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NOVEL APPROACHES TO INTERNATIONAL COOPERATION AND DATA SHARING FOR SSA

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In order to fully comprehend the extent of the space debris issue, help avoid collisions, and to eventually manage Active Debris Removal (ADR), a comprehensive Space Situational Awareness (SSA) network is required. Such networks already exist; the largest of these, however, belong to the United States and Russia and are run unilaterally and as part of defense networks. Thus the sharing of information obtained via these networks becomes difficult as it risks revealing strategic capabilities. Alternative means must be found in order to encourage the sharing of SSA data. One possible approach is the creation of a neutral international organization and network that exists solely to facilitate the collection and sharing of SSA data. The proposed network would utilize the capabilities of already existing SSA infrastructure that are not restricted by being part of a defensive network. Such a network could also be used as an alternate means for the international community to invest in the creation of new SSA systems including space based SSA facilities or further ground based infrastructure, in order to improve global SSA capabilities and facilitate information sharing. By having a neutrally run international SSA network, the current political problems with facilitating SSA data sharing can be sidestepped. For such a network and organization to be possible a number of issues need to be addressed. One of the key issues is funding. Such an organization could be funded by space faring nations and entities wishing to invest in SSA information sharing, however it would need to work on remaining neutral. Such an organization could also be commercially run, which would make it self-funding, however this may affect the extent of information sharing as not all orbital asset owner operators may be willing to pay for SSA data. Another issue is trust; space faring nations and entities may question whether they should invest or provide SSA data to an international organization. These concerns could be alleviated through a focus on transparency and input by contributing nations. This paper aims at analyzing a feasible method of internationally sharing SSA data and encouraging investments in SSA capabilities that are necessary in order to minimize the risk of orbital collisions by maximizing SSA information available to space asset owner operators. The creation of a neutral organization that operates an SSA network and catalogue could fulfill this necessity.

I. INTRODUCTION

Space Debris is a global problem, and thus requires a global solution. Orbital collisions pose a threat to all operators of orbital infrastructure, as the creation of more debris increases the risk for other spacecraft. Effective Space Situational Awareness is required to reduce this threat.

Currently, the vast majority of SSA data is collected via ground-based tracking stations that predominantly use either radar technology or optical telescopes. The present global SSA capability consists of two primary operating space surveillance networks. The Space Surveillance Network (SSN) of the United States (US) operates the largest network of sensors and has the most comprehensive catalogue of space objects [1]. There are gaps in the US coverage however, and the US catalogue is not complete. The Russian Space Surveillance System (SSS) operates the second largest space surveillance network and maintains its own catalogue of space objects [1]. In addition to these two primary operating space surveillance networks, there are a number of European sensors that are currently being integrated into a European SSA network [1]. The International Scientific Optical Network (ISON), a partnership of international scientific and academic institutions organized by the Russian Academy of Sciences in Moscow, also has a space surveillance capability [1]. Additionally, there are many amateur satellite observers loosely organized through the

Internet but capable of a non-trivial SSA contribution [1]. Private sector SSA initiatives also exist. The Space Data Association (SDA), for example, was formed in 2009 by Inmarsat, Intelsat and SES, the three largest commercial satellite companies and standardizes and compiles SSA data in a uniform and confidential format and then shares this information with its members [2].

None of the existing networks and SSA initiatives provides complete coverage or a comprehensive catalogue of all objects in orbit. The sharing of data is also limited. Presently, the US maintains the largest SSA capability and shares SSA data with non-US government affiliated entities through its SSA Sharing Program [2].

At present, no single nation or space entity possesses a complete and comprehensive catalogue and network. The creation of a comprehensive SSA catalogue by a single nation would pose challenges unless the information is shared internationally. If the SSA information is not shared with other space asset owner operators, the risk of collisions will not be reduced as much as it could if all satellite owner operators are provided with comprehensive SSA data.

Additionally, if a nation's SSA capabilities are run as part of national defense infrastructure, such as those of Russia and of the US, other nations may be less likely to contribute, out of an unwillingness to associate with a foreign military entity. The international sharing of data obtained through a nation's military infrastructure can also face opposition within that nation itself. The occurrence of this situation in the US is portrayed in a Secure World Foundation issue brief on SSA sharing, which describes how "some within the United States fear that the association between the SSA Sharing Program and the U.S. military undermines U.S. national security." [2] These factors hamper the ability of existing national military networks to be integrated into a global network, or to share the most accurate information, as doing so risks revealing sensitive defense capabilities.

It is thus necessary to create a global civil SSA network that does not primarily rely on military infrastructure and that enables worldwide data sharing. The aim of a global SSA network is to reduce the risk of future orbital collisions as much as possible. The most effective way to do this is to provide global spacecraft owners and operators with accurate situational awareness data, so that they can undertake effective collision avoidance maneuvers. Such international data sharing could be achieved through the creation of a neutral, international organization dedicated to gathering and sharing SSA data obtained primarily through civil infrastructure.

II. INSTITUTIONAL ORGANISATION

As the vast majority of SSA data is currently gathered through extensive military networks, it may seem counterintuitive to base an international SSA effort on civil infrastructure. In this regard, the space community may need to take a step back before it can successfully move forward. To avoid an ongoing clash between defense capabilities and SSA, it is important to attempt to sidestep the issue, and take the burden away from defense networks, such that the global sharing of SSA data is primarily reliant on civil networks. Defense networks can contribute information that they see fit, and maintain the right to keep their defense capabilities confidential, without this process leading to an SSA network reliant on less accurate and restricted data.

There are two major approaches that can be taken in the creation of this global organization. The proposed approaches could be run as an entirely internationally funded not for profit organization, or as a commercial venture.

II.I Internationally funded neutral organization model

One possible model would be a dedicated international SSA information sharing organization that is run with the input of all space faring nations and entities and is funded internationally. The internationally funded neutral organization (IFNO) model has the benefit of being able to focus the operation of the organization around the primary goal of effectively sharing SSA data with as many space faring organizations as possible. It would however need to structured in such a way that many nations and space organizations see the benefit of investing in the organization instead of developing their own SSA capabilities. By sharing the financial burden among multiple nations and space companies, the costs to any single space entity would be reduced, while still providing accurate SSA data. In order to entice nations to participate, the organization would need to be run transparently, and allow contributing parties to take part in the operation of the company. This could be achieved by allowing each participating entity to have a representative take part in the organization. Such an international model could also have the benefit of being provided with SSA data gathered by participating nations, as well as allow an avenue for the international investment of further civil SSA infrastructure run through the organization.

The information gathered by the IFNO model could either be available as raw data, or processed and compiled into an orbital object catalogue. Providing the international community with raw data would allow contributing nations to process the data as they see fit and would lighten the burden on the international organization. It may be preferable and more effective if the data is processed by the organization itself, in order to create a centralized extensive international debris tracking catalogue. The creation of such a catalogue could be contentious, as nations or satellite owner-operators may not want more sensitive orbital assets tracked. However, the amount of orbital debris vastly outnumbers the amount of operational, let alone sensitive, orbital assets. According to Union of Concerned Scientists, as of April 1, 2012 there are currently 999 operating satellites in orbit [3]. This number is dwarfed by the more than 21 000 human-made objects larger than ten centimeters in diameter, the 600 000 objects measuring between one and ten centimeters in diameter and the many hundreds of millions of objects smaller than one centimeter in diameter [4].

For this reason concerns about the tracking of sensitive objects should not be enough to completely reject the idea of an international catalogue of orbital objects. Various methods could be used to counteract any confidentiality concerns over the tracking of sensitive objects.

The primary solution to confidentiality concerns is to limit the type of information retained in the catalogue. Such a catalogue should only retain the essential information required to calculate the orbital path, so that the path of the object can be monitored, without giving away further details to the international community. Volatile orbital objects at risk of break-up such as used rocket bodies or larger bits of debris may need to have further pertinent information stored in the catalogue. Extra information is required on such volatile objects as it is estimated that 60 percent of the currently catalogued objects were generated from the break up or fragmentation of spacecraft and rocket bodies as the result of the explosions of leftover fuel or other reactive chemicals trapped inside [4]. Objects stored in the catalogue should then have an arbitrary reference assigned, and the position and trajectory should continue to be monitored through the catalogue.

II.II Alternate approaches to the organization of international orbital catalogues

Alternative approaches could be taken in the running of the international catalogue. It could be run as a mostly closed catalogue, whereby the catalogue is open only to the organization itself, which would then use the information to undertake conjunction assessment. The position and trajectory of any objects at risk of collision are then announced internationally. In this approach, if one of the objects involved in the potential collisions is a sensitive national or commercial asset, the operators could be informed and undertake the necessary maneuvers without revealing their affiliation with the object. Using this method, it would also be more difficult for one party to track the sensitive assets of another. One challenge of this approach would be finding a balance between allowing anonymity and promoting accountability

Another approach would be to allow spacecraft owner operators to request the tracking of specific objects. Operators that provide permission to openly have their assets tracked can do so, while those who do not want the origin of their assets revealed could avoid drawing attention to their assets by requesting positional data on numerous orbital objects. Collision warning would again be the responsibility of the proposed SSA organization. As in the previous approach, one challenge in this approach would be the lack of accountability, should a sensitive orbital asset be involved in a collision.

Finally, an open approach could be taken, where the catalogue is available to the entire space community. This approach would also involve the international SSA organization warning the community of impending collision risks. The benefits of this approach are the increased transparency and equal international footing, as well as increasing the information available, allowing satellite owner-operators to undertake their own conjunction assessment and making it more appealing for the space community to fund the global SSA organization. Such an approach would not restrict the information on sensitive orbital objects however, although only the data necessary for tracking the object would be stored. For all of these approaches, an international catalogue of orbital objects would need to be established, allowing for better international cooperation and orbital collision avoidance.

III. TECHNICAL CONSIDERATIONS

From sensor hardware and technology to data management and network architecture, in order to fully evaluate the design and implementation of a global SSA network the technical capabilities and challenges of an international SSA data gathering network need to be addressed. The following section aims to briefly outline the technical challenges that will need to be investigated to determine the technical feasibility of utilizing existing ground and space based technology, and future steps needed to establish international SSA organization.

III.I SSA Sensors

As mentioned previously, the two biggest SSA information contributors, US and Russia current use a combination of ground-based radar systems and optical telescopes for efficient surveillance of Low-Earth, Medium-Earth, and Highly Elliptical Orbits (LEO, MEO, HEO). This information produced by multiple sensor detections can be processed using several mathematical methods to calculate the orbital perturbations and element sets needed to calculate the location and reference of the tracked object [5]. To model the orbit of the debris, one has to propagate these Two-Line Elements (TLEs) and convert them into osculating elements by means of either Simplified General Perturbation theory (SGP-4) or Simplified Deep Space Perturbation theory (SDP-4) depending on the orbital time period [6]. Precise orbital elements must be known for accurate orbital calculations and collision simulations, and hence the quality, quantity, and timeliness of the metric tracking data are of great importance.

In addition, element sets may be stored in different frames of reference and be stored in various formats. In order to ensure complete orbital coverage of a global SSA system, a common astrodynamic model must be used to ensure that there is no compatibility issues between data is 'pooled' and consolidated. Though conversion between models is possible, this may lead to a decrease in accuracy [5]. Thus, without consistency between data sources, collision alerts may be subject to large errors. Accurate calibration procedures must also be utilized between sensors.

Two proposed ways to address this challenge include making the calibration procedures transparent to the global SSA system, or allowing time to recalibrate and validate sensors [6]. Furthermore, sensor tasking will be required to achieve a good tasking strategy whereby each sensor is assigned to a target. All participating sensor's capabilities and availability will have to be known by the global SSA system for the sensor tasking process.

III.II Geographical Distribution

The largest SSA sensors run by the US, Russia and Europe are situated in the Northern Hemisphere. In order to ensure a wider coverage of SSA, a more coordinated effort is needed to both SSA capability development and data sharing. The lack of geographical sensor distribution and coverage, particularly in the southern hemisphere is a growing concern. A global presence of sensors will ensure coverage of various orbital planes and enable the observation of an object in different parts of its trajectory. The efforts to -bridge the evident lack of SSA networks and infrastructure, and hence coverage in the Southern Hemisphere, has led to an increase in the number of space faring nations involved in SSA activities. A recent partnership between Australia and the US has led Australia to grow its expertise and capability in SSA through gaining access to US SSA data, training and advice [7]. Additionally, India, Japan and South Africa, among other nations also currently have or have plans in implementing sensors that are capable of SSA.

Though the addition of sensors in the Southern Hemisphere will increase the coverage in this region, it also poses a technical challenge in terms of volume of sensor observation. The SSN itself collects approximately 50 000 - 80 000 sensor observations each day [8]. Data collected from multiple sensors will potentially lead to an influx of data that requires complex and time-consuming analysis and cross-checking coordination of data by the centralized global SSA system needing significantly large computational power.

Weeden proposes that the difference between sharing observations from sensors and sharing element sets is "potentially the key decision" [5] in evaluating the feasibility of an international SSA organization. Though the sharing of observations from sensors would aid in developing accurate SSA data, the above technical challenges that have been discussed as well as political challenges that some partnering nations may face in data exchange may in fact hinder the feasibility of implementing this approach. A detailed feasibility analysis study is therefore required to assess the best approach for a global SSA system.

IV. LEGAL AND POLICY CONSIDERATIONS

This section will briefly explore a few of the major political and legal challenges associated with creating an IFNO for SSA. There are a variety of political aspects to consider when conceiving of an international civil SSA network, but this paper will limit itself to discussing the general obstacles of political priorities and foreign relations. While there seems to be a recent international consensus about the importance of debris mitigation and on-orbit safety, this does not always translate into all space faring nations and entities seeing eye to eye on the solution. The need for a neutral, global SSA body has been clearly laid out above, but even if the need is clear, not all concerned entities agree on the urgency of such a need or that it should be prioritized over other needs [9][10]. Unfortunately, in a broader geopolitical context, decisions are made in terms of trade-offs and arriving at a comprehensive and accessible SSA solution may not be a nation's highest priority. For some, preventing an arms race in space is more urgent than preventing collisions and debris creation. Further still, many countries may be far more concerned with non-space needs, such as economic development and strengthening governance. Establishing an IFNO will require commitment and dedication on the part of those involved. Many political leaders either do not value this goal enough, or value others more, to spend a great amount of their political capital to make it happen.

In addition to drumming up enough political will, there is a wider context of international relations and diplomacy to consider. Even if all States involved were able to agree on the urgent need for a global, civil SSA network, they may not be willing to see past their differences with each other to cooperate on the SSA effort. Further, in the cases where political leadership is willing to cooperate, they may be hamstrung by domestic considerations. For example, any effective international SSA solution would have to involve the United States and China, two of the largest space faring nations and owners of a significant portion of objects on orbit. However, two of the main government agencies who handle space issues, the National Aeronautics and Space Administration (NASA) and the White House Office of Science and Technology Policy (OSTP) are barred from conversing or cooperating with China by a piece of Congressional legislation [11]. This is just one example of seemingly unrelated politics that will have a direct hindering effect on an effort to establish an international, civil SSA body. There is a huge range of other political considerations, from historical precedents to linkages with other contentious issues, which will have to be accounted for as well.

Once these political hurdles are overcome, a range of legal issues will need to be resolved for the global, civil SSA network to come online. Chief among these issues are those related to protecting proprietary information, attribution of activities and events, and liability. As addressed earlier in this paper, many active satellites fulfill critical national security missions for the nations who operate or utilize them. Naturally, information about the spacecraft themselves and the functions they serve are sensitive. As such, those nations that rely upon these services desire to keep this information confidential. Similarly, the global satellite market is competitive. Individual companies will have trade secrets that give them a competitive edge, whether they are technological innovations or novel business models. An international civil SSA network would have to simultaneously protect sensitive information while enabling greater data sharing for the purposes of safer operations on orbit.

While there are likely other ways to resolve this issue of protecting proprietary information, this paper will focus on one real life solution as an example. The SDA has resolved these issues through its "black box format." As described by Rich DalBello of Intelsat General:

"Because of the proprietary nature of the operational data, the SDA has been designed to protect information and prevent members from using for commercial purposes the data supplied by competing companies. The members of the SDA contribute operational data through a secure web-based interface on a daily basis and can access data related only to the operation of their own satellites." [12]

SDA members input information about their assets, both sensitive and not, into a secure interface that automates its conjunction analysis [13]. Satellite owner-operators, who are members, only receive information back related to the safe operations of their own assets, thereby protecting other entities' proprietary information [13]. While this is simply one solution to one obstacle toward creating an international, civil SSA network, it demonstrates that sensitive SSA data can, in fact, be protected by basing data sharing on a "need to know" basis. Some of the most sensitive information in terms of national security missions, such as the capabilities, technology, and functions of a particular spacecraft, do not even factor into this level of sharing.

On a different note, this international SSA body would have to find a solution to attribution and liability issues, which are linked. These solutions would work to prevent the abuse of the central network, define indemnity in the event of abuse or collision, and outline the responsibilities of the SSA body in a range of situations. In terms of ensuring that participants do not misuse the information given to them, the SDA also provides a useful example. All SDA members agree to follow a set of strict rules about approved uses of the data they are privy to because of their membership [13]. Any infraction is met with penalties and liabilities, severe enough to deter abuse [13].

Furthermore, a substantial component of the SSA mission would be tracking debris, much of which is not identified or attributed to a single nation. If a collision occurs, somebody would have to assume responsibility for damage incurred. Without accurate identification and attribution of objects in space, this will be very difficult. Moreover, what would be the responsibility of the global, civil SSA network in that circumstance, especially if it had issued a close approach warning to the active spacecraft? The 1972 Liability Convention is vague about these issues and does not provide enough detail to guide actions in the event of a collision [14]. Presumably, a comprehensive, neutral SSA network would address some of these challenges by helping identify and attribute both active and inactive space objects, but the areas of liability would need to be fleshed out. These are all very complex legal issues that would need to be addressed in detail if an IFNO providing SSA were created.

V. FINANCING

Funding is a key issue when considering the proposal of a establishing a neutral SSA information sharing organization. This section addresses the current financial and budgetary models used for existing SSA infrastructure, and evaluates the proposal of incorporating commercial alternative for implementing an internationally funded model.

The current U.S. systems are largely funded by the US military through the Air Force research, development, test and evaluation budget line, as well as the Air Force Space Command budget and JSpOC budget [15]. For example, the US SSN is a critical part of United States Strategic Command's (USSTRATCOM) mission and involves detecting, tracking, cataloging and identifying artificial objects orbiting Earth.

The SSN is supported by the US government and is funded as part of the existing budgets for 'Space Situational Awareness Operations', 'Research and Development', as well as 'Advanced Weapons Technology'.[16]. The cost of the program in 2010 was estimated to be approximately $48 million, showing a decline in budgets over recent years [17].

While other nations and owner/operators are currently receiving SSA information provided by the US, the line with allowing selected SSA information to be shared in the 'best interest to all nations', the current service is clearly not ideal and in many ways falls short of a comprehensive SSA system. Recent bilateral agreements signed between the US and Australia, France, and Canada demonstrate that the US is taking a step toward collaborating with other nations' SSA capabilities, however this may be primarily focused on using these agreements as a basis for building new sensors in partnering countries [18]. As in the US, the development of the Russian SSS is intertwined with the development of the Russian Ballistic Missile Defense (BMD) and Ballistic Missile (BM) Early Warning systems, the development of which commenced in the late 50s [19]. From 2009 to 2011, 14% of the Russian federal budget was spent on national defense, which included space situational awareness operations for military purposes [20].

European states also view the space sector as a strategic asset "contributing to the independence, security, and prosperity of Europe." [21] Using funds from its General Budget, in November 2006, the European Space Agency (ESA) initiated three parallel industrial studies, whose main objectives were to support the compilation of an 'SSA users' needs list'. This list is established by a select group of user representatives, who translate these needs into technical requirements and design high-level architectural options in order to respond to these requirements. At the end of 2006, ESA set up an SSA users group representing the full spectrum of potential SSA user communities, including civil, military, and commercial operators, as well as national space agencies, insurance companies, and the scientific community, in order to provide guidance on the needs and of the requirements of the SSA user communities. In 2008, ESA Member States and Canada made a decision on which ongoing and new programs to implement in the European Space Policy. One issue at stake was the proposal for a preparatory program on SSA. Initially, a proposal was made for a five year program with a budget of €100 million. Previous figures even proposed budgets of up to €300 million, based on suggestions made in studies commissioned by ESA.

Following political concerns expressed by the Member States, changing viewpoints regarding space weather or near-Earth objects and given the overall financial and economical crisis, the proposal was then changed to a preparatory three year program with a budget of €55 million [22], [23], [24].

The SDA, is a non-profit organization with members in both the commercial and military sector [25]. The SDA financial model consists of 'paying for data with data'. Only those members who contribute data to the Space Data Center have the benefit of receiving the analysis of the pooled data obtained from all contributing members.

Building on current capabilities and existing infrastructure by incorporating the private space sector will provide a cost-effective solution to continue to build and to enhance SSA information collection. In recent years the commercial space industry has matured to the point where it provides a lot of opportunities to potentially reduce costs. To overcome the challenge of securing international funding for the proposal of an internationally funded SSA organization, a commercial alternative may be required in order to create a way to provide SSA data for the global space community. A commercial approach could comprise of an investment in global SSA infrastructure by a commercial entity, allowing for the 'sale' of SSA data to spacecraft owner-operators. The initial investment could be used to pay for SSA infrastructure and the raw SSA data or an orbital tracking service created though the use of the data could then be purchased by satellite owner operators. It may, however, be difficult to make a commercial approach cost effective due to the cost of the infrastructure required. For example, the first satellite in the US Space Based Surveillance Satellite (SBSS) program has an estimated program cost of $917 million [26]. By relying most heavily on technology such as satellite payload hosted SSA infrastructure, costs could be reduced in comparison to the creation of a fleet of dedicated SSA satellites. General John Campbell, Executive Vice President of Iridium's Government Program, stated in an interview that multi-payload satellite hosted SSA solutions evaluated by Iridium were typically 1/4 to 1/3 of the cost of a single SBSS satellite, showing the cost reduction made possible by using hosted solutions [27].

While commercial ventures avoid the reliance on the international community to fully subsidize their SSA network, they also risk losing their objectivity, and focusing more on the financial state of the venture, than on maximizing collision reduction through the extensive sharing of SSA data.

A neutral international SSA organization, whether commercial or internationally funded, could sidestep the issues preventing the international sharing of accurate and effective SSA data while promoting international cooperation and reducing the risk of orbital collisions for the entire space community.

VI. CONCLUSION

The approach to international cooperation and data sharing for a global SSA system discussed in this paper offers a critical approach to addressing some of the key organizational, technical and legal challenges identified in respect to implementing a neutral international SSA organization. The proposed international model may also provide a future framework for international active debris removal efforts. If neutrality and transparency is upheld, such an organization could allow space faring nations to combine efforts to remove larger and more volatile items from orbit. By making active debris removal an international collaborative undertaking, fears of the use of active debris removal technology as military anti-satellite measures could be eased, as the control over the project would not be unilateral.

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