Possible Ways Forward for the ISON Initiative and Similar Projects. A Consortium for Decentralized Sharing of SSA Data

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ABSTRACT

A core component of the ISON (International Scientific Optical Network) initiative of Keldysh Institute of Applied Mathematics of the Russian Academy of Sciences (the Keldysh Institute) is a network of optical small-aperture telescopes, which currently has about 15 sites worldwide, hosted and operated with the participation of the Keldysh Institute as well as of other domestic and foreign research and educational organizations based on agreements on scientific and technical cooperation. This approach has proven effective for the rapid development of an extensive network of geographically distributed telescopes enabling coverage of the entire GEO protected region for a relatively small investment within the realm of possibility for small-scale research projects. In addition to just gathering data on anthropogenic space objects in Earth orbit and sharing them to varying extents with partner organizations, one of the advantages is that ISON may draw institutions with different levels of expertise in the area to various modalities of mutually beneficial cooperation.

However, as described herein, ISON and ISON-like initiatives seem unable to compete in terms of performance with entities that employ a centralized and hierarchical organizational structure for obtaining data on anthropogenic space objects. Several rapidly developing private enterprises applying similar solutions for SSA in MEO, HEO and GEO based on ground-based passive optical observations but centrally managing all their observation facilities have already outperformed ISON in the number of telescopes in operation and, presumably, some of them in the amount of useful information obtained using the individual telescope of the network.

On the other hand, given the polycentric nature of outer space governance, that most likely will continue to be the case in the foreseeable future, ISON and similar projects may play an essential niche role in ensuring the long-term sustainability of outer space activities. The paper overviews the current status of the ISON initiative and related projects, and the advantages and disadvantages of such a model in the context of the rising contribution of private actors in the field of SSA.

A separate section focuses on the idea of sharing SSA data by means of a federated nodal database network within the framework of a consortium under the auspices of one of the concerned international organizations. This section addresses possible reasons that necessitate a decentralized component in sharing SSA data to increase the efficiency of outer space polycentric governance, along with common factors affecting sharing of SSA data. The given concept does not envision the consortium to be a part of ISON. Meanwhile, some of its features may resemble ISON, its implementation may bolster ISON and similar projects, and they, in return, may strengthen the consortium's position through data they provide within the framework thereof. This part of the paper also examines possible approaches to add-on services that might be provided within this data-sharing framework for facilitating inclusiveness in contributing to an SSA data pool by research and educational organizations from developing countries. Finally, this article includes draft terms of reference of the consortium in question.

1. INTRODUCTION

Problems relating to international coordination of SSA and space traffic management, in the first place, with regard to sharing of orbital data and information on planned maneuvers of anthropogenic space objects (ASOs), especially those in low Earth orbit and the geostationary region, pose a grave threat to further efforts toward the sustainable use and exploration of outer space. While there is no doubt that space technologies and various space-born services contribute significantly to the growth of the world economy, have a crucial role in achieving the UN Sustainable Development Goals, and are critical for national security objectives of countries having relevant space-related capabilities, the practice of exchange of timely and accurate data on ASOs is substantially limited owing mainly to security concerns of space-faring nations. Generally, organizations holding data on ASOs provide only selective, limited, and commercial access to SSA data unless it is their responsibility to own governments. In global terms, this leads to duplication of efforts and significant losses in the quantity of information available compared to a comprehensive combined SSA system having legitimate channels for communicating information on ASOs between different nations. The situation described may hinder access of some stakeholders in space activities to SSA data that they may need to make informed decisions and participate in improving rules of the road for outer space on an equal footing.

Commercial SSA that is now developing by leaps and bounds, as many other commercial capabilities related to space, will most likely have a positive impact on the amount of SSA data available to humanity coupled with more opportunities for data sharing through commercial contracts owing to more lax security restrictions under certain circumstances. A possible downside to the ever-increasing share of private companies in SSA, which may experience harsh competition for limited national or regional funding sources, is that they may be reluctant to share their data, technology, or knowledge with anyone except their governments and customers. That, in turn, may contribute to constructing an environment unfavorable to the inclusive sharing of data on space objects, an admittedly essential component for building a system for ensuring the long-term sustainability of outer space activities [1].

Further extensive commercialization of SSA will by no means always encourage sharing of data and technology with developing countries, even if some foreign sensors operate on their territory. On top of that, it remains unclear what mechanisms can be employed to enable potentially numerous but not advanced actors to make their SSA data broadly shared, considering that some SSA activities, e.g., ground-based passive optical observations, may have a relatively low barrier to entry by using COTS components. As a result, despite the private sector's current and possible future achievements in collecting, processing, and fusing data on ASOs, contributions of international non-profit organizations, projects, and initiatives in this regard may also be necessary for ensuring sustainable outer space activities.

2. ISON OPERATION

ISON, which stands for International Scientific Optical Network, is an initiative of the Keldysh Institute's research fellows designed as an international framework for sharing data primarily on ASOs and near-Earth objects and carrying out joint observing campaigns thereon. Following a period of closer cooperation and greater coherence of actions, several Russian organizations made a decision to develop and operate their SSA facilities and capabilities independently of the Keldysh Institute. Still, the Keldysh Institute continues to use data from almost every of about 80 electro-optical sensors feeding data to Russian civil organizations in its SSA database. This often resulted in misinterpretation of many of these telescopes as affiliated with ISON. In fact, besides sensors related to the Keldysh Institute, this number also includes electro-optical systems of Roscosmos, JSC Astronomical Research Center[1], JSC MAC Vympel[2], and others. A map showing the current location of ISON's sensors, i.e., linked to the Keldysh Institute (KIAM RAS), is in Fig. 1, including its optical telescopes, optical telescopes operated by other research and educational entities that are regularly or occasionally participating in ISON's observing campaigns.

At this point, ISON has no legal status. It is rather a framework led by the Keldysh Institute for scientific and technical cooperation, data sharing, and coordination of optical observations of objects in the near-Earth space. This, regrettably, limits the possibility of preventing other organizations from far-fetched claims to the right of solely representing ISON. However, the only example of this kind to date is a small Russian company called ISON Ballistics-Service [2], which is believed to use the name ISON to benefit from facilitating the development of Chinese SSA capabilities.

3. ISON-LIKE FRAMEWORKS

It is worth noting that ISON-like frameworks, based on scientific and technical cooperation agreements and relying on optical observations of objects in the near-Earth space, are gaining traction in recent years. These include the Chinese Asia-Pacific Ground-Based Optical Satellite Observation System (APOSOS) [3], probably the closest counterpart to ISON in terms of the operational structure, the Falcon Telescope Network of the United States Air Force Academy [4], which can provide some data sharing opportunities, the Korean Optical Wide-field patroL-Network (OWL-Net) [5] and international networks of electro-optical systems included into the European Union

[1] https://www.ancprotek.ru/
[2] https://macvympel.ru/en/

Space Surveillance and Tracking (EU SST) Support Framework. Automated small-aperture optical telescope networks offering observing time of their sensors are not given as they are not dedicated SSA frameworks.

Regardless of the advantages of the aforementioned networks in data acquisition or track II diplomacy for states that run them, potential opportunities for sharing of technology and data that these networks can provide to foreign partners may contribute to more comprehensive and inclusive monitoring of the near-Earth space. As shown below, the latter is one of the conditions necessary for efficient polycentric governance of the near-Earth space.

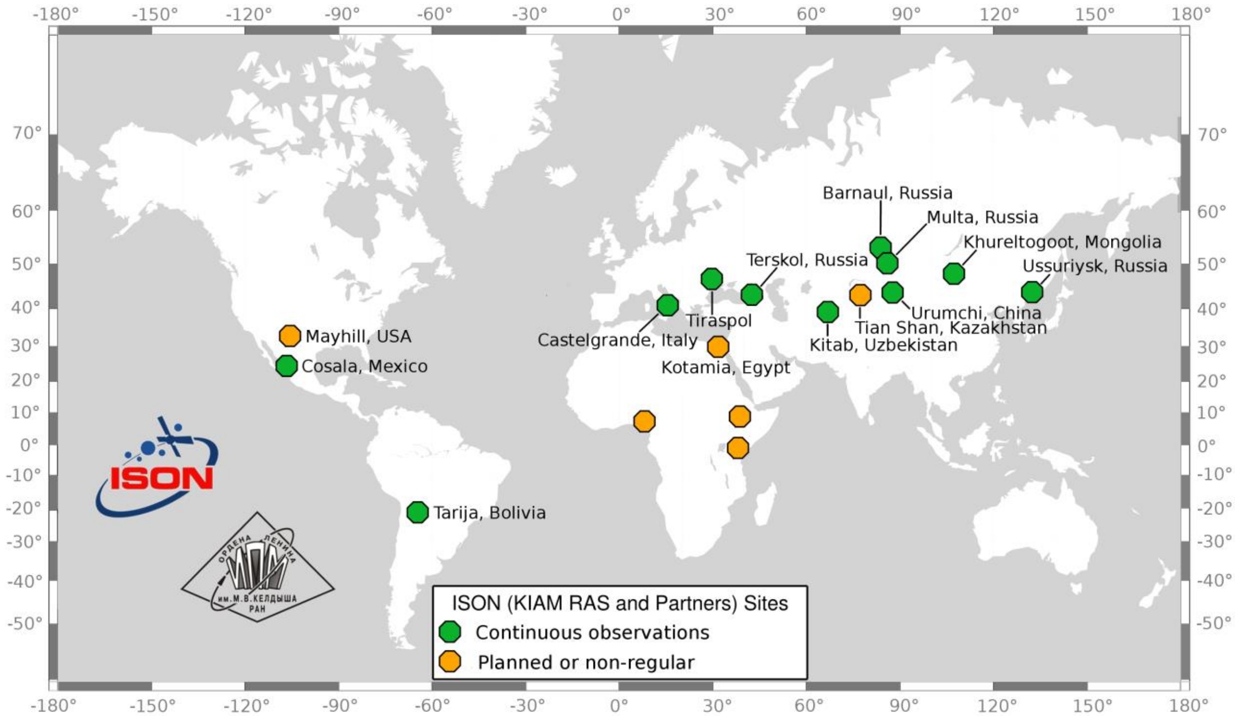

Fig. 1. Map showing the location of ISON's sites as of 2023

4. COMPARISON WITH MORE CENTRALIZED NETWORKS

In the context of this paper, "more centralized" means networks of ground-based electro-optical sensors which are single-handedly operated by one entity and its contractors without using a mechanism of agreements on scientific and technical cooperation and are leaving no room for sharing of data and technology with organizations that host equipment. Among Russian networks, those of Roscosmos and JSC Astronomical Research Center are centralized counterparts to ISON. According to internal evaluations, each of these networks was about ten times more efficient at monitoring the regions of interest (MEO, GEO, and HEO) than ISON in 2022. However, this assessment is algorithm-dependent and only partially considers changes in the catalog of ASOs. In contrast, the scheduling of observations within ISON was based on prioritizing observations of ASOs having a longer time elapsed since the last observation rather than attempting to maximize the efficiency score per se, as was the case with other networks. It is also important to note that a considerable portion of the observing time of ISON's sensors is allotted for near-Earth asteroid observing campaigns and tasks of host organizations. Either way, regardless of methods used for evaluating the performance of networks of electro-optical sensors for SSA purposes, at the moment, the networks of Roscosmos and JSC Astronomical Research Center certainly surpass ISON at least several times.

The American companies Slingshot Aerospace and ExoAnalytic Solutions currently appear to have the most advanced private SSA capabilities of their kind supported by networks of small-aperture electro-optical sensors, which can be considered centralized within the meaning of this paper. And although there is no doubt that Slingshot's network of over 150 sensors at more than 20 sites worldwide[3] and ExoAnalytic's network numbering more than 300 sensors

[3] https://slingshotaerospace.com/slingshot-vantage

operating globally at more than 30 sites[4] are far superior to ISON, more or less accurate comparisons of their efficiency are difficult to make. A lack of publicly available information about mentioned siloed systems limits the ability to model actual networks. Knowledge of many parameters, ranging from sensor specifications, their location, used catalog of ASOs and scheduling algorithms to methods for evaluating and forecasting weather conditions for observing sites, is critical for modeling and authoritative comparisons of these networks with ISON. In addition, even when comparing the performance of similar networks, it is necessary to take cognizance of slight differences in tasks to which they may be fitted.

One possible simplified performance indicator is the number of objects in the in-house catalog maintained based on proprietary data obtained by the network of sensors. As of 2022, the largest private network of ExoAnalytic Solutions provided an amount of data sufficient for getting accurate enough state vectors in its catalog for at least about 4,500 ASOs in GEO and HEO [6]. The catalog based on optical observations of Russian networks of small-aperture electro-optical sensors contained 8,000+ objects in GEO and HEO in 2022, about 4.5 thousand of which had been observed by ISON's sensors in 2022. However, it is necessary to consider that ISON's observations alone would have been insufficient to include or maintain all these objects in the catalog. Also, the scheduling of ISON's observations for tracking ASOs relied on the catalog backed not only by ISON's previous data but by other Russian networks. Using the number of cataloged ASOs for comparison of SSA capabilities is only a rough estimate as it does not account for properties of the catalog itself, including criteria for inclusion of objects, the average percentage of lost objects, uniqueness of data in the catalog compared to other sources, in particular publicly available ones like space-track.org, etc.

5. ISONSCOPE

Since 2019, the cooperation between the Keldysh Institute and the United Nations Office for Outer Space Affairs (UNOOSA) has been becoming increasingly important for ISON's development. In 2021, UNOOSA and the Keldysh Institute announced two opportunities for research and educational organizations from developing countries, each including the provision of a small-aperture electro-optical sensor suitable for SSA purposes, auxiliary equipment, related training and software. This initiative, named ISONscope, implies the implementation of multiple rounds. It is envisaged that the next round of ISONscope in the next future will comprise up to five such opportunities. An organization selected through a competition within ISONscope has up to 50 percent of a sensor's observing time for its scientific, educational and outreach purposes, not necessarily associated with SSA. The remaining portion of a sensor's time is designated for ISON's observing campaigns, mainly related to SSA. Using provided sensors for SSA observations is driven not only by the Keldysh Institute's interest in new data sources but also by the idea that participation in these observations can spur the host organization and its government to be more involved in the near-Earth space monitoring. This is a win-win situation more than just for parties to ISONscope but from the perspective of outer space polycentric governance also for all space actors, especially if the selected organization's nation is already a participant in outer space activities or a participant of international space fora, including the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS). In the same way as within ISON, organizations that host sensors provided within ISONscope are supposed to be directly engaged in their operation and processing of their data. Currently, the Keldysh Institute is working toward developing a standardized design of an automated telescope pavilion to streamline the technical harmonization of pavilions with organizations to be selected at the next rounds of ISONscope.

6. CONSORTIUM FOR DECENTRALIZED DATA SHARING

6.1 DECENTRALIZED DATA SHARING AND POLYCENTRIC GOVERNANCE

The existing body of international legally-binding treaties governing activities in outer space provides an insufficient framework to curb the space debris problem [7][8]. Although drawing up and concluding a new foundational treaty for space activities may improve the situation, it will probably take decades [9]. At the same time, a comprehensive international body responsible for space traffic management and sharing SSA information seems hardly feasible in the foreseeable future, owing primarily to mistrust and security concerns among the main space actors and the competing interests of many. In contrast, calls for decisive actions concerning space debris mitigation, including establishing data-sharing mechanisms for the long-term sustainability of space activities, are reflected in various non-

[4] https://exoanalytic.com/space-domain-awareness/

binding documents [1][10]. As highlighted in [11], the way to ensure both accurate and precise SSA information is "aggregating, curating, and fusing massive quantities of disparate and independent observations," which in turn are required to "inform meaningful space policies, rules, regulations, and norms of behavior."

Efforts to agree on a platform for inclusive sharing of data on ASOs, or at least for discussion of this matter, within the UN COPUOS [12][13] were unsuccessful, most likely due to the related complexities and consensus-based nature of the forum. However, internationally recognized concerned organizations, including UNOOSA, can potentially implement a framework for sharing data on ASOs as a part of one of their projects.

A centralized approach successfully implemented by the Minor Planet Center[5] of the International Astronomical Union for receipt and distribution largely of data on minor planets and comets would likely be challenging to apply to ASOs in the near term due to the aforementioned factors. A more forward-looking model of a framework for sharing SSA data is the International GNSS Service (IGS)[6] of the International Association of Geodesy, providing online access to products related to operational global navigation satellite systems (GNSS). IGS makes data from its data centers, voluntarily maintained by various independent organizations, available to the public. In addition to providing access to their certain GNSS products, IGS's approved data centers are required to "backup and secure their holdings of IGS data and products, exchanging data between other data centers in order to ensure equalization of data holdings."[7] IGS, supporting sharing of GNSS-related data, including precise GNSS satellite ephemerides, positions and velocities of GNSS ground-based stations, and Earth orientation parameters, contributes to greater accuracy of data of the world's leading centers in the field, many of which maintain an IGS's data center, and forms the foundation for solving numerous research and applied tasks.

Apparently, in order to overcome initial resistance to the idea of an international framework for SSA data sharing, its implementation should imply decentralization, simplicity and transparency, a minimum level of international harmonization, the lowest possible barriers to entry, and the non-use of multi-tier access to data. All of these are prerequisites for bringing more stakeholders, including organizations from China and Russia.

An approach to decentralized sharing of SSA data proposed in [14] with the use of a permissioned blockchain and different data access levels depending on the data consumer, according to the paper, can simultaneously help effectively manage cyber security threats and establish an ecosystem for international data-sharing trusted by most stakeholders. The concept of a permissioned blockchain limits who can participate in its activities and typically implies the presence of the administrator controlled by the governing authority. Although the level of decentralization of a permissioned blockchain can be changed by its governing body, it is still limited. This problem of lack of transparency is usually resolved by the trust in the governing body, which, however, may be difficult to achieve for comprehensive international SSA data sharing, even if the governing body is a steering committee representing all the members of a permissioned blockchain, as critical software would likely be developed and managed only by some entities.

Employing the approach described in [14] seems more promising in cases where greater commitment and trust are already developed among partners than between some of the main space actors today. A framework built on these principles would probably be a useful mechanism when it comes to limited access to national security sensitive information and protection of proprietary rights, which makes it better suited to, for instance, a system composed of organizations from the US and its allies rather than for comprehensive international sharing of SSA data. However, a framework based on a permissioned blockchain can leave many potential members behind as a result of its inherent limitations, possible entry thresholds, and potential difficulties in reaching a consensus on its modus operandi.

Aside from being a hurdle to the participation of a certain portion of organizations, especially from developing countries, a high threshold for entering a framework for sharing SSA data can disincentivize the development of SSA capabilities in some countries. Many states do not prioritize SSA, as do space-faring nations, due to its less critical role in national security policies and fewer space assets. In such countries, activities related to SSA are carried out primarily by research and educational organizations, which may substantially limit resources allocated for regular monitoring of the near-Earth space and cataloging ASOs. According to ISON's experience, in these cases,

[5] https://minorplanetcenter.net/
[6] https://igs.org/
[7] https://igs.org/data-access/#definitions

governments would likely not be interested even in data obtained within national territories in cooperation with organizations from their countries.

Several authors have recently proposed applying the principles of the Nobel laureate Elinor Ostrom to the governance of the near-Earth space under the assumption that it can be considered a common-pool resource (CPR), a resource that is both non-excludable and rivalrous [7][15][16][17][18]. Two of the eight elements suggested by E. Ostrom for managing CPRs based on examples of successful practices imply the participation of most entities affected by the operational rules in their modification and the participation of appropriators of the CPR in monitoring its conditions and behavior of other appropriators [19].

At the same time, according to E. Ostrom, polycentric systems, meaning multiple governing authorities at differing scales, can be more effective for the governance of global commons than centralized structures in terms of sustainability [20]. This polycentric approach is already playing a significant role in the governance of outer space, which is commonly regarded as a global commons. It can also be used for further improvement of this governance [7][18]. Polycentric systems "favor the experimentation of different approaches, which generate learning and innovation," thereby providing flexibility and mechanisms for self-correction and incremental evolution necessary for the governance of the near-Earth space [7], characterized by rapid changes, multiple actors, and uncertain information on ASOs. As summarized in [21], "Ostrom's principles indicate that for maximum effectiveness, the monitoring of the CPR should be done by the resource appropriators themselves. This indicates that rather than push for a single nation or international entity to provide SSA to all space actors, efforts should instead focus on increasing SSA capabilities among and data sharing between many space actors. This allows many space actors to verify at least some of the activities in space using their own capabilities, leading to greater overall trust." In this way, comprehensive sharing of SSA information, beyond building trust among the main space actors, can inform the work of a greater number of nations on developing norms of behavior in outer space and thus reinforce the commitment of these nations to their fulfillment.

Polycentric governance and Ostrom's principles for CPRs are not a panacea, a new legally-binding space treaty and an international body for space traffic management would significantly improve the situation, but at this moment, adherence to the proposed principles appears promising for space debris mitigation. The growth of ISON-like frameworks based on agreements on scientific and technical cooperation will most likely foster sharing of SSA data and technology, thereby creating preconditions for developing independent SSA capabilities of various states. Nevertheless, establishing an appropriate fully-fledged inclusive international online platform seems necessary to allow better sharing of SSA data among organizations from both space-faring and emerging space nations. As noted in [22] in the context of polycentric governance of outer space, "With some reservations, lower levels of governance will be more equipped to oversee domains with low barriers to entry, as they are more agile," which can be applied to the monitoring of the near-Earth space, particularly with the use of passive optical observations based on COTS components, and to sharing of related data. Besides the importance of the proposed platform for increasing the total amount of available SSA data by reducing duplication of efforts, it can also ensure non-discriminatory access of all interested organizations to a common data pool. This, in turn, should lead to more effective monitoring of the near-Earth space and the behavior of its appropriators by other appropriators, a critical component of sustainable governance of a CPR under Ostrom's principles. On the other hand, the idea of a permissioned blockchain discussed in [14], which suggests that access to SSA information provided to eligible members has to be limited to a necessary minimum, would likely weaken the foundation for innovative and adaptive practices needed for the near-Earth space governance.

Summing up, establishing the discussed online platform for SSA data sharing, which makes its data widely available, looks promising for sustainable governance from the perspective of Ostrom's principles. In order to build trust, it can be coordinated by one of the concerned international organizations and employ a decentralized file storage system. The platform is unlikely to be sufficient for meaningful space domain awareness. But it can provide a framework for cooperation development, and its data can serve as a sandbox for various scientific and commercial projects, including projects of organizations from developing countries. The platform can reduce the uncertainty of information on ASOs, contribute to creating data fusion products and to developing of various add-on services. In addition, this platform could support the development of SSA capabilities of different nations by providing free services, e.g., on-demand observation planning based on available information on ASOs to increase the value of observations performed by interested organizations.

Although data repositories of various organizations voluntarily providing access to them through the platform would likely require validation, submission of data on ASOs through the platform should be subject to minimal barriers. Data of the platform may, among other things, include orbital and photometric data and information on planned activities and possible events (launches, maneuvers, orbit insertions, rendezvous and proximity operations, fragmentations, re-entries, etc.). At the initial stage of the platform's development, sharing mainly limited to data on space debris objects and data of some private operators on their active satellites appears to be the most realistic. To facilitate the implementation of the platform, it could utilize existing or proposed data formats such as Tracking Data Message (TDM) and Orbit Data Messages (ODM) of the Consultative Committee for Space Data Systems (CCSDS) [23][24], additions to TDM suggested by the Inter-Agency Space Debris Coordination Committee (IADC) [25], the Electro-Optical Space Situational Awareness (EOSSA) format developed by Applied Optimization [26], and others. A proposal for draft terms of reference of a consortium responsible for developing and administrating such a platform is presented below.

6.2 PROPOSED TERMS OF REFERENCE OF THE CONSORTIUM

Given the above, it is assumed that interested organizations (hereinafter referred to as "the Members") may agree to develop a consortium for sharing data on ASOs (hereinafter referred to as "the Consortium") for sharing SSA data, including but not limited to orbital data. The Members can work toward promoting the Consortium to attract new members and increase the amount of data regularly coming to repositories related to the Consortium and available to the public through their own efforts and by means of international fora. An implementation of the Consortium may be based on the following principles.

1. The Members shall create and coordinate a federated nodal database network (hereinafter referred to as "FNDN") that consists of nodes, which shall be responsible for collection, storage, processing, and provision of data on ASOs, and means for synchronizing data between nodes and provision of data of all nodes to the public. Each node affiliated with one of the Members shall develop and maintain its own database on ASOs (hereinafter referred to as "Nodal Database") available to other nodes and to the public through FNDN. Data available on various ASOs may differ for different Nodal Databases depending on data and methods nodes use for processing and deriving aggregated data. Nodal Databases of the Members may contain both their own data and merged/fused weighted data of other Nodal Databases.
2. Data on ASOs within FNDN shall mainly include precise, accurate, and regularly updated orbital data on space debris objects in Earth's orbit to help address the Members' possible national security and proprietary concerns related to sharing data on ASOs. The Members shall seek opportunities to maximize the total number of ASOs within FNDN having precise and accurate orbital data. If some of the Members deem it appropriate, they may also incorporate their data on active ASOs, including information on planned maneuvers thereof, photometric measurements of ASOs, etc., into their Nodal Databases.
3. Sharing data on ASOs within FNDN and their provision to the public shall be carried out using software developed and maintained under the auspices of a concerned international organization (hereinafter referred to as "IO"). This software shall include an online platform (hereinafter referred to as "the Online Platform") providing the Members and the public both API (application programming interface) and UI (user interface) access to all Nodal Databases of FNDN as well as enabling submission of data on ASOs to FNDN by the Members and third parties. In addition, the Online Platform may provide a free service of automated planning of optical observations of ASOs to third parties based on their input information (observing conditions, technical specifications of their observing facilities, etc.) and taking into account the current priority assigned to each ASO within FNDN.
4. The Consortium has no legal status and is based on non-legally binding statements of intent of the Members that follow these principles. To facilitate the promotion and implementation of the goals and targets of the Consortium, in particular collection, processing, storage, and provision of data on ASOs, development and maintenance of Nodal Databases and the Online Platform, IO and the Members shall allocate in accordance with their resources appropriate financial and other means, engage their staff members taking into account their expertise and experience in related fields as well as the scope of their ongoing projects. The Members, if they deem it appropriate, may receive additional resources from public, commercial, and private funders to promote and implement the goals and targets of the Consortium.
5. To facilitate the promotion of the Consortium's activities, establishment (or engagement) and operation of a relevant non-profit organization might be needed.
6. A Steering Committee and a Technical Committee of the Consortium shall be responsible for overseeing and administrating the work of the Consortium. Compliance with recommendations of the Steering Committee and the Technical Committee, similar to participation in the Consortium, shall be voluntary for the Members. The

Steering Committee shall determine the composition and competence of the Technical Committee. The Members shall determine the composition and competence of the Steering Committee. Both the Steering Committee and the Technical Committee should include representatives of IO. The Steering Committee shall admit new members to the Consortium based on their statements of intent.

7. The Steering Committee and the Technical Committee shall develop and implement a mechanism to validate compliance of Nodal Databases with agreed minimum requirements prior to making their data available through the Online Platform.
8. The Members shall use data on ASOs under their control for their Nodal Databases with due regard to national security constraints and rights of third parties.
9. The Members, any third-party organizations, and individuals should be able to provide their observation data on ASOs to FNDN through the Online Platform using dedicated interfaces and agreed formats. If the Members deem it appropriate according to their own criteria, they may use these data to improve their Nodal Databases.
10. The Online Platform shall promptly provide the Members, third-party organizations, and individuals who submitted their data with records of receipt. These records should be issued even if an error occurs, containing error information in this case.
11. If necessary, the Steering Committee, the Technical Committee, and the Members shall develop methods of accessing supplementary data of the Members falling within the scope of the Consortium with due regard to proprietary rights and security limitations. This should facilitate interaction between providers and users of data and contribute to research activities and innovations among data users.
12. The Steering Committee, the Technical Committee, and the Members shall develop and apply mechanisms to protect all valuable data and information of FNDN against unauthorized access and various contingencies.
13. The Steering Committee, the Technical Committee, and the Members shall develop a standard mechanism to track SSA data changes over time. The Members are encouraged to use this mechanism, where appropriate, or their own mechanisms to track data changes within FNDN.
14. The Members are encouraged to promote the use of data available through the Online Platform by national entities as well as internationally.
15. The Steering Committee and the Technical Committee shall agree on protocols and data formats that are recommended to use within FNDN. If necessary, the Steering Committee and the Technical Committee shall improve existing data formats relevant to FNDN or develop new ones. In this regard, due consideration should be given to the recommendations of the Consultative Committee for Space Data Systems, related fundamental documents of international fora, and national norms and standards of states of the Members. IO shall seek to implement agreed protocols and data formats in the Online Platform under its oversight and administration. The Members shall seek to use these protocols and data formats in their Nodal Databases.
16. The Members agree to define and use common terms and concepts to simplify and ensure consistency of the Consortium's activities.
17. The Members shall seek to retain all data on ASOs coming into their Nodal Databases for a period of at least three years for scientific and applied purposes as well as to increase the efficiency of data collection and processing.
18. The Members shall seek to follow promising software solutions that may be used for the purposes of the Consortium.
19. The Steering Committee shall seek to identify and meet the needs of diverse groups of users of SSA data available through the Online Platform.
20. The Members are encouraged to seek opportunities to provide to third parties that contribute significantly to FNDN or intend to do so, especially to scientific and educational organizations from developing countries, technical assistance, training, and software to enable optical observations of ASOs and related data processing.
21. The Steering Committee and the Technical Committee may develop a one-size-fits-all approach to assess the current contribution of each party to an SSA data pool of FNDN. The Members and IO may conduct such an assessment using this approach and make its results available to the public.
22. The Steering Committee and the Members shall seek opportunities to provide information on the Consortium's activities to the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS) and its Scientific and Technical Subcommittee through delegations of the Members' nations and international organizations with observer status.

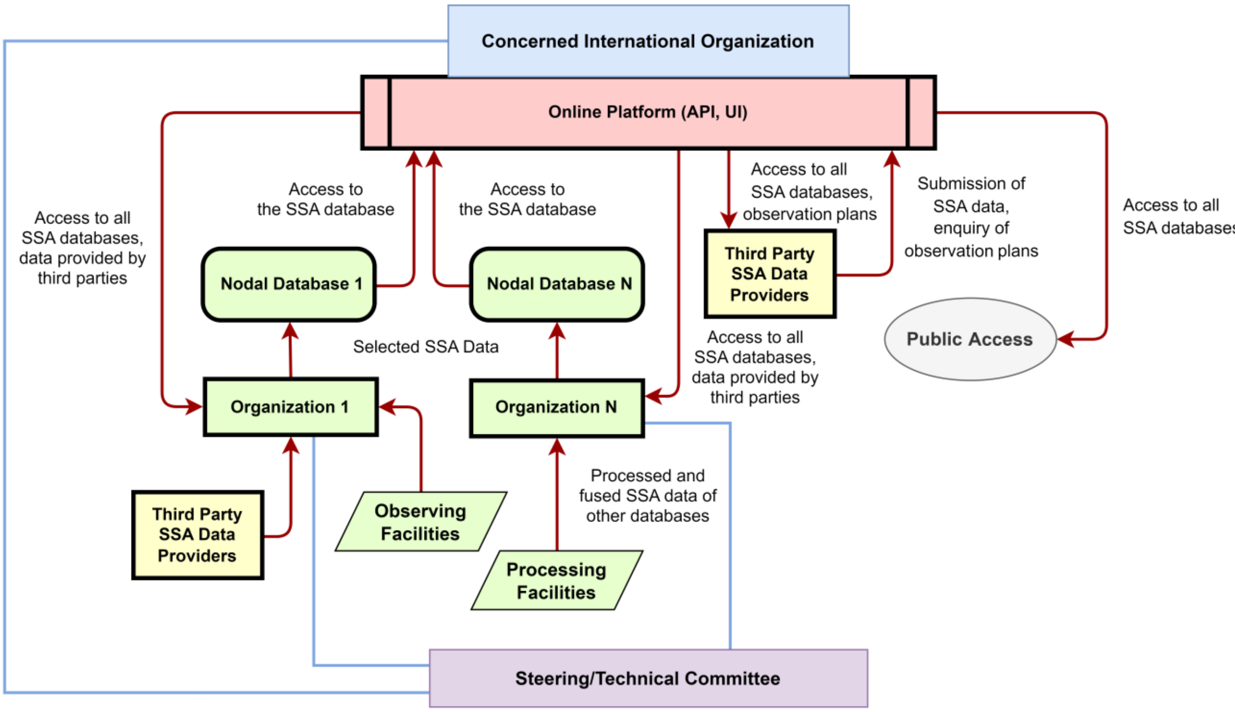

Fig. 2. Simplified operational structure of the Consortium

6.3 POSSIBLE POSITIVE IMPACT OF THE CONSORTIUM

The following is a non-exhaustive list of potential benefits of successful implementation of the goals and targets of the Consortium.

1. The Consortium may provide existing and potential space actors with additional SSA capabilities to support their participation in relevant international fora and to inform their work on developing policies, rules, and regulations governing space activities.
2. The Consortium may facilitate equitable access of all nations to SSA data.
3. The Consortium may contribute to confidence building and greater transparency in outer space activities.
4. The Consortium may increase the amount of information on ASOs available to all nations by avoiding duplication of some efforts to detect and monitor ASOs.
5. The Consortium may increase public interest in the space debris problem, SSA, and, overall, in preserving the long-term use of outer space.
6. The Consortium may draw various organizations and individuals by making it possible for them to contribute to SSA.
7. The Online Platform of the Consortium may serve as a recognized test data source for various SSA applications.
8. The Consortium may enhance the public value of SSA activities.
9. The Consortium may foster the growth of scientific and educational projects and start-ups related to SSA, especially in developing countries.

7. CONCLUSIONS

The paper presents an overview of the current state of the ISON initiative and its brief comparison with similar projects. Although the author recognizes the need to conduct a quantitative performance comparison of ISON with other networks of small-aperture optical telescopes by various parameters based on their numerical models within some assumptions and limitations, this appears to be challenging due to the scarcity of publicly available information. This problem was not the main focus of this paper, but more in-depth analysis in this regard is foreseen in the future.

As shown above, despite the possible greater efficiency of more centralized networks of electro-optical sensors, including networks of private companies, in obtaining SSA data, ISON-like frameworks, implying a potential for data and technology sharing in addition to their intended purpose, can make a unique contribution to polycentric governance of the near-Earth space and thus to the sustainability of outer space activities as a whole.

Decentralized sharing of SSA data may be a useful instrument to ensure effective governance of the near-Earth space in the foreseeable future, while it still remains insufficiently developed to date. The paper proposes the idea of an online platform coordinated by one of the concerned international organizations and backed by a dedicated consortium of organizations participating in the platform. The presented draft concept of this consortium is not final and likely to be modified, including in order to harmonize it with other similar proposals.

REFERENCES

[1] United Nations Office for Outer Space Affairs. *Guidelines for the Long-term Sustainability of Outer Space Activities of the Committee on the Peaceful Uses of Outer Space*, 2021. [Online]. Available: https://spacesustainability.unoosa.org/sites/spacesustainability.unoosa.org/files/21-02562_lts_ebook_english_june2021.pdf.

[2] I. Molotov. New status of the ISON project and results of space debris optical monitoring, *44th COSPAR Scientific Assembly*. *Abstract PEDAS.1-0002-22*, 2022. [Online]. Available: https://ui.adsabs.harvard.edu/abs/2022cosp...44.3143M/abstract.

[3] Xiaozhong Guo, Pengqi Gao, Ming Shen, et al. Introduction to APOSOS project: 15 cm aperture electro-optical telescopes to track space objects, *Advances in Space Research,* Volume 65, Issue 8, 2020.

[4] Francis K. Chun, Roger D. Tippets, David M. Strong, et al. A New Global Array of Optical Telescopes: The Falcon Telescope Network, *Publications of the Astronomical Society of the Pacific*, Volume 130, Number 991, 2018.

[5] Jang-Hyun Park, Young-Jun Choi, Jung Hyun Jo, et al. Korean Space Situational Awareness Program: OWL Network, *Proceedings of the Advanced Maui Optical and Space Surveillance Technologies Conference (AMOS),* 2012.

[6] C. Ingram, J. Bishop, P. Cunio, et al. ExoALERT: 1 Year of AI-Enabled Space Traffic Management Services at GEO, *Proceedings of the Advanced Maui Optical and Space Surveillance Technologies Conference (AMOS),* 2022.

[7] Jean-Frédéric Morin and Benjamin Richard. Astro-Environmentalism: Towards a Polycentric Governance of Space Debris, *Global Policy*, Volume 12, Issue 4, 2021.

[8] L. D. Roberts. Addressing the Problem of Orbital Space Debris: Combining International Regulatory and Liability Regimes, *Boston College International and Comparative Law Review*, 15 (1), 1992.

[9] Clementine G. Starling, Mark J. Massa, Christopher P. Mulder, et al. *The Future of Security in Space: A Thirty-Year US Strategy*, Atlantic Council, 2021.

[10] World Economic Forum. *Space Industry Debris Mitigation Recommendations*, 2023.

[11] Moriba K. Jah. Space Situational Awareness: Guiding the Transition to a Civil Capability, *Statement to the Committee on Science, Space, and Technology, Subcommittee on Space and Aeronautics,* U. S. House of Representatives, *2022.*

[12] Proposal by the United States of America for an expert group on space objects and events. *Working paper submitted by the United States of America*, UN COPUOS, STSC, 53rd session, A/AC.105/C.1/L.347, 2016.

[13] Considerations on the set of prime requirements and factors that should shape the policy of international information-sharing serving safety of space operations. *Working paper submitted by the Russian Federation*, UN COPUOS, 59th session, A/AC.105/L.303, 2016.

[14] H. Reed, R. Stilwell, B. Weeden, et al. Sharing Operational Risk Information in the Space Domain to Facilitate Norms Development and Compliance Monitoring, *Proceedings of the Advanced Maui Optical and Space Surveillance Technologies Conference (AMOS),* 2022.

[15] B. Weeden and T. Chow. Developing a Framework and Potential Policies for Space Sustainability Based on Sustainable Management of Common-Pool Resources, *Proceedings of the International Astronautical Congress*, 2011.

[16] J. Johnson-Freese, B. Weeden. Application of Ostrom's Principles for Sustainable Governance of Common-Pool Resources to Near-Earth Orbit, *Global Policy*, Volume 3, Issue 1, 2012.

[17] E Tepper. Applying Ostrom's Nobel Winning Study to International Cooperation in Space Activities, *Proceedings of the International Institute of Space Law*, 675–686, 2014.

[18] R. Zhang, A. Balakrishnan. From Ozone Depletion to Orbital Debris: Lessons Learned from the Montreal Protocol, *Proceedings of the Advanced Maui Optical and Space Surveillance Technologies Conference (AMOS),* 2022.

[19] E. Ostrom. *Governing the Commons*. Cambridge University Press, 1990.
[20] E. Ostrom. Polycentric Systems for Coping with Collective Action and Global Environmental Change, *Global Environmental Change*, Volume 20, Issue 4, 550–557, 2010.
[21] B. Weeden. The economics of space sustainability, *The Space Review*, 2012. [Online]. Available: https://www.thespacereview.com/article/2093/2.
[22] C. Oto. Polycentricity and Space Governance, *Secure World Foundation Space Sustainability Briefs*, 2022/2, 2022.
[23] *Tracking Data Message*, Recommendation for Space Data System Standards (Blue Book), CCSDS 503.0-B-2, Issue 2, CCSDS, 2020.
[24] *Orbit Data Messages*, Recommendation for Space Data System Standards (Blue Book), CCSDS 502.0-B-2, Issue 2, CCSDS, 2009.
[25] *Recommendation for the optical observations data exchange format*, IADC, 2023. [Online]. Available: https://www.iadc-home.org/documents_public/file_down/id/5588.
[26] *Electro-Optical Space Situational Awareness (EOSSA)*, File Format Description Document, Version 3.1.1, Release 4, Applied Optimization, 2021. [Online]. Available: https://amostech.com/TechnicalPapers/2021/EOSSA_File_Specification_v3.1.1_release4_DistroA.pdf.