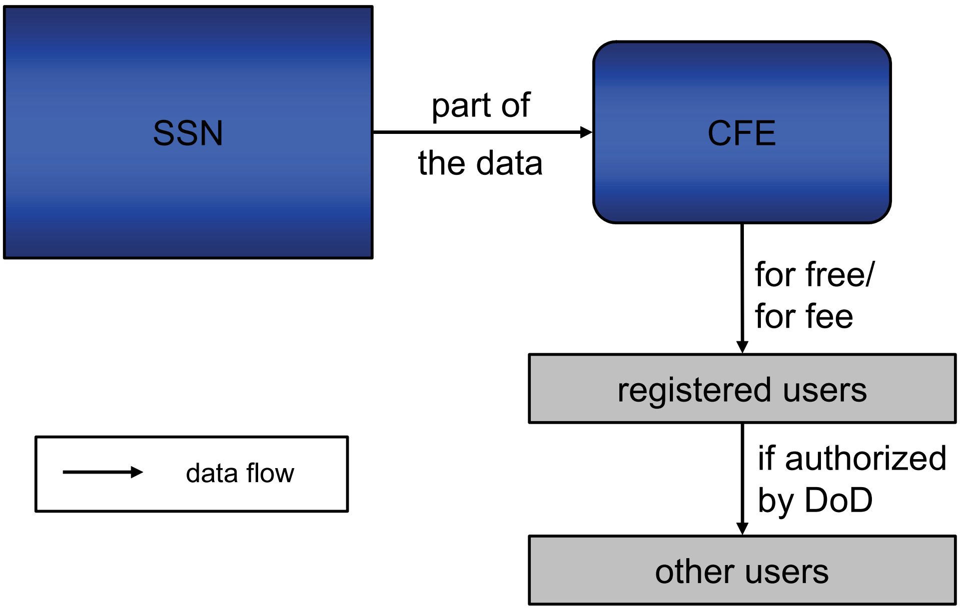

Figure 1: CFE Data Flow

[7] www.cdi.org/news/SSA/Jefferson.htm
[8] www.space-track.org

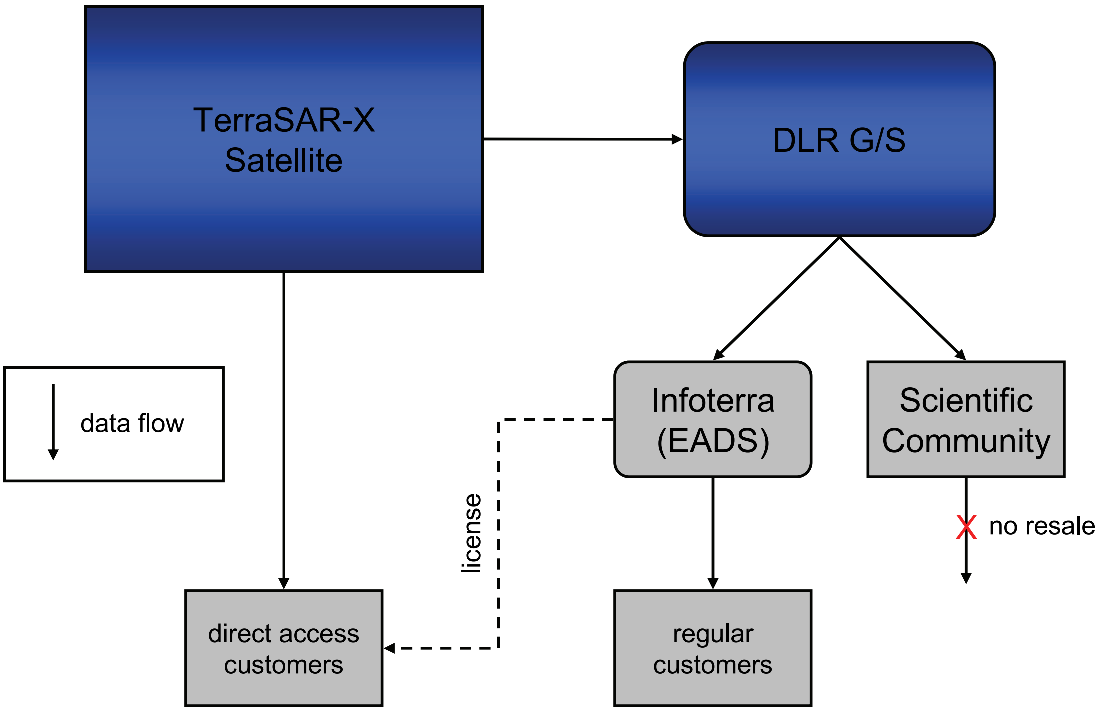

Figure 2: TerraSAR-X Data Flow

Observation, similar to the development in the telecommunications sector.

TerraSAR features a Synthetic Aperture Radar (SAR), allowing high resolution mapping around the clock, regardless of the weather conditions or sun illu
mination. It weighs around 1.200 kg and follows an almost polar orbit of 514 km altitude along the day-night boundary of the Earth. Operating in the X-Band, it can switch between Spotlight, Stripmap and ScanSAR mode. Experimentally, it can also use the Dual Receive Antenna (DRA) mode which enables Along Track Interferometry. It is planned to complement TerraSAR by another Radar satellite called TanDEM-X, also to be procured by means of a PPP. Flying in parallel, the two satellites will be able to work in an interferometric mode, generating a digital terrain model of the complete surface of the Earth within two and a half years.

The TerraSAR PPP-Agreement between DLR and EADS defines, among other things, the programme's data policy. DLR is tasked with commanding, operating, calibrating and receiving data. Representing the state, DLR is the owner of the TerraSAR-X data. It is in charge of processing and archiving the data as well as distributing it to the scientific community (both inside and outside DLR) via an order interface. EADS/Infoterra, in exchange for contributing to the development costs of the satellite, gains the exclusive commercial utilization rights. It develops geo-information products and markets the data. Delivery of the data is through Infoterra or via direct satellite access (upon purchase of a license) for customers that have their own reception facilities and processing capabilities. It is worthwhile noting that data subsets can be kept out of the distribution process according to the provisions of the German law on satellite data security (which will be discussed later on), and that commercial and scientific users are given equal shares of the satellite's observation time. Figure 2 shows the data flow for the TerraSAR-X programme.

ORFEO

The Franco-Italian ORFEO (Optical and Radar Federated Earth Observation) System is a project for optical and Radar Earth Observation specifically set up to serve the needs of both civilian and military users. It is thus a multiple use system according to the definition above. The optical component consists of the French PLEIADES satellite developed by CNES, which is also the owner. The radar component consists of the Italian COSMO-Skymed satellites that were developed by ASI and are owned by ASI and the Italian Ministry of Defence.

The configuration of ORFEO was set up in an agreement between France and Italy signed

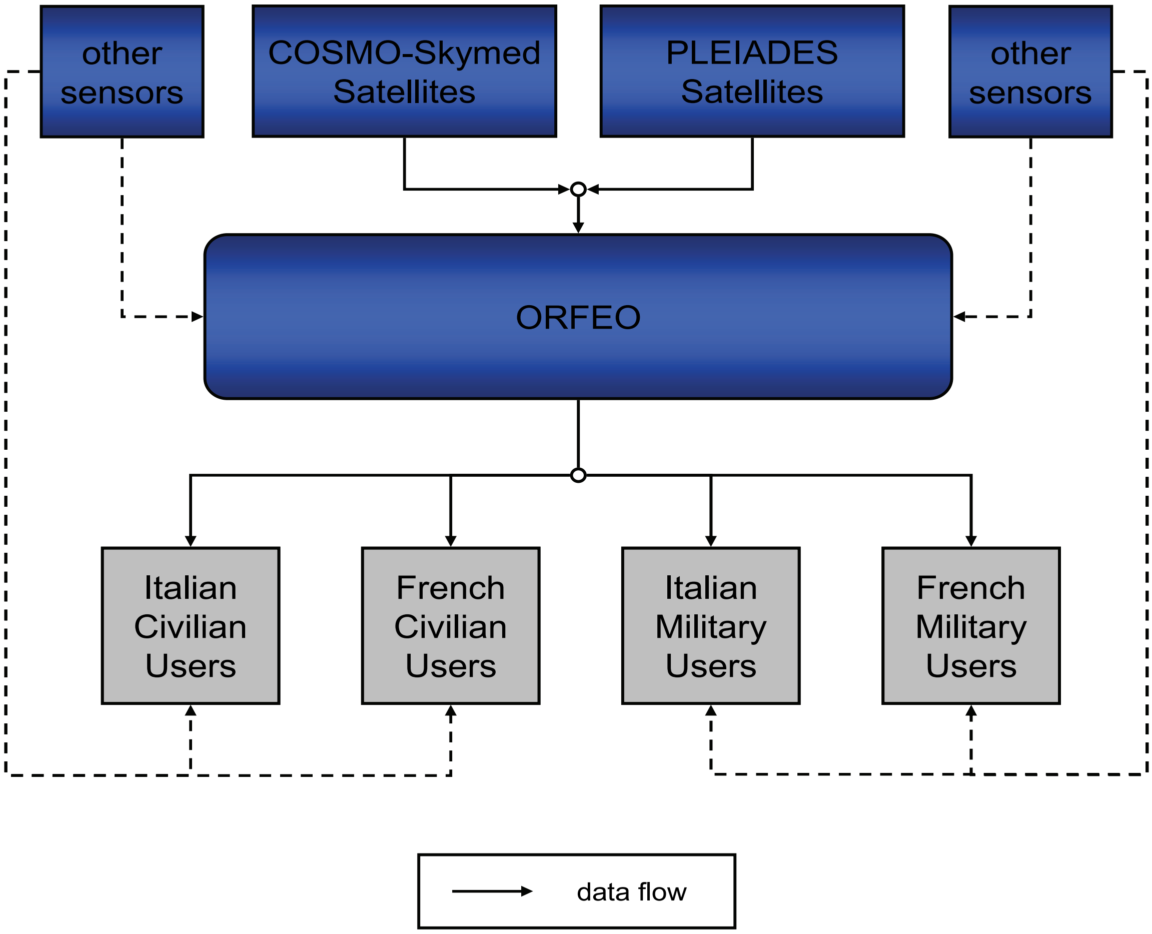

Figure 3: ORFEO Configuration

in 2001[9]. A cooperation scheme for Earth Observation with optical and radar sensors was implemented, also granting Italy access to the French Helios 2 and SPOT 5 satellite imagery. The first two COSMO-Skymed satellites have already been launched, whereas there has been a delay for the PLEIADES. It is not yet clear how this delay will affect the implementation of the agreement.

The four COSMO-Skymed satellites, designed for a lifespan of five years weigh around 1.700 kg each and follow a sun synchronous orbit of 620 km altitude. They are equipped with X-Band SAR for ScanSAR, Stripmap and Spotlight operation. The latter is able to achieve submetric resolution, although the corresponding data will be reserved for defence use. A special orbital configuration will also enable interferometry[10]. The COSMO-Skymed system is instructive, because it has been designed to work in a multiple use mode from the outset, and features interoperability, expandability, and multi-mission/sensor capability. It is one of the few Earth Observation systems of that kind that are actually being implemented. The two PLEIADES satellites are expected to operate for five years as well. They weigh around 1.000 kg each and follow a circular orbit of 695 km altitude. Featuring stereoscopic acquisition capacity, their resolution is 0.7 m for the panchromatic band and 2.8 m for the multi-spectral band. The swath width is 20 km at nadir[11].

Neither COSMO-Skymed nor PLEIADES are to be used exclusively for ORFEO. Thus far, ASI has signed an agreement with the Argentinean Space Agency on the joint operation of COSMO-Skymed with future Argentinean satellites. Likewise, CNES has signed cooperation agreements regarding the use of PLEIADES with Austria, Belgium, Spain (which will develop its own reception and processing means and will also have access to high-priority programming), and Sweden (which will support data reception and TT&C). Figure 3 shows a schematic, conceptual set up of the ORFEO system with its external interfaces and its complex internal structure shown as a black box.

[9] Act of 10 January 2004, No. 20 on the Ratification and Execution of the Agreement between the Government of the Italian Republic and the Government of the French Republic regarding cooperation in the field of earth observation, done in Turin on 29 January 2001, Gazzetta Ufficiale (Official Gazette) 31 January 2004, # 25.

[10] directory.eoportal.org

[11] earth.esa.int, smsc.cnes.fr/PLEIADES

However, these cooperation ventures are subject to the constraints of the Franco-Italian agreement, which includes provisions and guidelines for data handling, defining the general principles valid throughout all cooperation phases. Specific details like the use of data are deferred to subsequent negotiations and agreements. In broader terms, the existing agreement ensures the system to safeguard defence interests like security and mission request priority as well as to meet civil or commercial user requirements in terms of overall operational capacity, rapid data access, availability, image quality and service competitiveness. Various user categories are discerned: public, institutional, private and commercial. Accounting for users of the two contractual parties' defence ministries, different obligations are listed, including the following ones:

- Mission requests from the defence ministries must be satisfied as a matter of priority.
- Upon definition of "very urgent cases", the system must allow for mission reprogramming and data processing within the shortest possible time, putting the specific request before any other, including those from the defence ministries.
- Knowledge about mission requests, planning and products of each defence ministries must be restricted to the specific defence ministry.
- Compliance of the civil plan with the common security rules is controlled by government security bodies.
- The corresponding measures will be carried out by a civil or military coordinating body yet to be set up.
- Secured connections between different system components will be put into place. Defence-related data will be encoded.
- Defence ministry users will have free access to raw data from civil archives, according to the ORFEO data policy agreement.
- Defence-related products could be transferred to civil users after having been degraded and declassified.
- The parties will have the right of veto/shutter control on mission requests and on the release of archive data (with the exception of requests from the defence ministries).
- The parties will have access to the mission requests of other system users.

Potential Data Flow of a Future European SSA System

Following the considerations of existing Space Surveillance and Earth Observation data flow models, one could devise a data flow model for a future European SSA system. A basic sketch is given in Figure 4. Again, the boxes are to be understood in a general way, encompassing the systems themselves – as previously stated, European SSA will be a system of systems. Two basic branches/levels should be distinguished: The national and the European one. In this context, military entities are presumed to stay under national control for the time being. At this point, the question of who orchestrates, controls and supervises the complete system is not considered. It will be addressed in the section on operational questions.

The sensor stage in Figure 4 is understood to comprise reception facilities where necessary (e.g. for space-based sensors). National sensors like the French GRAVES or the German TIRA already exist. European sensors (like the telescope of the European Space Agency ESA on Mt. Teide), however, would have to be augmented in the framework of a future SSA system. The model foresees (selective) data exchange both in raw and in processed format. A crucial role will be played by system interoperability, requiring, among other things, standardized interfaces. The decision on which data is to be released for exchange (alternately, which data is retained) is taken by the sensor operator, following common rules laid down beforehand.

The handling/processing stage involves all institutions concerned with processing, calibration, refinement, archiving, etc. A variety of actors like military bodies, agencies, public institutions or even private companies are involved. Beyond this stage, data format / product standardization is more difficult to achieve than at the raw data stage.

As before, the decision on which processed data/products are to be fed into the common system is taken by the producing entity in accordance to the general system operation rules agreed upon.

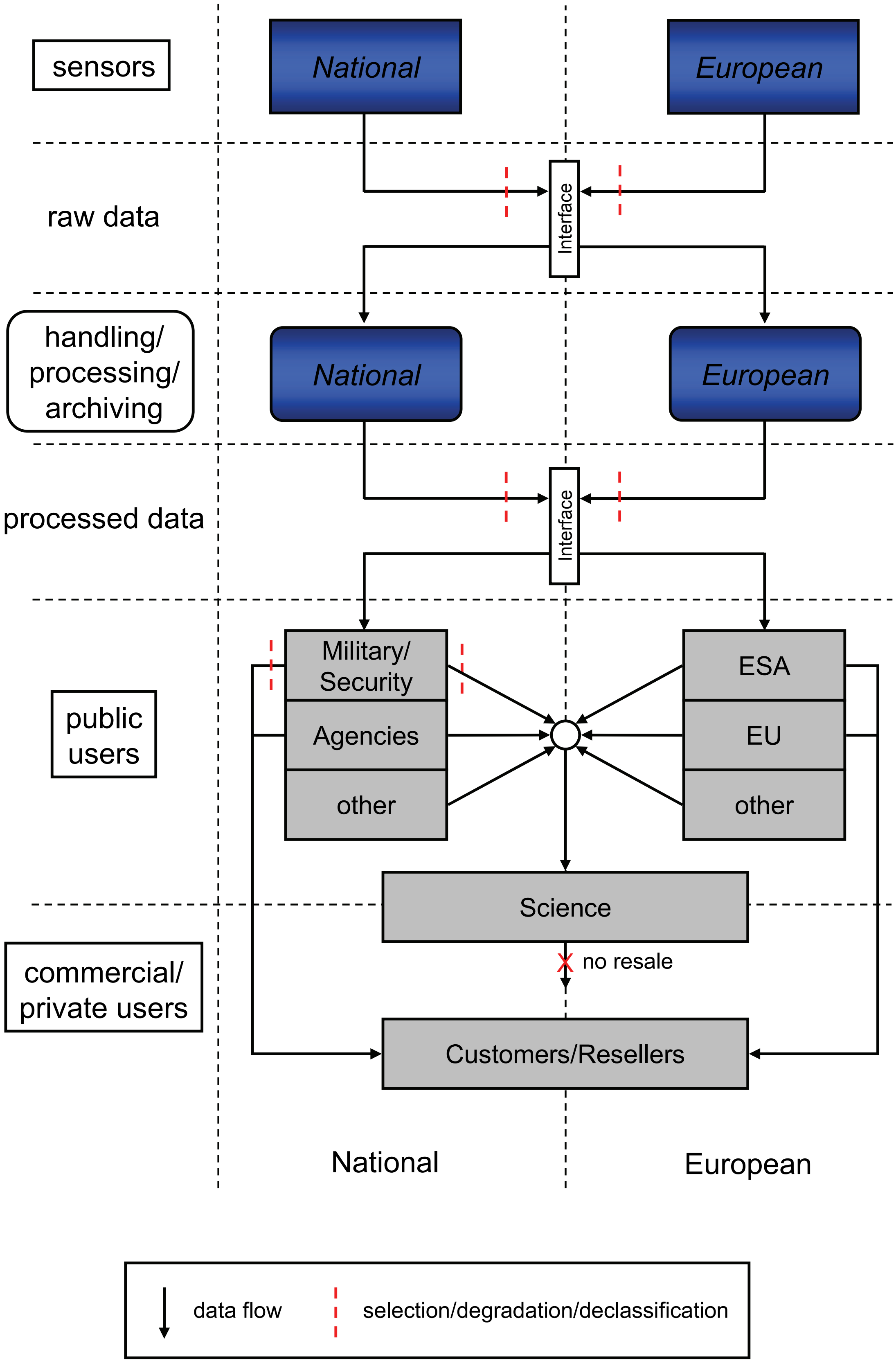

Figure 4: Potential European SSA System Data Flow

Finally, the data/products are passed on to the users, which will often be the same organizations that have been involved so far. In addition to fulfilling their own needs, they pass on part or all of their data to the system for common use. A special case is constituted by the military that might not block data completely, but degrade or declassify it instead. In the suggested scenario, data passes the public user stage before being transferred to (semi)commercial or private users. This accounts for the fact that public users will be the most important sensor contributors, which should be rewarded by priority use. If conditions change, this pattern can be adapted accordingly.

To ensure the smooth and efficient data flow of any future European SSA system, some issues will have to be addressed. For example, national stakeholders must be brought to participate and contribute to the system, both in terms of data and of funds. At present, entities like the British Fylingdales radar or the Norwegian Globus II radar do not pass on their data to other European states, just to the US. Furthermore, the participating and contributing entities will have to be convinced to share as much of their data as possible, given the fact that they will not pass on all the data they gather to the European system. Also, the national entities will need to be won over to standardize their products.

The best incentive for national stakeholders to follow these requirements is the creation of win-win-situations in which sharing data and spending extra time or costs is rewarded by access to complementary data or products not available otherwise. Another question is how the multiple use character of SSA data can be accounted for appropriately. If military entities are to pass on some of their sensitive or classified data, they will need to be able to rely on the careful handling of this data.

Legal Aspects

Having a look at data flows reveals only part of the picture, because once the desired flows have been defined, realization is only a matter of technology. To develop a full blown data policy, one will also have to pay attention to formal and legal aspects governing data access and distribution. In this regard, it is instructive to have a look at the Earth Observation sector[12], because many of its features will be displayed within a European SSA system as well.

One of the similarities is that national law will play a significant role for SSA data access and distribution as well, because much of it will be provided by national means. Accordingly, the laws governing freedom of information and access to public data (Freedom of Information Acts FOIA) are, and will remain, important for SSA data distribution. In principle, they grant citizens the right to access the data gathered by public authorities or agencies. At the same time, all FOIA in force also state exemptions from information access. Reasons not to grant access typically belong to one of the following categories:

- Requested data are available through other means as well.
- Data are planned to be published.
- National security or defence interests are concerned.
- International relations are endangered.
- Data contain health, safety or personal information.

An example of a new type of national law is given by the German Satellitendaten-sicherheitsgesetz SatDSiG (Satellite Data Security Act)[13] adopted in 2007 in view of the new Earth Observation systems like TerraSAR-X. The intent of the law is to make sure that Earth Observation data from German satellites or satellites operated by German ground stations do not endanger the security interests of Germany or its allies, the reference level being constituted by worldwide freely available data. The law incorporates a semi-automatic parametric sensitivity analysis of requested image products. A numerical value is calculated for each request, taking into account the requesting person and the user, scene location, sensor mode, processing parameters and the timeliness of data delivery. If this value is below a threshold, the provider can pass on the scene. If the value exceeds a threshold, the request has to be authorized by German authorities. This approach allows for political adjustments in the course of operation, while not interfering with the main part of the business.

European legislation exists as well and will probably increase in significance for SSA data

[12] Smith, Lesley Jane and Catherine Doldirina, Proceedings of the ESA/ESTEC Symposium on Space Options for the 21st Century, February 2007.

[13] Bundesgesetzblatt 2007 I, Nr. 58, Bonn, 28 November 2007.

distribution, as the European system components become more numerous and important. There is a 2001 Regulation on public access to documents of the European Union (which might become relevant if the EU takes part in a future European SSA system)[14] and a 2003 Directive on the re-use of public sector information[15]. The latter states that there is no obligation of public authorities to allow re-use of documents and that they are entitled to charge fees that facilitate a "reasonable return" on investment. The European initiatives GMES (Global Monitoring for Environment and Security) and INSPIRE (Infrastructure for Spatial Information in Europe)[16] will influence the data policy of a future European SSA system as well. This is due to the fact that they depend heavily on data sharing and interoperability between different subsystems.

It is also instructive to look at current data distribution models in international organizations. The World Meteorological Organization (WMO) has adopted a resolution on the free and unrestricted exchange of meteorological data and products[17], relying on a three-tier approach:

- A minimum set of essential data and products required to accurately describe and forecast the weather and climate is to be provided on a free and unrestricted basis.
- Additional data and products required to sustain WMO programmes at the global level are to be exchanged freely, as long as the members retain the ability to place justified conditions upon the data and the re-export of the products for commercial purposes.
- Data and products exchanged under WMO auspices for research and education communities for their non-commercial use are to be accessible in an open and unrestricted manner.

The resolution's wording implies that only the first category of data *shall* be accessible in a free and unrestricted way, the data of the other two categories *should* be made available. In any case, national authorities remain quite free to decide which data to pass on in their jurisdiction. This seems to reflect an overall trend.

The European Space Agency also has its data distribution models laid down in the Earth Explorer Data Policy or the Envisat Exploitation Policy. On behalf of its Member States, ESA maintains ownership of all primary data and ESA-derived products. They are protected by database rules, copyright laws and other forms of Intellectual Property Rights (IPR). There are two categories of use with different distribution modes and prices. For research and application development supporting the mission objective the data is distributed solely under ESA responsibility, only for project purposes and at the cost of reproduction. For all other uses, ESA appoints distributing entities that are in charge of delivering services and are fully free to set the prices.

One has to check whether and to what extent data distribution models like the three-tier approach are applicable to a future European SSA system. It will also have to be examined whether SSA data constitute a public good or are of public interest. If this applies, citizens' access to public authorities' data will be affected. In addition, public authorities might essentially gain access to privately/commercially collected data. This has implications for the business model that will be discussed next.

3.2. Business Model and Operational Questions

Before setting up a business model for a future European SSA system, one needs to ask the basic question how commercial the system should be, i.e., to what degree is profit-orientation to be allowed or even targeted. The system could either be run completely by public entities or completely by commercial entities, or by a combination of both. Depending on the system philosophy and configuration, the degree of profit orientation will change. The same is valid vice versa. It should be borne in mind that the examples of ISS utilization and Galileo have shown that a purely commercial orientation may not be sufficient for successful system implementation.

If profit orientation is desired, sufficient business opportunities for commercial stakeholders have to be ensured. These business opportunities can arise internally (for commercial entities taking over part of

[14] Regulation (EC) 1049/2001 of the European Parliament and of the Council of 30 May 2001.
[15] Directive 2003/98/EC of the European Parliament and of the Council of 17 November 2003.
[16] Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007.
[17] WMO Resolution 40, 26 October 1995.

the system operation) or externally (for commercial entities selling system data or derived products to customers outside the system). A special case of commercial entities pursuing internal business opportunities could be constituted by sensors or processing units that are run within a public private partnership (PPP), constructed publicly and operated privately.

Commercial entities pursuing external business opportunities will have to be able to offer products and services with added value compared to those freely available. The added value may consist of the fact that the product and services are guaranteed on a contractual basis, i.e., the provider can be held liable if products and services are not available or the quality is deficient. The rendered quality and quantity would have to be defined in Service Level Agreements (SLA). The added value can also consist in providing reliability information about the data, e.g., in the form of covariance matrices, or in providing the actual osculating elements describing the object trajectory, not just averaged two line elements (TLE) or pure positional data. Classical candidates for purchase of SSA data/products are customers like spacecraft operators, Launch and Early Operation Phase (LEOP) service providers, insurance companies, space application (telecommunication, satellite navigation) service providers, etc. Space weather data can be of interest to airlines, electricity suppliers and grid operators, etc. More innovative marketing models include data warehouses for commercial operators, where system data are available for external analysis without interfering with the actual system's operation. In the context of commercial exploitation, associated issues and technical boundary conditions have to be considered.

Regarding the operational and institutional aspect, some basic questions have to be answered. Who will be in charge of system operation, maintenance and updates? Who controls the performance of the overall system (both technically and financially)? Who oversees and enforces rule/procedure compliance? Should an existing entity be picked or a new one created? Should the concessionaire model be applied? Should the operator be public (civilian), military or commercial? Table 2 gives some pros and cons for the different kinds of operators.

If one chooses a commercial operator, it is worth considering the application of a concessionaire model. Hereby, one understands the exclusive operation of a business under a contract or license. The operator of the business is called the concessionaire. It pays a fixed sum or a share in revenues to the entity that is entitled to grant the licence or operating rights. The latter often include the transfer of existing infrastructure to the concessionaire.

Where public services are run by a concessionaire, the government transfers the rights to operate, maintain and invest in public assets to a private company. The Galileo case, in which an industry consortium was to be awarded a concession by the Galileo Joint Undertaking (GJU) formed by EC and ESA is a special example in the space sector, because the concession did not only comprise system operation and maintenance, but deployment as well. The concessionaire

Operator	Pros	Cons
Public (civilian)	Installation, regulation and operation done by same body/related entities; Clear cut liability; Serving public welfare/commonwealth; Data sharing attitude	Subject to state influence Difficult governance
Military	Experienced and effective operation; Robust and reliable procedures	No data sharing attitude; Subject to national interests; Longer development and procurement cycles; Conservative handling
Commercial/ Concessionaire	Cost efficient; Liability on contractual basis; Actively seeking customers/users; Experience in marketing	Profit-oriented; Subject to political influence; Difficult public control; Unclear property questions might hinder maintenance

Table 2: Pros and Cons of different Operators

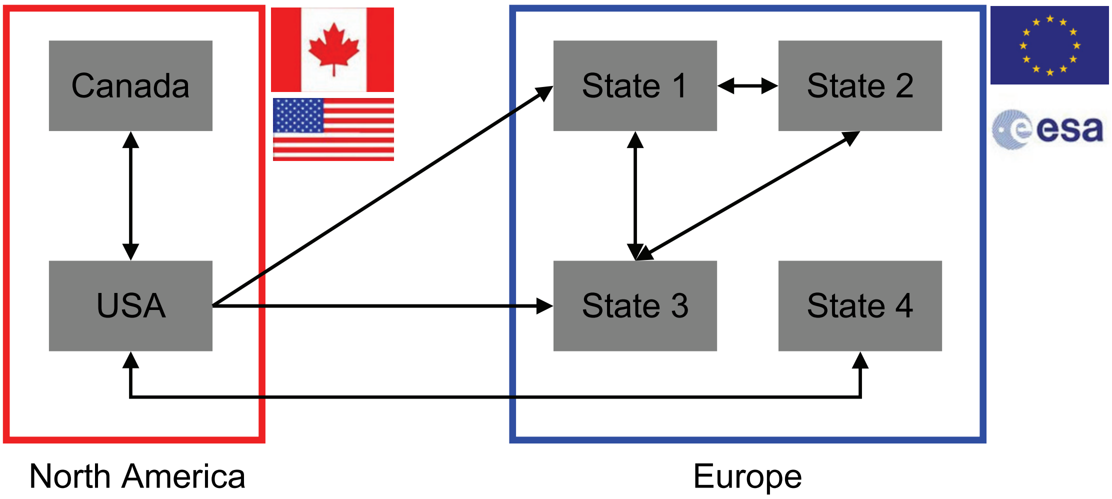

Figure 5: Current Transatlantic SSA Data Sharing

model bears certain similarities to public-private-partnerships such as the one mentioned in the chapter on TerraSAR-X. In both cases, the public sector is able to offer infrastructure or services at a relatively low cost. In addition, responsibility assigned to private entities leads to better risk allocation, while keeping the public sector accountable for certain aspects of service provision. The drawback of these models is weaker public influence on the actual system operation.

Different hardware and system architecture options have been suggested in various studies by ESA internally as well as by external consortia within the framework of the ESA General Studies Programme (GSP) and the General Support and Technology Programme (GSTP). They either employ a distributed approach, a centralized concept or a mixture of both.

The question of centralization touches upon cooperation between regional SSA systems like a North American or a European one. Such cooperation is needed over the long run, because SSA endeavours need to be conducted globally. "Regional" in this context refers to SSA cooperation between states within a geographically limited area, resulting in non-complete coverage of space by ground-based means. Figure 5 schematically shows the present situation with regard to transatlantic data sharing. Current European SSA data sharing is done bilaterally, with some states sharing data with the US exclusively, and others receiving data from the US only. The existence of various possible data paths can create a situation of unwanted data spill-through with difficult accountability.

Figure 6, on the other hand, shows a potential future set up that is more

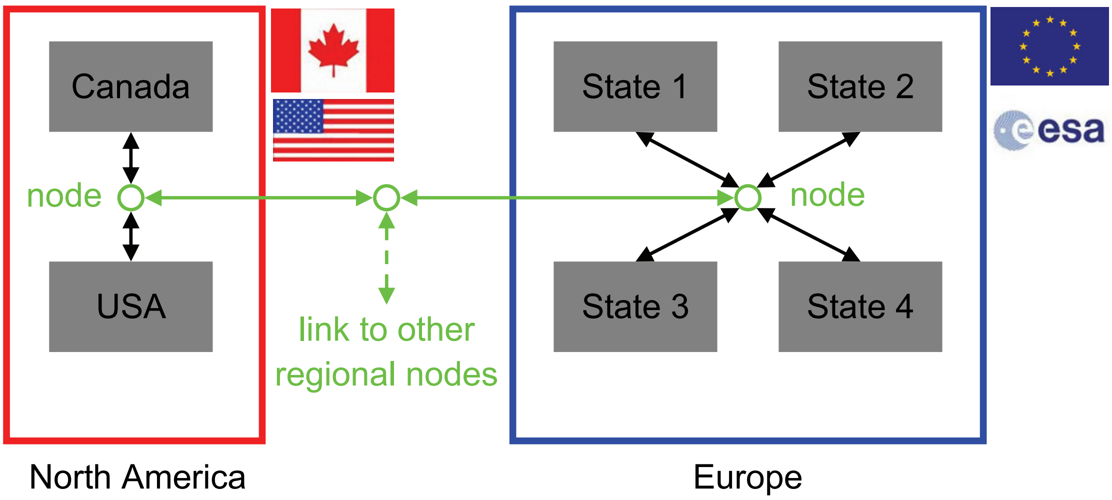

Figure 6: Potential Future Transatlantic SSA Data Sharing

centralized: Each regional system has a regional hub for data exchange. This hub can be either virtual or a physical centre. It can serve either as a communication port only, or it can be charged with tasks like data archiving or system guidance. For a North American SSA system, the situation is not too different from the present, where the US and Canada already run NORAD together. In any case, the regional hubs are the unique linking points to other regional SSA systems. This leads to a clear accountability for inter-regional SSA data exchange. Figure 6 is actually a top view on a three dimensional data sharing pattern, because the regional hubs can incorporate a multiple level approach: They can exchange data within the region according to regional data policies and pass on a subset of these data for inter-regional SSA data exchange.

The choice between centralized and distributed architecture also occurs at the meta level: It would have to be decided whether the regional hubs communicate with each other directly, incorporating a distributed approach, or whether they are all linked to each other via a hub of hubs, constituting a centralized solution. If the second alternative is chosen, the question of a global SSA authority with its associated political aspects arises.

4. Link to future Space Traffic Management

It is obvious that the existence of a functional SSA system is the precondition for a future Space Traffic Management (STM), which can be defined as "the set of technical and regulatory provisions for promoting safe access into outer space, operations in outer space and return from outer space to Earth free from physical and radio-frequency interference"[18].

- A future STM regime will comprise various areas, including the securing of information needs, concrete traffic rules and mechanisms for implementation and control[19]. These areas have direct links to SSA:

- Securing information needs is the very core task of an SSA system. Providing a sound information base by sharing knowledge about what is going on in space and about space weather is a prerequisite for meaningful space traffic rules.

- The traffic rules could include right-of-way provisions, manoeuvre prioritizations, keep-out-zones, safety corridors and special regulations for satellite constellations. Compliance with these traffic rules can only be checked if the supervising entity is capable of SSA.

Mechanisms for implementation and control would most likely be based on an international treaty, with the subsequent rules of the road and standards being drafted as soft law. Ultimately, this might result in a sort of outer space policing. Again, this will require SSA capability.

The question what institution will be in charge of operative STM oversight is currently being discussed in academic circles. A new body might be created, or the responsibility of an existing one might be expanded. These considerations could also influence the question of the SSA system operator. As already mentioned, SSA information revealing compliance with traffic rules is needed for their implementation and control.

It has to be decided if the operator of the SSA system (who has access to all the relevant data) should also be in charge of enforcing STM rules and procedures, similarly to a highway police on earth that collects motion data of road traffic participants and enforces the law on this basis. Should the SSA system operator also be the STM rule enforcement entity, it will have to be picked or created accordingly, allowing for scalability in terms of staff and competence.

It is obvious that the operator of a European SSA system, being a regional actor, could only contribute to STM rule enforcement to a limited extent, because STM is a truly global concept. Accordingly, various regional SSA system operators would have to cooperate to support STM. As has been stated before, such cooperation is facilitated by a centralized architecture.

STM deals with all phases of space traffic – access to space, operation in space and return from space. As a consequence, integration with air traffic management has to be achieved. Due to the different physical boundary conditions, this does not mean identical regimes, but compatible ones. This has to be reflected technically: the SSA system should be interoperable with air traffic control systems to fully support STM throughout the three phases described above.

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[18] Schrogl, Kai-Uwe. "Space traffic management: The new comprehensive approach for regulating the use of outer space – Results from the 2006 IAA cosmic study." Acta Astronautica Jan. 2008: 272-76.

[19] "Space Traffic Management. The new comprehensive approach for regulating the use of outer space", ESPI Flash Report #3, Vienna, 2007.

5. The Role of ESA

The responsibilities and duties of ESA within a future European SSA system depend on the system configuration chosen. If ESA is tasked with procurement or parts thereof, different approaches can be taken - either big bang or spiral procurement.

Big bang procurement stands for provision of the complete system at one specific point of time. While allowing for efficient system optimization from the very outset, the complexity of this endeavour often hinders successful implementation. Moreover, experiences from system operation under real-world conditions can no longer be drawn on easily as regards hardware once the system has been fully deployed.

Spiral procurement, on the other hand, refers to providing system parts over an extended period of time, supplying the different components on a piecemeal basis. This increases the time needed for system completion, but fitting the subsystems into an existing system frame is easier and experiences gathered in real-life operation can be applied in the development of the subsystems to be added. Aside from that, the continuous procurement and development process is sustainable, because it ensures evenly distributed capacity utilization, a prolonged build-up and preservation of technological know-how.

Of course, ESA's role within a future European SSA system could also exceed merely procurement. In fact, the complete system development, deployment and operation could be performed within the framework of an optional ESA programme. In this manner, the participating states could decide upon the level of funding they provide and profit from the geographical return principle. At the same time, programme execution could rely on established management structures well suited for the space sector.

If a centralized architecture for the future European SSA system is chosen, a minimal version of ESA's role could consist of initially running the centralized unit for system guidance, introducing, testing and establishing procedures and best practices before handing over responsibility to the designated system operator. In any case, it will make sense for a future European SSA system to integrate existing know-how, both at the national and European levels. In the important area of Space Surveillance, for example, the expertise of the ESA's European Space Operations Centre (ESOC) needs to be incorporated. ESOC's Space Debris Office (SDO) offers a wide range of services, such as conjunction event analysis or de-orbit and re-entry support. It also provides software tools for system, sensor simulation or environment modelling as well as for correlation, like MASTER (Meteoroid and Space Debris Terrestrial Environment Reference Model), DRAMA (Debris Risk Assessment and Mitigation Analysis) or PROOF (Programme for Radar and Optical Observation Forecasting). In addition, it maintains the DISCOS (Database and Information System Characterising Objects in Space) to track all space debris.

DISCOS is fed from various sources, including the aforementioned SSN and the ESA telescope at Mt. Teide, Tenerife. If needed, additional data are provided by the TIRA (Tracking and Imaging Radar) of the German FGAN. The SDO's role in a future European SSA system could be the one of technical consultancy, supplying state of the art knowledge and being less involved in routine operation.

6. The Way Forward

Looking at the considerations put forth and taking up the issues that have been touched upon both explicitly and inherently, some general observations and suggestions for further action can be given with a view to contributing to the swift resolution of open questions as well as the efficient implementation and operation of a future European SSA system:

General Approach

- Awareness of the importance of a European SSA system should be raised and increased. It should be made clear to decision-makers and to the public that an interruption of space services would cause most severe damage to European and global well-being. Public outreach will be more difficult to achieve here, because a European SSA system will not offer tangible benefits to the citizens as space applications do.

- A European SSA system should be broadly supported and backed at the highest political level. Important stakeholders have already expressed their interest. This now has to translate into sufficient funding that must be managed efficiently. An optional ESA programme for SSA could be an adequate solution. In addition, the EU should become involved in line with its general role and under the auspices of European Space Policy. Eventually, this could make SSA another European space flagship project like Galileo or GMES.

- A European SSA system must offer added value with regard to currently available SSA information from the United States. Such added value could consist in completeness, increased reliability and timeliness, new products and services and the availability of data on a contractual basis implying liability.

- The motivation for Europe to have a SSA system should not just be to free itself from dependence on the US. Rather, Europe should try to establish an own capability so that it has something to offer and is able to interact with others on equal grounds. This is a precondition for setting up a possible global SSA system in the long run.

Cooperation

- With a view to such a potential global SSA system, Europeans should acquire a SSA system that, beyond necessarily duplicating core functions of other regional SSA systems, has the potential to supply additional information complementary to other systems' data. This will facilitate exchange between all systems. Space Weather data are a prime candidate for initiating global cooperation in SSA. Relevant sensors should be put on future European space assets like the Galileo satellites, and the gap after the SOHO mission has to be filled.

- International and regional cooperation should also be supported by common definitions to establish a sound basis of understanding. The notions of "civilian", "military", "public", "institutional", "private" or "commercial" should be clarified and used in a uniform way. Furthermore, the different implications of the terms have to be considered. For example, Space Situational Awareness is understood to be self-standing in Europe, while the US tends to see it as a pre-stage of both defensive and offensive counter-space concepts.

Initial and Mid-term Design

- Being envisaged as user-driven, a European SSA system has to be set up in a genuinely multiple use fashion. In this context, multiple use should not be seen as a feature introducing additional complexity and cost. Instead, it should be recognized as an optimum usage of available assets. Taking into account military interests will be a challenge for ESA that has been reconsidering its understanding of security and its treatment of associated issues.

- Various hardware and architectural solutions for a European SSA system have been suggested by different studies. A decision on the final set up should take into account the desired amount of system profit orientation. A key role will be played by data policy. However, a chicken and egg situation where data policy design waits for hardware configuration and vice versa has to be avoided. Accounting for the fact that there is a strong interlink between the two processes, they should initially be run in parallel with iterative adjustments on both sides.

- The first step in building up a European SSA system should be to enhance cooperation between existing national and European facilities. Common features of different architectural solutions should be identified and implemented as a scalable precursor. Interoperability should be increased by means of standardization, connectivity and procedural harmonization. Setting up what has been called a European SSA system of systems will involve not only adding new facilities to the existing ones, but also linking them together in a 3C manner: comprehensive, coherent and clever.

- Provisions should be made for the SSA system to support a global STM regime. This would include an interface to air traffic control systems, since STM will have to govern the whole domain of space travel, comprising access to space, the operation in space and the return from space. Covering all three of these phases will account for a possible future situation where Member States and private "spaceliners" operate side by side.

Annex

Current European Facilities

The following is a list of currently available European facilities[20] that are capable of Space Surveillance, although it might not be their main activity. Technical details are not specified here since they could not be assessed for all facilities, being partially classified. Appearance in this table does not necessarily imply that the respective facilities are (fully) available for a future European SSA system.

	Name	**Location**	**Operator**	**Remarks**
Radar	GRAVES	Broyes-de-Pesmes and Revest-du-Bion, France	ONERA, owned by French Ministry of Defence	Bistatic, capable of creating an autonomous catalogue
	Fylingdales	Fylingdales Air Force Base, UK	British Ministry of Defence (together with US)	Part of SSN, no data sharing with other European states
	Globus II	Vardø, Norway	Norwegian Intelligence Service (together with US)	Part of SSN, no data sharing with other European states
	TIRA	Wachtberg, Germany	FGAN	Capable of tandem mode with radiotelescope Effelsberg
	Armor	Brest, France (Homeport)	French MoD (DGA/DCE)	Mounted on the "Monge" tracking ship
	EISCAT	various Scandinavian sites	Multinational scientific network	Provides range and Doppler data only
optical	SPOC	Toulon and Odeillo, France	French MoD	Capable of providing initial orbits for some objects
	ROSACE	Haute Provence, France	CNES	Precise orbit determination near geo
	TAROT	Calern Palteau, France	CNES	To be used together with Rosace
	PIMS	Herstmonceux, UK, Gibraltar, Cyprus	British MoD	Used by IADC
	Zimlat	close to Bern, Switzerland	University of Bern	Primarily used for satellite laser ranging

Table 3: Current European Facilities Capable of Space Surveillance

[20] Hitchens, Theresa and Thomas Valasek. European Military Space Capabilities. Washington, D.C.: Center for Defense Information (CDI), 2006.

Acronyms

3C	Comprehensive, Coherent and Clever
AFSPC	Air Force Space Command
ASI	Agenzia Spaziale Italiana
BMD	Ballistic Missile Defense
CFE	Commercial and Foreign Entities
CNES	Centre National d'Etudes Spatiales
DEM	Digital Elevation Model
DGA	Délégation Générale pour l'Armement
DISCOS	Database and Information System Characterising Objects in Space
DLR	Deutsches Zentrum für Luft- und Raumfahrt
DRA	Dual Receive Antenna
DRAMA	Debris Risk Assessment and Mitigation Analysis
EADS	European Aeronautic Defence and Space Company
EC	European Commission
EISC	European Interparliamentary Space Conference
EISCAT	European Incoherent Scatter Radar
ESA	European Space Agency
ESOC	European Space Operations Centre
ESPI	European Space Policy Institute
ESTEC	European Space Research and Technology Centre
EU	European Union
EUSC	European Union Satellite Centre
FGAN	Forschungsgesellschaft für Angewandte Naturwissenschaften
FOIA	Freedom of Information Act
G/S	Ground Segment
GEO	Geostationary Earth Orbit
GJU	Galileo Joint Undertaking
GMES	Global Monitoring for Environment and Security
GRAVES	Grand Reseau Adapté à la Veille Spatiale
GSP	General Studies Programme
GSTP	General Support and Technology Programme
IADC	Inter Agency Space Debris Coordination Committee
IFRI	Institut Francais des Relations Internationales
INSPIRE	Infrastructure for Spatial Information in Europe
IPR	Intellectual Property Rights
ISS	International Space Station
LEOP	Launch and Early Operation Phase
MASTER	Meteoroid and Space Debris Terrestrial Environment Reference Model
MoD	Ministry of Defence
NASA	National Aeronautics and Space Association
NORAD	North American Aerospace Defense Command
OIG	Orbital Information Group
ORFEO	Optical and Radar Federated Earth Observation
PIMS	Passive Imaging Metric Sensor
PPP	Public-Private Partnership
PROOF	Programme for Radar and Optical Observation Forecasting
SAR	Synthetic Aperture Radar
SatDSiG	Satellitendatensicherheitsgesetz (satellite data security law)
SDO	Space Debris Office
SLA	Service Level Agreement
SOHO	Solar Heliospheric Observatory
SPASEC	Space and Security Panel of Experts
SPOC	Système Probatoire d'Observation du Ciel
SPOT	Satellite Pour l'Observation de la Terre
SSA	Space Situational Awareness
SSN	Space Surveillance Network
STM	Space Traffic Management
TAROT	Télescope à Action Rapide pour les Objets Transitoires

TIRA	Tracking and Imaging Radar
TLE	Two Line Elements
TT&C	Telemetry, Tracking and Command
UK	United Kingdom
US	United States
WMO	World Meteorological Organization

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