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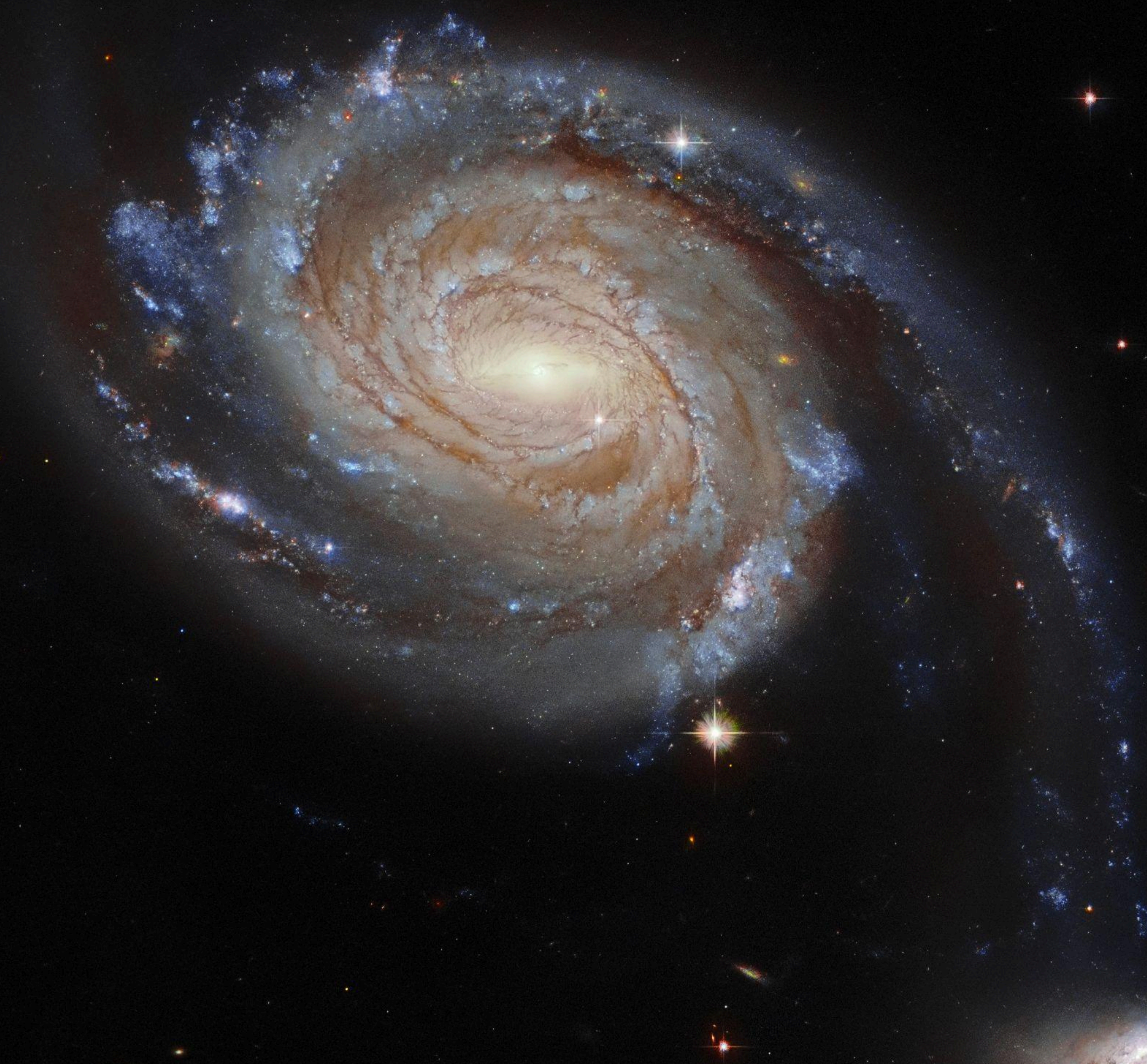

MARCH 2024

COSMIC CONDUCT

CONSTRUCTING *a* FRAMEWORK *for* RESPONSIBLE SPACE BEHAVIOR

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EXECUTIVE SUMMARY

Earth orbit is more crowded than ever with satellites and debris. Dead satellites, clusters of active satellites, and large-scale incidents, such as China's 2007 antisatellite test and a 2009 accidental collision between US and Russian satellites, have increased debris in low Earth orbit by 70% (NASA, 2023). The increase in activity and technology over the 67 years of space flight has not corresponded with strengthened regulations governing responsible behavior in space. This poses a serious risk to future operations because the lack of visibility, increased space traffic, and unclear guidelines dictating responsible interaction between space programs and debris mitigation make operating in space increasingly challenging. If nothing is done to establish rules and guidelines for responsible behavior, space could become unusable in the near future. Humanity's use of space is not just long-term space exploration or scientific discovery. Space impacts everyday life. Everything from using GPS to your credit card depends upon satellites in space, so the inability to use space would have far-reaching civilian and security implications.

This study was conducted for the Space Security Defense Program out of the Department of Defense to propose solutions for defining and establishing responsible behavior in space. One way to establish a ubiquitous definition of responsible behavior in space is for the US to establish its own criteria, incorporate norms, and begin to develop a framework for evaluating its own behavior in space. The US can obtain international buy-in by creating a framework, eventually reaching a saturation point, where the norms become laws.

<u>Alternatives, Criteria, and Evaluation</u>

To help define responsible behavior, the US can contribute to the conversation by creating a framework to evaluate its own space missions before soliciting international cooperation. For any framework to establish norms effectively, it should be objective, transparent, specific, and include international cooperation (Harrison, n.d.). Two current frameworks exist to evaluate responsible behavior: David Lindgren's "Assessment Framework for Compliance with International Space Law and Norms" and the Space Sustainability Rating (SSR). To add a third consideration, the author created a new framework called the Objective and Responsible Behavior Indicator for Transparency, or ORBIT. These frameworks incorporate elements of current frameworks to establish responsible behavior, such as the Freedom of the World rating, the Mediterranean Action Plan, and the Antarctic Treaty. The three proposed solutions to SSDP's problem were evaluated using the requirements of objectivity, transparency, specificity, and international cooperation. These requirements were incorporated into the criteria of cost-effectiveness, political feasibility, and information & transparency.

Lindgren's framework uses predominantly qualitative questions to evaluate each country's space laws and compliance with legally binding international agreements. However, these agreements are limited in scope and do not incorporate current debris mitigation and collision avoidance norms. SSR incorporates more recent norms surrounding debris mitigation and quantitative measurements for mission sustainability. This framework incorporates international agreements and international cooperation in its creation. ORBIT takes elements from both frameworks and incorporates additional norms missing from each. ORBIT also streamlines the evaluation process for maximum transparency and implementation.

Recommendation and Implementation

Lindgren's framework scored lower than SSR and ORBIT across the board. While SSR had the same score as ORBIT, SSDP is recommended to pursue ORBIT as its framework. While SSR might be more effective in the short term as it is already established, ORBIT's effectiveness will increase over time as additional norms are incorporated into the framework critical for long-term space sustainability measures. ORBIT is also preferred because it simplifies the overall scoring system, making it a more digestible and transparent framework.

ORBIT is designed not to be a final product but a starting point for discussion surrounding defining responsibility in space. To implement ORBIT, it is recommended that the DOD create a task force and work alongside US government agencies involved in regulating space to solicit framework feedback and collect the data required to evaluate US space missions. After the task force refines and begins to implement the framework, they are recommended to work with international partners to further refine and collect data from international space programs. For increased trust and greater international buy-in, the framework will need to move into a civilian governing agency instead of the DOD. Once this is completed, the framework can be implemented by civilian agencies and organizations across the globe.

Conclusion

As objects in space increase rapidly, international agreements on what constitutes responsible behavior in space have not kept pace. To prevent collisions and an increase in debris, it is recommended that SSDP construct a framework on what they believe is responsible behavior to lead the conversation about space norms. While ORBIT is not a perfect solution, it is a jumping-off point for defining and evaluating responsible space behavior. By implementing ORBIT, SSDP can create a more sustainable and safe space environment for future generations.

ACKNOWLEDGMENTS
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DISCLAIMER
The author conducted this study as part of the program of professional education at the Frank Batten School of Leadership and Public Policy, University of Virginia. This paper is submitted in partial fulfillment of the course requirements for the Master of Public Policy degree. The judgments and conclusions are solely those of the author, are not necessarily endorsed by the Batten School, by the University of Virginia, or by any other agency.

HONOR STATEMENT
On my honor as a student, I have neither given nor received unauthorized aid on this assignment.

Cover photograph: NASA Hubble Space Telescope

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Glossary

Abbreviation	Meaning
ASAT	Antisatellite
DOD	Department of Defense
DOS	Department of State
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
GEO	Geostationary orbit: altitude of 35,786 km above the equator
LEO	Low Earth orbit: between 1000-160 km above the earth
MEO	Medium Earth orbit: between LEO and GEO
NPT	Treaty on the Non-Proliferation of Nuclear Weapons
ORBIT	Objective and Responsible Behavior Indicator for Transparency
OSC	Office of Space Commerce in the Department of Commerce and the National Oceanic and Atmospheric Administration
SSA	Space Situational Awareness
SSDP	Space Security and Defense Program
SSR	Space Sustainability Rating
UN	The United Nations

Client Overview

This analysis was conducted for the Space Situational Awareness (SSA) Initiative with the Space Security and Defense Program (SSDP) under the Department of Defense’s (DOD) National Security Innovation Network. SSDP works with students nationwide to tackle prevalent issues regarding SSA and help inform future US space policy. As space becomes more crowded and adversaries begin to develop new space technologies, SSDP is interested in understanding how responsible the US government and companies behave in space in relation to foreign space programs.

As the understanding of how behavior impacts long-term space sustainability rapidly changes, the US government has not provided enough guidance to the six executive departments' jurisdiction over certain space policy requirements. For example, the Federal Communications Commission, tasked with regulating satellite radio frequencies, has chosen to enforce space debris mitigation plans to fill a gap in regulatory authority (Federal Communications Commission, 2004) (Space Foundation, n.d.). As the previous owner of SSA, the DOD has a unique opportunity to begin the conversation surrounding responsible behavior in space to understand the US and adversary behavior, even if the ultimate implementation will be conducted by a non-military department. This research is meant to inform policymakers in the DOD about possible options for defining and enforcing responsible behavior in space.

Introduction

Space, often called the "final frontier," is not as limitless as we would expect, especially in Earth orbit, the most popular of which are low Earth orbit (LEO), medium Earth orbit (MEO), and geosynchronous orbit (GEO). There are several challenges to sustainability in outer space, including space junk, orbital crowding, and space security. As more countries and companies send objects into orbit, managing sustainability and ensuring that space objects do not conjunct becomes increasingly important and challenging. This paper will evaluate different methods of establishing guidelines for behavior in space that will reduce collisions, identify irresponsible behavior, and help establish a cooperative environment to ensure future generations can utilize space.

Problem Definition

As the number of objects in space has increased from 210 to 2,664 (1,168%) since 2013, international law has not kept pace with the increased activity in space (Our World in Data, 2024). This has led to a gap in understanding what constitutes responsible behavior in space.

The increased number of objects in space, a lack of ability to track space objects, inadequate data sharing, and no established norms governing responsible behavior increase the risk of Kessler's syndrome, where cascading collisions of space debris render Earth orbits unusable (Combs, 2024). With the last legally binding agreement governing responsible behavior in 1975 (McClintock et al., 2020), space-faring countries struggle to establish norms defining responsible behavior and hold each other accountable for irresponsible behavior in space. The question remains: how should the US objectively and transparently define responsible behavior in space to hold itself accountable and begin to work towards developing international space norms?

Background

The number of objects in space has rapidly increased, outpacing international regulation. As countries and companies send more objects into space, the lack of visibility, data sharing, and norms establishing responsible behavior heightens the risk of collision. 96% of all objects in space are untracked, and in 2017, the US made 655 emergency calls to space agencies worldwide warning of imminent collisions (Pace & Baiocchi, 2020). As the OSC works on addressing issues with tracking by creating an SSA interface with international and domestic partners, a lack of norms and standards surrounding responsible behavior, including how satellites should avoid collisions, how data should be shared, and how debris should be handled, remains (Office of Space Commerce, n.d.).

As of March 2024, there are 9,494 active satellites in Earth orbit, and the debris created from this increased activity has only grown (see Figure 1) (Kongsberg, 2023). For example, a 2007 Chinese antisatellite (ASAT) test created 35,000 pieces of debris, increasing the overall debris in LEO by 20% (Pace & Baiocchi, 2020) (see Figure 2 for a graphic on what debris clouds from collisions can look like). While several nations have agreed that China's actions in 2007 fall under the category of "irresponsible behavior," accountability is difficult to maintain when there are no set international regulations or repercussions for misbehavior (National Security Innovation Network, 2022). Objects in LEO travel at a speed of 17,000 miles per hour, meaning a collision between objects could result in large amounts of debris. As space debris increases, this could cause Earth orbits to become unusable, and taking no action could be devastating to the future of spaceflight (Byrne et al., 2021). In a 1978 paper, Donald Kessler proposed the now-famous theory called the Kessler Syndrome. This paper detailed how increased activity in space will increase the likelihood of random satellite collisions that will produce hazardous debris. The collisions will have a cascading effect on debris and will eventually reach a point where Earth orbits are unusable (Wall, 2022). While the Kessler Syndrome has yet to be reached, the number of objects in space has increased the risk of collision.

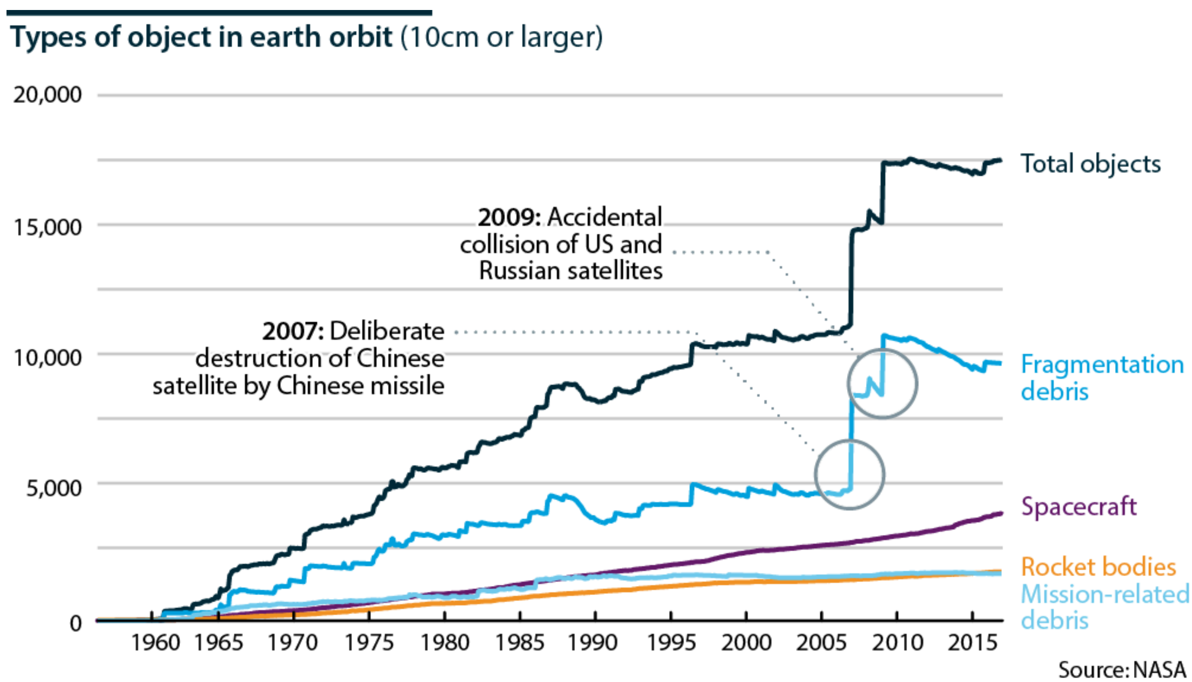

Figure 1: Objects in Earth orbit are increasing over time. (*Space Debris Threatens Global Economy and Security*, 2018)

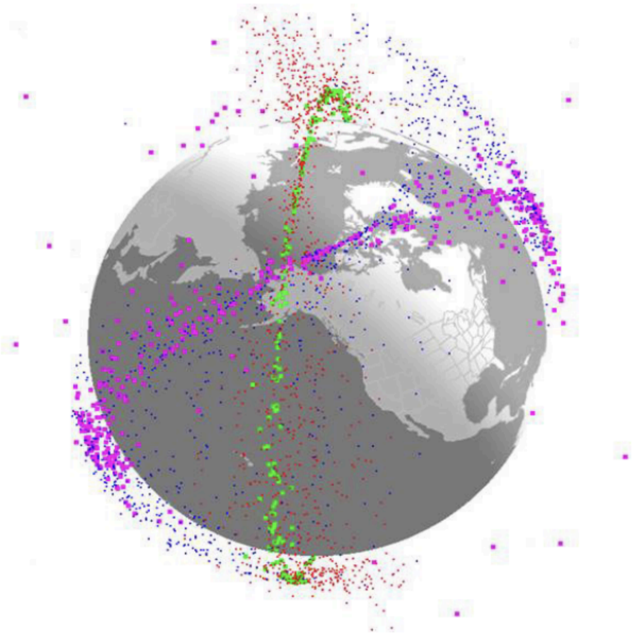

Figure 2: Debris clouds from collisions can be incredibly impactful for the operability of Earth orbits. This graphic depicts the 2009 accidental crash between US and Russian satellites. The green and purple dots represent debris larger than 10 cm (which can be tracked), while the red dots represent predicted debris smaller than 10 cm. The dots are positional and do not reflect the relative size of the debris created by the crash (Dickey, 2023).

History of Space Law

Humanity has explored space for over 60 years, but space policy has not changed significantly. The Cold War was the first catalyst for space regulation and led to the seminal body of space law, the Outer Space Treaty (OST). OST was followed up by four other international legal agreements, the last of which was ratified in 1975. Since then, there have been other voluntary agreements and guidelines and no other substantial legal international framework (Pace & Baiocchi, 2020). The four other legal obligations include the "Rescue Agreement," the "Liability Convention," and the "Registration Convention." These existing frameworks address issues such as the return of rescued astronauts and objects launched into space, nuclear weapons in space, and the usage of the moon and other celestial bodies. The additional voluntary agreements address sustainability and debris issues, but the scope is limited, and not all nations have signed. The question of responsible behavior in space is up for debate as each space-capable nation has different approaches to space governance (National Security Innovation Network, 2022) (The Group of Government Experts on TCBMs, 2011).

Importance of Space

The importance of space cannot be understated. Satellites in Earth orbit touch every aspect of our lives. They are used for televisions, GPS, banking, and credit card authorizations (Union of Concerned Scientists, 2014). They help connect rural and remote areas, photograph the earth, and help analyze the effects of climate change. Satellites also have military purposes including the command and control of nuclear weapons and being able to navigate service members in the field (West et al., 2023). Satellite constellations provide reliable communication networks that have civilian and military applications, as evident from the war in Ukraine (Roulette, 2023). While only countries were previously involved in space, civilian space use has far outpaced government use, and militaries have begun using commercial satellites for operations. Cooperation between countries establishing guidelines for actions in space is necessary, or else space will become too congested to use, and newcomers to space will be boxed out. This would create inequity within space exploration, which goes directly against the Outer Space Treaty (West et al., 2023).

However, creating norms that all countries agree to and adhere to is difficult because most nations do not want restrictions on their ability to operate freely in space. In addition, unclear guidelines for responsible behavior in space could create enforcement issues, breed mistrust between space-faring nations, and potentially create conflict between nations (Group of Government Experts, 2013). While there is a desire to establish responsible space norms, there is still a long way to go in ensuring the safe usage of space. One way that the international community is working together to ensure the safe usage of space is through a space situational awareness monitoring system. There are seven space agencies worldwide (China, Russia, the EU, Canada, India, and Japan). While each of these organizations employs its own debris monitoring systems, the US system is taking on much of the reporting burden (Pace & Baiocchi, 2020). To streamline space situational awareness, the US government is working to create a unified space situational awareness program where all nations contribute and share data to ensure that space remains usable for generations to come (Office of Space Commerce, n.d.). While space situational awareness is a vital component of space safety, a framework that helps establish norms and responsible behavior is also important. In 2019, the United Nations adopted the Long-Term Sustainability (LTS) Guidelines. They provided a framework to nations on space operations, international cooperation, and research and development (National Security Innovation Network, 2022). However, these guidelines are not well followed or adhered to. Without universal acceptance of what constitutes responsible behavior in space, the U.S. government has focused on creating norms. The aim is to rely on transparency and confidence measures (TCBMs) in a bottom-up approach to improve international peace, stability, and security in space. Using a bottom-up approach, the U.S. hopes to create a stable ground upon which legislation can be formed. In addition, this approach would allow norms to quickly adapt to changing technology, allow civil and commercial input, and enable new space capabilities to be explored (Tok, 2022).

Potential Solutions

A 1998 study by Finnemore and Sikkink laid out a norm life cycle in which concepts with enough buy-in from international partners can tip norms into domestic laws. During the initial stage of norm emergence, advocates can persuade nations to accept their norms (Finnemore &

Sikkink, 1998). One way to accomplish this is through frameworks. There has been conflicting literature on the effectiveness of international frameworks, with some stating that international verification systems work and others claiming that weak enforcement mechanisms in international treaty agreements lead to little change in adherence (Hill Jr., 2010) (Hoffman et al., 2022). However, these issues stem around enforcement capabilities and the policy area instead of the frameworks themselves. Concerning these criticisms, any framework proposed must have the potential for enforcement. Ambassador Roger G. Harrison's paper on "Space and Verification" emphasizes the importance of any space compliance framework being objective, specific, inclusive of international collaboration, and transparent. He lays out four types of verification frameworks that currently exist: unilateral verification, cooperative verification, multilateral verification, and open verification (Harrison, n.d.). Adding to this literature, a hybrid framework incorporating data sharing and verification elements was proposed (Gleason, 2022). According to this research, hybrid frameworks were the most effective type of framework for verification and enforcement in space. Consequentially, the majority of the alternatives assessed in this paper are hybrid frameworks. See Appendix IV for additional analysis of verification frameworks that apply to the alternatives presented.

To create norms defining responsible space behavior, the US can establish its own criteria and adjust the framework through cooperation with foreign countries, academics, and the civil space sector. This collaboration aims to increase international buy-in, solidify space norms, and eventually become international or domestic law. There are three alternatives that this paper evaluates to create an objective method to measure accountability in space. These frameworks are Lindgren's "Assessment Framework for Compliance with International Space Law and Norms," the Space Sustainability Rating, and the Objective and Responsible Behavior Indicator for Transparency (ORBIT) that the author created.

Criteria

Three frameworks were considered to define and evaluate responsible behavior in space: Lindgren's assessment framework, the Space Sustainability Rating (SSR), and the Objective and Responsible Behavior Indicator for Transparency (ORBIT) created by the author. Lindgren's assessment framework and SSR are currently the only two proposed frameworks for defining and evaluating responsible behavior in space. ORBIT was created to add a third consideration, combining norms gathered from academic documents and elements from Lindgren's assessment framework and SSR.

These frameworks were evaluated on their Cost-Effectiveness, Political Feasibility, and Information Access & Transparency. Each framework was evaluated against a set of questions (see Appendix II). Questions evaluating Political Feasibility and Information Access & Transparency focused on evaluating each framework's objectivity, specificity, transparency, and potential for international collaboration reflect Ambassador Roger G. Harrison's paper on "Space and Verification," where he emphasizes the importance of these qualities for an effective space compliance framework (Harrison, n.d.). Cost-effectiveness was evaluated using estimated costs and each framework's potential impact on satellites and debris (see Appendix I). Each framework was closely evaluated and rated against these set criteria and given a score. Political Feasibility and Information Access & Transparency were rated "high" if the frameworks answered "yes" to over 90% of the evaluation questions. "Medium" was given to frameworks that answered "yes" to over 50%, and "low" was given to frameworks that did not answer "yes" to at least 50% (see Appendix II). Cost-effectiveness scores were split into three bands based on cost-effectiveness ratios, with 0 being the highest in cost-effectiveness. The bands are as follows: "high" (below 5,000), "medium" (above 5,000), and "low" (above 10,000) (see Appendix I).

Cost-Effectiveness

Cost-effectiveness evaluates the cost of implementing the framework in the United States. Maintenance, staffing, and technology needs were considered for the cost evaluation. Effectiveness was estimated by the potential number of satellites accessed or evaluated in Earth orbit, and the predicted debris decreased. See Appendix I and the Cost Analysis Excel document for cost-effect estimations.

Political Feasibility

Political Feasibility includes international and domestic political feasibility and potential buy-in from the scientific community. Questions evaluate the level of objectivity, specificity, and potential for international collaboration. In addition, political feasibility evaluates each framework's potential to be implemented globally, as requested by the client. See Appendix II for framing questions.

Information Access & Transparency

The Information Access & Transparency criteria consider the ease of accessing information required for each framework and the voluntary and involuntary disclosure of information. It also considers the potential for the gathered data to be public to increase transparency in the final evaluation. See Appendix II for framing questions.

Alternatives and Evaluation

<u>Inaction: The Do-Nothing Approach</u>

The number of satellites and debris in orbit is rapidly increasing. Taking no action would devastate the future of spaceflight. In a 1978 paper, Donald Kessler proposed the now-famous theory called the Kessler Syndrome. This paper details how increased activity in space will increase the likelihood of random satellite collisions and produce hazardous debris. The collisions will have a cascading effect on debris and will eventually reach a point where Earth orbits are unusable (Wall, 2022). While the Kessler Syndrome has yet to be reached, the number of objects in space has increased the risk of collision. In 2017, the US SSA system reported 655 emergency alerts and 310,000 close-collision calls (Pace & Biaocchi, 2020). The increase in close calls and recent "irresponsible behavior" by a 2007 Chinese Anti-Satellite test that increased the overall debris in orbit by 20% means that finding a solution to evaluate responsible behavior is vital (Pace & Baiocchi, 2020). See Figure 3 for a graphic description of objects and debris increasing over time and predicted trends to 2023.

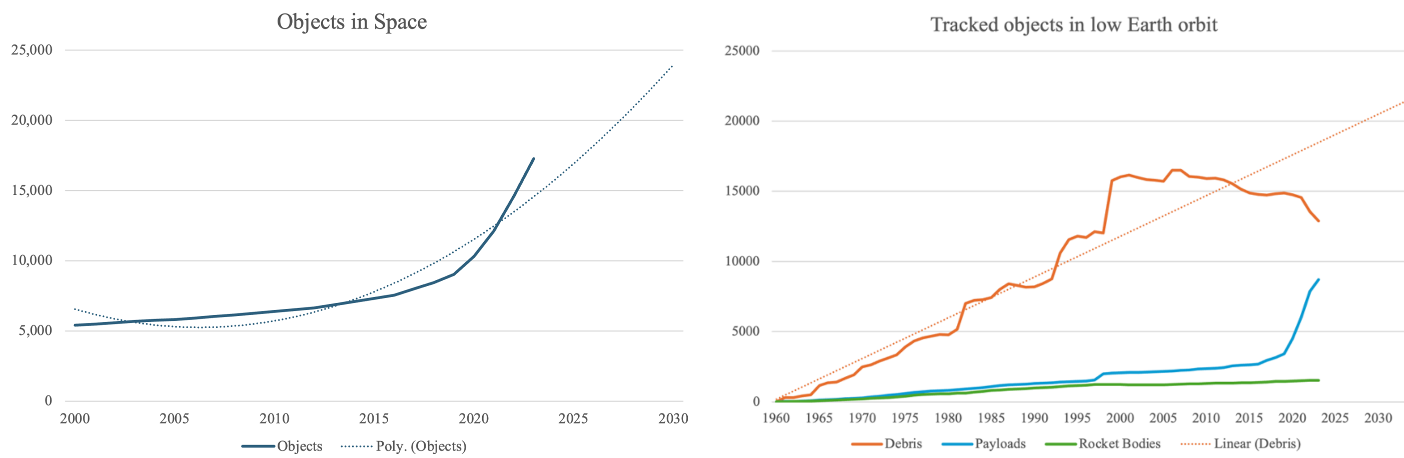

Figure 3: Objects in space are increasing over time and are predicted to increase further (United Nations Office for Outer Space Affairs, 2024). Debris in orbit are increasing over time and are predicted to continue to increase as the number of objects increases, even as the payload-to-debris ratio in LEO decreases (US Space Force, 2024).

<u>Lindgren's Assessment Framework</u>

Lindgren's framework, proposed in 2020 by David Lindgren, focuses on domestic laws to assess adherence to international treaties. The framework uses open-sourced research to assess how well domestic space law reflects international treaties and notes instances of treaty violation. Lindgren's framework defines responsible behavior as adherence to international treaties and scores compliance on a scale of "0" to "2." Countries are scored using qualitative questions derived from binding and non-binding international treaties. A score of "0" is given when countries never participate in a defined responsible behavior, and "2" is given when they frequently engage. These scores are weighted accordingly if the question associated with the international treaty is binding or non-binding for each country. For example, the US scored a "2" on the question, "Has the country placed into orbit or installed on celestial bodies weapons of mass destruction, including nuclear weapons," indicating the US's adherence to the responsible behavior of not putting nuclear weapons in space. Lindgren weights "Highly Compliant" composite scores for emerging and advanced space programs differently to avoid over-penalizing or over-rewarding emerging programs that might not have certain capabilities being tested. For example, Turkey, an emerging space-faring country, will be considered "Highly Compliant" at a lower composite score than the US, an advanced space-faring country with more advanced capabilities (European Space Policy Institute, 2021).

Lindgren's assessment framework is an open verification program. It aligns closely with human rights verification models such as the Freedom in the World, the Economist Intelligence Unit, the Helsinki Watch Group, and the Mediterranean Action Plan. While academics dispute the effectiveness of open verification models, a 2022 research study found that the ineffectiveness depends primarily upon the policy area. For example, human rights open verification models are less effective than other policy areas (Hoffman et al., 2022). Although disputed, open verification models have been quite effective at "naming and shaming" and changing government behavior when there is extensive cooperation across sectors. Examples include Human Rights Watch, which won a Nobel Peace Prize for its efforts in illuminating human rights violations worldwide (Human Rights Watch, n.d.), and the Mediterranean Action Plan, which reduced the number of unsafe beaches in the Mediterranean over the course of 20 years by 39% (UN Environment Programme, n.d.).

SSDP could use Lindgren's assessment framework to assess all civilian and government space programs using publicly available knowledge. This framework would require open-source researchers knowledgeable about each country's domestic space laws and the enforcement of those laws on government and civil programs.

Cost-Effectiveness

Lindgren's framework could evaluate all countries with publicly available space laws if implemented. According to the United Nations (UN) Office for Outer Space Affairs, only 48% of space programs worldwide have open-source space laws (Central Intelligence Agency, n.d.) (UN Office for Outer Space Affairs, n.d.). As such, this framework could access 86% of the satellites in orbit. However, while Lindgren's framework evaluates a country's debris mitigation laws, it does not evaluate the enforcement of those laws. Because of the lack of emphasis on the outcomes of a space mission, it is assumed that Lindgren's framework would not be able to reduce debris adequately. Lindgren's framework has a higher cost due to the number of estimated experts required to research individual countries' domestic space laws. Lindgren's framework is the least effective framework, as the others contain language surrounding outcomes of space missions, not just legal regulation. In addition, it is the most expensive due to the expertise required to understand international space law. Lindgren's framework See Appendix I for additional cost-effective calculations.

Political Feasibility

Lindgren's assessment framework scored 50% in the Political Feasibility category, giving it a medium for political feasibility. This framework was highly objective and internationally collaborative because a country's space program is only evaluated based on binding international agreements it has voluntarily entered (Lindgren, 2020, 93). However, this framework did not incorporate hard data or observational behaviors to responsible behaviors in space, relying instead on the existence of domestic laws. In addition, it would require extensive knowledge of foreign countries' domestic space laws and does not incorporate current norms or academic suggestions for responsible behavior. See Appendix III for evaluative questions and scoring.

Information Access & Transparency
Lindgren's framework received 50% in the Information Access & Transparency category, giving it a medium rating. While evaluators can easily share gathered data, only 48% of space programs have open-source space laws, according to the UN Office for Outer Space Affairs, making accessing information difficult without cooperation from international partners (UN Office for Outer Space Affairs, n.d.). See Appendix III for evaluative questions and scoring.

Space Sustainability Rating (SSR)
The Space Sustainability Rating, which completed its first trial period in 2023, focuses on voluntary involvement by privately owned and government-run space programs. The framework uses a tiered scoring system run by an independent organization with ties to the European Space Agency and several space groups, non-profits, and universities. Their activities are funded through space partners and donations. eSpace at the Swiss Federal Institute of Technology Lausanne is currently leading and operating SSR (The World Economic Forum, 2023). Companies or government organizations can request the SSR team evaluate their space mission. SSR takes this voluntarily submitted data and gives the mission a base score of 0-1. Five models comprise the overall base score: Mission Index, DIT (Detectability, Identification, and Trackability), Collision Avoidance Capabilities, Data Sharing, and Design and Operational Standards. Within these models, various weighting, scoring, and metrics are applied (Space Sustainability Rating, n.d.). Additional points are awarded for adhering to voluntary international regulations and providing external services such as life extension services and debris removal. SSR adds prevalent sustainability measures beyond international frameworks, such as “data sharing, choice of orbit, measures taken to avoid collisions, plans to de-orbit,” and detectability (The World Economic Forum, 2023). However, two scoring systems can add additional complications, and various scoring methods within each category could cause further confusion and potential for disagreements regarding objectivity.

SSR is a hybrid framework for monitoring space activity (Gleason, 2022). This is because the framework has a built-in incentive structure where governments or private companies can choose how much information it reveals. The more transparent and independently verified submissions are, the higher the rating a space mission can achieve. While hybrid verification programs are a new concept, several programs include data sharing and verification elements that exist in SSR. This includes the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), the Antarctic Treaty, the Convention of International Trade in Endangered Species of Wild Fauna and Flora (CITES), and the Long-Range Transboundary Air Pollution (LRTAP). These programs have been largely effective and use a mix of government and private sector-supplied data and verification. For example, the Antarctic Treaty has facilitated extensive international cooperation, leading to scientific advancements and the discovery of seasonal ozone depletion. This treaty has been largely responsible for the Arctic remaining undisturbed (British Antarctic Survey, n.d.). Using another example, the LRTAP uses a cooperative framework, similar to SSR, and has prevented 600,000 premature deaths in Europe annually (EUR-Lex, 2020).

Cost-Effectiveness

SSR is highly cost-effective due to its satellite reach, debris decrease, and overall program cost. If implemented, SSR would be able to reach US satellites. In addition, it is assumed that in an ideal scenario, it would also reach at least 46% of space programs, mirroring the number of countries that have open-source space laws (not including the US, China, and Russia) (Central Intelligence Agency, n.d.) (UN Office for Outer Space Affairs, n.d.). As such, this framework could access 86% of the satellites in orbit. Because SSR has provisions for evaluating the collision probability and the severity of that collision, it is estimated that it will be able to reduce accidental and non-accidental debris creation (Aschbacher, n.d.), excluding ASAT tests, which it does not include in its rating. With a high estimated startup cost of $167.5M due to the systems required to maintain this data, the overall effectiveness of this framework means that it has a high cost-effectiveness ratio. See Appendix I for additional cost-effective calculations.

Political Feasibility

SSR received 93% in the Political Feasibility category, giving it an overall high rating. SSR was highly objective, specific, and collaborative internationally and domestically. SSR remains objective and specific due to its specific framing questions, quantitative metrics, and option for third-party verification of data provided, mitigating potential political interference in reporting (Space Sustainability Rating, n.d.). SSR is also highly collaborative, working with international partners to create and implement the rating. Originating from a grassroots approach, preferred by the US government, and from technical communities, SSR is likely to garner US government buy-in (Ker & Tok, 2022) (Space Sustainability Rating, n.d.). Despite these excellent qualities, SSR has difficulties scaling should this be adopted at a US government level. Current evaluations are done on a mission-by-mission basis and would require large administrative costs to gather, evaluate, and report on every space mission worldwide. See Appendix III for evaluative questions and scoring.

Information Access & Transparency

SSR received 50% on Information Access & Transparency questions, giving it an overall medium rating. SSR was estimated to reach the US and cooperating nations that provide data on their space programs, which equates to about 46% of all space programs, giving it an overall medium rating for information accessibility (UN Office for Outer Space Affairs, n.d.). Because current norms do not publish publicly the data required to conduct an SSR rating and the data would require voluntary disclosure of information, SSR rated medium in transparency and accessibility (Space Sustainability Rating, n.d.). See Appendix III for evaluative questions and scoring.

Objective and Responsible Behavior Indicator for Transparency (ORBIT)

ORBIT was created by the author using a combination of the Freedom of the World, SSR, and Lindgren's framework to create a new hybrid framework. ORBIT uses open-sourced data from government agencies, NGOs, and other partners to evaluate behavior qualitatively and quantitatively. ORBIT was based on current international treaties, obligations, voluntary provisions, and norms. This framework follows the tenets of Defense Secretary Lloyd Austin's 2021 memorandum on the Tenets of Responsible Behavior in space, which mentioned five key elements of the DOD's mission. These tenets are:

1. "Operate in, from, to, and through space with due regard to others in a professional manner.
2. Limit the generation of long-lived debris.
3. Avoid the creation of harmful interference.
4. Maintain safe separation and safety trajectory.
5. Communicate and make notifications to enhance the safety and stability of the domain." (Space Security and Defense Program, 2022)

ORBIT splits the evaluative questions into two sections: sustainability and security. Each question is given a score of "0" if the evaluated action decreases sustainability and security or "1" if the action increases responsible use of space. There are 20 possible points for sustainability and 28 possible points for safety. Once the points are tallied, the countries are sorted into three categories (compliant, partially compliant, and non-compliant) using a compliance matrix. See Appendix V for the evaluative questions and framework.

ORBIT is a hybrid framework similar to the Antarctic Treaty, the NPT, and the Freedom of the World, all of which have successfully established norms. For example, the NPT has decreased the US and Russian nuclear stockpiles by 90% and has been largely successful at preventing signatory countries from acquiring nuclear weapons (Brookings Institution, 2020). ORBIT learns from these programs and incorporates norms using transparency and confidence measures (TCBMs) that the US government has been interested in implementing (Tok, 2022). ORBIT aims to incorporate norms and technical and legal requirements to discuss how responsibility should be defined.

Cost-Effectiveness

ORBIT is highly cost-effective due to its satellite reach, debris decrease, and overall program cost. Similar to SSR in cost-effectiveness, if implemented, ORBIT is predicted to reach all satellites and decrease an identical number of debris as the SSR. This is due to the nature of ASAT tests, which are often conducted to demonstrate national security capabilities and are unlikely to change as only 13 countries have signed the ASAT test ban, one of which has successfully conducted an ASAT test (the US) (Wall, 2023). The other three countries, China, India, and Russia have yet to commit to the program and are unlikely to do so in the next ten years. With a high estimated startup cost of $167.5M due to the systems required to maintain this data, the overall effectiveness of this framework means that it has a high cost-effectiveness ratio. See Appendix I for additional cost-effective calculations.

Political Feasibility

ORBIT received 93% on the Political Feasibility questions, giving it an overall high rating. ORBIT is highly objective and specific, with potential for US government and scientific community buy-in. Like the SSR, ORBIT incorporates specific “yes”/”no” questions and quantitative evaluations for debris mitigation. It also draws directly from international treaties and incorporates norms created at a grassroots level, both of which the US government has expressed preference (Ker & Tok, 2022). Even though it currently has no international cooperation because the author created this framework, it incorporates international treaties and, if implemented, would be able to adjust according to international opinion. See Appendix III for evaluative questions and scoring.

Information Access & Transparency

ORBIT rates 50% on the Information Access and Transparency, giving it an overall medium rating. ORBIT is developed to use information from open-sourced data that can be accessed through observation or voluntary disclosure. As the current data-sharing information systems are not yet developed to the level of operability, ORBIT currently requires voluntary disclosure from countries and satellite operators (Office of Space Commerce, n.d.). As such, ORBIT received a medium score across the board due to the lack of publicly available knowledge. See Appendix III for evaluative questions and scoring.

Outcomes Matrix

The following is the framework evaluation matrix. See Appendix I for assumptions, calculations, and costs. See Appendix II for evaluation questions and Appendix III for framework scoring. The total of each of these criteria is established by the most frequent evaluation. For example, if two categories are rated "low" and one "medium," the overall rating will be "low."

Framework Evaluation Matrix

Alternatives	Criteria			Total
	Cost-Effectiveness	Political Feasibility	Information Access & Transparency	
Lindgren's Assessment Framework	LOW	MEDIUM	MEDIUM	MEDIUM
Space Sustainability Rating	HIGH	HIGH	MEDIUM	HIGH
Objective and Responsible Behavior Indicator for Transparency	HIGH	HIGH	MEDIUM	HIGH

Recommendation

The Space Security and Defense Program is recommended to pursue and encourage other government stakeholders to pursue the ORBIT rating. While the ORBIT and SSR are identical in outcomes, ORBIT incorporates norms not included in previous frameworks. SSR and ORBIT are very similar, so the recommendation comes down to whether you propose a new model (ORBIT) or work with the one you already have (SSR). ORBIT might not be as effective as SSR for the next five years because it is less established, but introducing ORBIT into the conversation will help incorporate behavioral norms. While ORBIT might not be as successful in the short run, its effectiveness will increase as additional norms are incorporated. ORBIT is also preferred because the framework is more digestible and allows for full data transparency after implementation, increasing international trust and cooperation. Once ORBIT is public and open for international collaboration, it will become more politically feasible than SSR due to its inherent transparency. Using ORBIT allows for an ongoing conversation surrounding responsible behavior in space that can incorporate international and domestic partners.

Implementation

The implementation of the ORBIT framework will need to be an ongoing conversation between stakeholders. While one framework proposed by the US is a good start for defining responsible behavior, international cooperation will be needed to ensure cooperation from all space-faring countries. Below is a roadmap for the successful implementation of the ORBIT framework.

Challenges and Risks to Implementation

Implementing a framework defining responsible behavior in space presents several challenges. These include accurate orbital tracking, transparent information sharing, data management, data reporting norms, and the division of space oversight in US departments. As the US government addresses these challenges (as demonstrated by the author's interview with stakeholders), the framework and implementation timeline can be adjusted to compensate.

One large hurdle in establishing responsible space behavior that is not directly being addressed is the lack of publicly available data. Any implemented framework will require a certain amount of data to evaluate a space mission, program, or country. There are two methods of obtaining that data. The first is through open-source research and observation of satellites; the second is through voluntary data submission. Lindgren's framework operates solely with observational data, while SSR relies on voluntary disclosure that it keeps private. However, other programs, such as the Antarctic Treaty and the Mediterranean Plan, include voluntary disclosure and observational data that it publicizes. This is the method that ORBIT will need to operate under, a combination of voluntary and observational data that can then be made public. For this to happen, the US must establish new norms for making civil satellite dimensions, orbital trajectory, frequency use, and payloads publicly available to ensure transparency in the framework's evaluation. While some requirements exist for providing data to international regulatory bodies such as the UN for space tracking, this information disclosure is not routine and timely. However, there is an expressed desire for regulation, demonstrated by the author's interviews with internal and commercial partners and through congressional actions, including the Commercial Space Act of 2023, which moved the Office of Space Commerce to the Department of Commerce to streamline the mission of enhancing space situational awareness (House Republicans, 2023). To overcome this implementation barrier, it is recommended that the US begin requiring its satellite operators to openly provide that data for space situational awareness purposes and use that information to assess their responsibility in space. This would fall directly upon the Department of Space Commerce and the Federal Aviation Administration to require space actors to submit the data already collected before launch into a space situational awareness database. In addition, these departments would need to ensure that regulation is created to allow for the required information to be shared publicly and that those who own the satellites submit the information as opposed to the launch site or, in the case of rideshares, those who own the rocket to reduce confusion and the burden of launching facilities. Accessing and making this data public would need congressional approval or a change in policy from regulating agencies. Any data-sharing policy would need to be open for input from the commercial and scientific community to better understand information that is truly too sensitive for publication.

In addition to implementation challenges, there are many areas where implementing this framework can go awry. This includes the possibility of overregulation, underregulation, and implementation delays. These risks would make administering and ensuring that space remains usable in the future difficult.

Overregulate

Overregulation is a medium-probability, low-risk scenario. The combination of multiple administrations involved in regulating space, bureaucratic slowdown, and the government's inability to keep pace with technology could cause the US to lose its competitive edge in space. Should the government overregulate, this could result in job losses and hamper industry growth (Autry, 2022). This is unlikely to happen in an environment where there is currently little regulation, making it a medium risk. However, it is recommended that implementing administrative organizations be minimized to prevent mission creep and that all regulations undergo a commentary period to understand the tradeoffs between regulation and innovation.

Underregulate

Underregulation is a high-probability, high-risk scenario. Without proper regulation and consequences for irresponsible behavior, the ORBIT framework could become ineffective, wasting FTEs (full-time equivalent), decreasing operational safety, increasing collisions, and failing to prevent an arms race in space (Torkington, 2023). It is recommended that the US attempt a framework, however imperfect, to begin the conversation with other countries and work to form a consensus for the future of space flight.

Delay Implementation

Implementation delays are a high-probability, high-risk scenario. Even as the US attempts a framework, implementation delays could result in a potential conjunction. With 11,500 satellites, only 9,000 of them operational, and an estimated 100 trillion untracked space debris, implementation delay, or worse, doing nothing, could be catastrophic to space sustainability (Combs, 2024) (Wall, 2024). While a large collision incident could create the international and domestic political motivation to support an assessment framework, it would contribute to the debris in space, bringing the Kessler Syndrome closer to reality.

<u>Stakeholder Involvement</u>

Government stakeholders outside of the DOD involved in regulating US space activities include the Federal Aviation Administration (FAA), the Federal Communications Commission (FCC), and the newly created Office of Space Commerce (OSC) in the Department of Commerce. The FAA regulates commercial spaceflight, the FCC regulates radio frequencies, and while the OSC is still building itself, its mission includes fostering "the conditions for the economic growth and technological advancement of the US commercial space industry" (Space Foundation, n.d.). The ORBIT framework was created to be implemented by the DOD but will need cooperating agencies to provide data and regulations to obtain data for evaluation. However, this framework does not need to be implemented solely by the DOD; other agencies can use this framework to establish responsible behaviors in space for individual companies. In addition, the framework will eventually need to be moved out of the DOD to reach a broader international audience. Because cooperation amongst agencies is required, data-sharing might be difficult due to potential commercial aversion to publicly providing key information. To get this information, the DOD can first request and keep the data private before working with the regulating organizations and Congress to make it public.

While space situational awareness is something that all international and domestic agencies want to figure out, it can be a political minefield. Removing space situational awareness and responsible space behavior frameworks from the DOD into a non-military governing body will increase the trust and confidence in the objectivity of the assessment framework. Eventually, it would be ideal if this framework were implemented by a national regulation agency similar to how the International Atomic Energy Agency regulates nuclear security. The FAA, FCC, DOD, and OSC will support a framework establishing responsible behaviors in space outside the DOD domestically. However, the Department of State's (DOS) support is required to move the ORBIT framework onto the international stage. DOS support will depend upon the administration and whoever holds the presidency. While some political parties favor international organizations over others, most people in politics and commercial space companies want to keep space usable for future generations and are open to space regulation. While elements of the framework might need to be adjusted to fit the needs of regulators, there is a possibility of moving the ORBIT framework onto the international stage. Should the administration oppose international treaties and obligations, it is recommended that the US first implement this framework on itself and its allies before involving the United Nations, a polarizing organization in American politics (The Pew Research Center, 2020).

International actors such as the European Space Agency, which is already working with the US government to establish a robust space situational awareness program, and countries signatory to the Artemis Accords, a cooperative program to kickstart space exploration that includes provisions on transparency and debris mitigation are likely to continue cooperating with the US in space (Lea, 2024). However, countries such as Russia and China are unlikely to work with the US in space. In early 2024, the National Security Council spokesman stated that Russia was developing nuclear weapons capabilities in space in clear violation of the OST (Davenport et al., 2024). In addition, recent reports claim that China and Russia are planning on developing a nuclear reactor on the moon, which could be considered to violate the OST's restrictions on contaminating celestial bodies (Open Lunar Foundation, 2021) (Einhorn et al., 2024). As the current treaties begin to break down, China and Russia will be reluctant to participate in any framework the US poses or that restricts its technological developments. While China has ratified several international agreements on trade, it has avoided entering treaties that would encroach upon its national security and sovereignty, which would include restrictions on its behavior in space (Matthew, 2021). For example, China is not a part of the International Space Station due to concerns about its scientists having connections to the Chinese People's Liberation

Army (Jones, 2023). Russia, meanwhile, has violated international law during its war with Ukraine and is contemplating violating the OST by developing nuclear weapon capabilities in space (Ermochenko, 2022) (Davenport et al., 2024). For the best possible outcome and adherence to the framework, it is recommended that the US continue to work with the European Space Agency and other allies. In addition, it is recommended that the US begin a dialogue with China about space situational awareness and making space free and usable for all (interview by author with international partners).

<u>Implementation Timeline</u>

The following implementation timeline is recommended (see Figure 4). The SSDP should first set up a task force to implement the strategy. This task force should work with US stakeholders to collect data from US missions and develop relationships with the OSC, which is creating a non-military-run space situational awareness system. By month 4, the task force should begin to assess US behaviors in space. It should begin working with DOS and international organizations to refine the framework, using US missions as a metric. During this time, the task force should seek input from the scientific community by hosting open forums, presenting at conferences, and allowing a commentary window. By month 10, the task force should work with US agency stakeholders such as the FAA and the OSC to make the privately collected information from US space missions public. During this time, the task force should keep congressional members informed, solicit feedback, and have open conversations with private companies to work through any concerns. In addition, the task force should be working with US stakeholders to move the framework out of SSDP, which will solicit greater international buy-in and bring more credibility to the framework. This is also when the task force can work with DOS to get international buy-in on making required data from space missions publicly available. To fully move this framework out of the DOD, SSDP would need to get executive approval to expand the current mandates of the FAA or the OSC to include this evaluation framework. As it currently stands, the jurisdiction between the different organizations is not clear, and often, regulations are added as a stopgap in various stakeholder rules. For example, the FCC requires companies to provide a debris mitigation alternative, even though this has nothing to do with its signal mandate. Therefore, SSDP would need to work with the heads of each stakeholder group and the executive branch to find an appropriate home for the framework. This would not be that difficult, as politicians enjoy discussing space, and all organizations are motivated to adapt current regulations to safeguard the future of space. Finally, the task force, or the agency that now owns the framework should the SSDP successfully move ORBIT out of the DOD, can work with international organizations to collect data and begin to implement the data internationally. These steps are a suggested timeline, and further refinement will be required as new information and opinions come to light (see Figure 4).

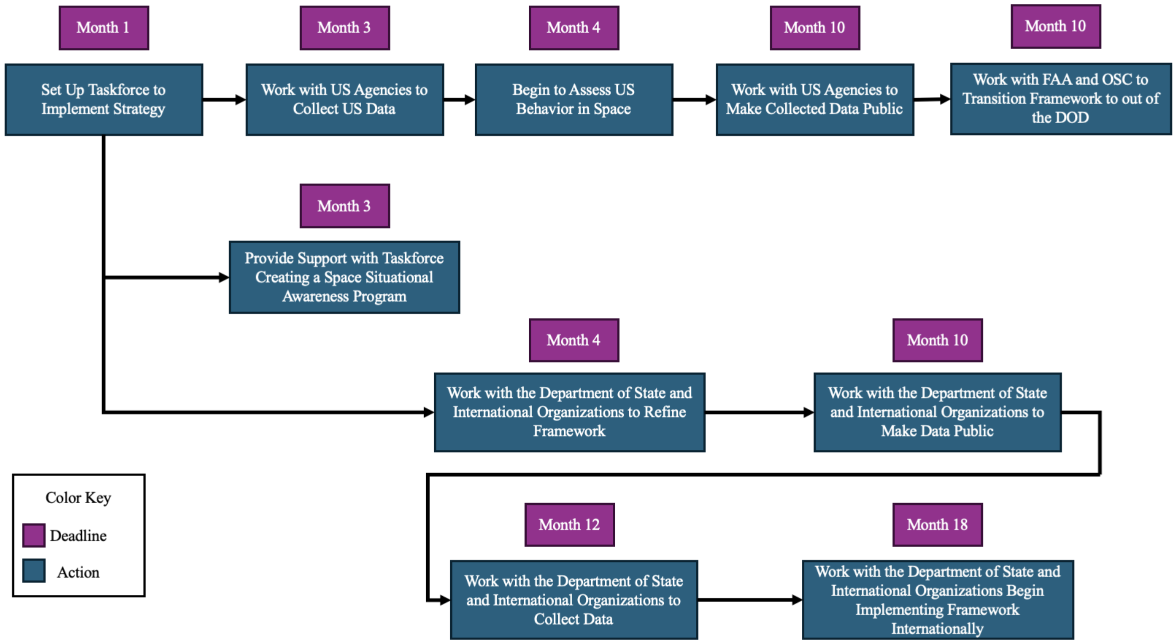

Figure 4: ORBIT implementation timeline.

Conclusion

Uncertainty abounds in space. As space becomes commercialized and more satellites enter Earth orbit, limited guidelines, insufficient space situational awareness, and lack of data sharing have created a dangerous environment increasingly susceptible to the Kessler Syndrome. While US government organizations work towards proper space situational awareness and data sharing, the question of what constitutes responsible behavior remains. This paper evaluated three possible frameworks for defining responsible behavior for cost-effectiveness, objectivity, transparency, specificity, and international collaboration. From this evaluation, the author recommends that the SSDP proceed with the ORBIT framework due to the norms that ORBIT integrates and the full transparency of data it allows in implementation. ORBIT is predicted to evaluate all currently orbiting satellites and significantly decrease debris. While ORBIT is not perfect, it is a good jumping-off point for defining and evaluating responsible space behavior. It is recommended that the SSDP work with US government, commercial, academic, and international stakeholders to refine and enhance an evaluative framework. By implementing ORBIT, SSDP can help create a safer, more sustainable environment for future space exploration.

APPENDIX I

Cost Effectiveness Calculations

See the Cost Analysis Excel document for additional cost calculations.

<u>Costs</u>

Total Personnel Costs

Total personnel costs were estimated using the 2024 federal pay scale. A typical office will possibly have 2 GS7, 2 GS12, 1 SES5, and 1 SES4. This grouping includes entry-level personnel, individuals with experience and master's degrees, and those with Ph.Ds. With Lindgren's framework, additional GS12 and SES5 were estimated to account for the expertise required to evaluate international domestic space policy.

Total Training Costs

Total training costs were estimated at $10,000 for each individual, using another government program's travel and training budget for fellows. These costs would include both startup costs and travel costs to training sites.

Information Management System

The informational management system cost was estimated using a federal bid by an organization to create a space situational awareness program. This was estimated to be $167,500,000. This cost could be cut depending on how the implementing department implements this framework. These frameworks could be conducted using Excel spreadsheets, significantly reducing this estimate. However, this would be the highest possible cost to create a space situational awareness program that could help facilitate these frameworks.

Education and Promotion Campaign

The educational promotional campaign was estimated using a NASA education and promotional campaign budget divided by the number of educational programs it offers. This estimate was $311,111.

<u>Effectiveness</u>

Estimated Debris Decrease

The estimated debris decrease was calculated by looking at the change in debris increase over the past ten years and projecting that same increase for the next ten. That change was estimated for accidental debris creation, non-accidental debris creation, and ASAT debris. Lindgren's framework was estimated to decrease no debris because it focuses on legal documentation and not implementation (Lindgren, 2020). SSR was estimated to eliminate all but ASAT debris creation because there were no provisions in SSR regarding ASAT tests, and any ASAT mission is highly unlikely to volunteer for a rating due to the destructive nature of the test. ORBIT was estimated to decrease the same amount as SSR, due to the national security implications of

ASAT tests, which are usually conducted to demonstrate capabilities to adversaries (Paikowsky, 2021).

Total Satellite Programs Evaluated

The total satellite program evaluated was estimated by projecting the number of satellites in LEO for the next ten years. This was done by looking at the change in satellite increase over the last ten years and projecting outwards. These satellites were also broken out into Russia and China, the US, and the rest of the world. According to the UN Office for Outer Space Affairs, only 48% of space programs worldwide have open-source space laws (Central Intelligence Agency, n.d.) (UN Office for Outer Space Affairs, n.d.). As such, Lindgren's framework was estimated to have reached 48% of the world that published domestic space laws. SSR was estimated to have reached the US and the rest of the world satellites that voluntarily provide domestic space laws, not including Russia and China, which are assumed to refrain from participating. Due to the involuntary nature of ORBIT, it is estimated that ORBIT will be able to access all operating satellites.

Cost-Effectiveness Ratio

The costs were divided by the debris and satellite programs. The cost-effective ratio of each program was compared with that of the other.

Cost Effectiveness Rating = Costs/ Effectiveness

Rating Key

HIGH = under 5,000
MEDIUM = +5,000
LOW = +10,000

APPENDIX II

Evaluative Framework

Evaluation Key
High: Always
Medium: Sometimes
Low: Hardly Ever

Cost Effectiveness

See Appendix I

Political Feasibility (X/7)

- Does the framework limit the possibility for politicization in question interpretation and data acquisition (objective)?
- Does the alternative have specific and measurable questions (specific)?
- Does the framework include quantitative metrics (specific, scientific)?
- Are other international organizations or governments involved in creating and implementing the framework (collaboration)?
- Can this be applied to a variety of programs across the world (logistics)?
- Are scientists and interest groups interested and involved in this framework (scientific)?
- Is there a possibility for the U.S. government to adopt this framework (US government)?

Information Access & Transparency (X/3)

- Can the data be readily accessed by the evaluators?
- Can the data be shared once it is accessed by the evaluators?
- Can the data be readily accessed by the evaluators without their permission?

Rating Key
HIGH = + 90%
MEDIUM = +50%
LOW = under 50%

APPENDIX III

Alternatives Evaluation

Evaluation Key
High: Always
Medium: Sometimes
Low: Hardly Ever

Lindgren's Assessment
The evaluation was completed using Lindgren's Assessment Framework (Lindgren, 2020, 93).

Political Feasibility (50%)

- Does the framework limit the possibility for politicization in question interpretation and data acquisition (objective)?
  - Lindgren's framework is highly objective because it evaluates each country's domestic laws and incidents of international compliance. This allows for nuance in evaluation and for the framework to remain objective and non-politicized (Lindgren, 2020, 93).
- Does the alternative have specific and measurable questions (specific)?
- Does the framework include quantitative metrics (specific, scientific)?
  - Lindgren's framework does not incorporate hard data to determine responsible behaviors and relies instead on qualitative assessment questions.
- Are other international organizations or governments involved in creating and implementing the framework (collaboration)?
  - Lindgren's framework is highly likely to garner international collaboration because a country's space program is only evaluated based on binding international agreements it has voluntarily entered into (Lindgren, 2020, 93).
- Can this be applied to a variety of programs across the world (logistics)?
  - Lindgren's framework is difficult to scale logistically due to the level of knowledge required to evaluate individual countries' space laws.
- Are scientists and interest groups interested and involved in this framework (scientific)?
  - Lindgren's lack of observational and quantitative questions will make it difficult to gain buy-in from the scientific community (interview by the author with scientific community partners).
- Is there a possibility for the U.S. government to adopt this framework (US government)?
  - The framework is plausible but fails to keep pace with the growing space industry and the rules required for responsible behavior. As such, it does not meet the client's requirements. If the framework included metrics beyond international treaties or if additional international treaties were to come into effect, including additional regulations regarding responsible space behavior, this framework

would be more plausible. While this is good for cooperation, it is unlikely that this framework will have the desired effect of increasing responsible behavior in space.

Information Access & Transparency (50%)

- Can the data be readily accessed by the evaluators?
  - Only 48% of space programs have open-source space laws. In addition, translation difficulties, variations in judicial enforcement, and legal interpretation make assessing international compliance with space laws difficult (UN Office for Outer Space Affairs, n.d.).
- Can the data be shared once it is accessed by the evaluators?
  - Because Lindgren's questions use published open-source domestic space laws, there is no barrier to sharing this information with a wide audience.
- Can the data be readily accessed by the evaluators without their permission?
  - Since only 48% of individuals have open-sourced space laws, implementing this framework would require cooperation from international organizations.

<u>SSR</u>

Evaluation was completed using the Space Sustainability Rating publication (Space Sustainability Rating, n.d.).

Political Feasibility (93%)

- Does the framework limit the possibility for politicization in question interpretation and data acquisition (objective)?
  - The SSR is highly objective due to its use of objective quantitative metrics. Although the data it collects is voluntary, higher ratings are given to those who provide more and verify that data using a third party, ensuring its accuracy and preventing potential political interference (Space Sustainability Rating, n.d.).
- Does the alternative have specific and measurable questions (specific)?
- Does the framework include quantitative metrics (specific, scientific)?
  - The SSR includes qualitative metrics focusing on international treaties and quantitative metrics for measuring sustainability. In addition, it is highly specific regarding its framing questions, which are typically “yes” or “no” questions.
- Are other international organizations or governments involved in creating and implementing the framework (collaboration)?
- SSR is highly collaborative, working with Japanese, US, and European high education institutes, space companies, think tanks, and international space agencies (Space Sustainability Rating, n.d.).
- Can this be applied to a variety of programs across the world (logistics)?

    - SSR rates are medium for the logistical component due to its scalability. Currently, space actors must pay for evaluation, which is done by a few full-time evaluators. To scale this to an international level, additional evaluators would be required. Increased international data sharing could mitigate this drawback.
- Are scientists and interest groups interested and involved in this framework (scientific)?
    - While this framework rates high on scientific community buy-in due to the current cooperation of scientists and specific quantitative data analysis, there is room for improvement in including more international norms and treaty obligations into the framework, garnering more support (interview by author with scientific community partners).
- Is there a possibility for the U.S. government to adopt this framework (US government)?
    - While potential US adoption remains unclear, there is reason to believe that the US government prefers a grassroots approach like the SSR to establish space norms with various institutions and voices involved (Ker & Tok, 2022).

Information Access & Transparency (50%)
- Can the data be readily accessed by the evaluators?
    - SSR has medium access to information because while the US would be able to access US satellite launches, it is unlikely that the US could acquire access to the data from all international space organizations.
- Can the data be shared once it is accessed by the evaluators?
    - SSR has medium information transparency because the current setup does not allow for the release of information to the public due to proprietary information. While this increases cooperation, additional trust will be placed in the evaluating body, and the process will be less transparent. In addition, there is no requirement for the data provided to the evaluators to be independently verified.
- Can the data be readily accessed by the evaluators without their permission?
    - SSR has medium information accessibility without cooperation because not all the information required for evaluation is readily available and must be requested from individual space actors. Currently, this framework cannot be completed without international cooperation.

<u>ORBIT</u>
The evaluation was completed using the Space Transparency for Awareness and Responsibility rating (see Appendix V).

Political Feasibility (93%)
- Does the framework limit the possibility for politicization in question interpretation and data acquisition (objective)?

- ORBIT is highly objective because it sticks to qualitative questions drawn directly from treaties and limits the possibility for politicization in question interpretation and data acquisition because it relies purely on open-source information incorporating either provided or observed data.

- Does the alternative have specific and measurable questions (specific)?
- Does the framework include quantitative metrics (specific, scientific)?
  - ORBIT is highly specific because it has specific measurable questions that allow for "yes" or "no" answers for qualitative and quantitative measures.
- Are other international organizations or governments involved in creating and implementing the framework (collaboration)?
  - ORBIT has medium international collaboration because it lacks international cooperation in creating the framework and includes current and future space behavior norms outside of international legal requirements. However, if this framework were to be adopted, there would be opportunities for future adjustments to appeal to international space agencies.
- Can this be applied to a variety of programs across the world (logistics)?
  - ORBIT is logistically scalable because it is based primarily on external observations; it evaluates overall programs, allowing for an understanding of an entire nation's space program instead of one mission, and can be applied to various international organizations.
- Are scientists and interest groups interested and involved in this framework (scientific)?
  - ORBIT is highly likely to gain support from the scientific community because it incorporates treaty language and preferred norms in the qualitative metrics and highly specific quantitative metrics (interview by the author with scientific community partners).
- Is there a possibility for the U.S. government to adopt this framework (US government)?
  - ORBIT will likely have high US government buy-in because it was developed for and with the commentary of domestic stakeholders such as scientists and government officials. It has a grassroots approach to determining space norms, which is how the US government is reported to prefer the establishment of norms (Ker & Tok, 2022). In addition, ORBIT was created specifically with US government agencies in mind and is likely to be adopted or adjusted further to meet the government's needs.

Information Access & Transparency (50%)

- Can the data be readily accessed by the evaluators?
  - ORBIT has medium information accessibility because while data regarding US space missions will be available, the framework will require cooperation from international actors to receive the necessary data as the current data-sharing

structure stands. This rating can be changed should better data-sharing practices be implemented globally.

- Can the data be shared once it is accessed by the evaluators?
    - ORBIT ranks high for information transparency because the current format of this framework would make all questions and answers to these questions public. Information that would be made public includes the dimensions, payload, projected orbit, and location of US satellite operations. While projected orbit and location have little pushback from the commercial community due to the desire to avoid collisions and adhere to SSA best practices, there could be some pushback to making payload and dimensions publicly available. Further interviews are being conducted to assess information transparency for this framework.
- Can the data be readily accessed by the evaluators without their permission?
    - Currently, ORBIT requires information from international actors voluntarily. The data required includes satellite dimensions, payload, location, and projected orbit. As it stands, this is not publicly available information for all space actors. While the US has this information from US-based missions, it does not have it for all international operations. However, most of this information has been guesstimated by scientists and can be used until better data-sharing practices come to fruition.

APPENDIX IV

Expanded Alternatives Analysis

The alternatives presented in this paper align with open verification and hybrid frameworks. The following is further research detailing other operational frameworks that adhere to the open and hybrid definitions.

<u>Open Verification Programs</u>

Open verification programs like Lindgren's Assessment Framework align closely with human rights verification models such as the Freedom in the World, the Economist Intelligence Unit, and the Helsinki Watch group. Freedom of the World is one of the most cited and read reports on political and civil liberties worldwide (Freedom in the World, n.d.). Meanwhile, the Economist Intelligence Unit uses similar open-source methods to evaluate freedom worldwide. The impact of these human rights frameworks is disputed; however, a 2022 research study found that the ineffectiveness of international frameworks was due to the policy area as opposed to the framework's validity (Hoffman et al., 2022). The Helsinki Watch Group of 1976 was created to verify the Soviet Union's compliance with the Helsinki Accords (“The Human Rights Movement During Detente,” n.d.). This method of "naming and shaming" governments for their noncompliance with international treaties expanded into the organization Human Rights Watch. The Human Rights Watch has helped bring forward many human rights violations worldwide, winning a Nobel Peace Prize for its efforts (Human Rights Watch, n.d.).

Another open verification model unrelated to human rights is the Mediterranean Action Plan (Med Plan). Med Plan is an agreement between the private sector, government institutions, research, industry, and non-government organizations. Through its eight projects, it aims to reduce pollution in the Mediterranean (UN Environment Programme, n.d.). Adherence to the Med Plan was assessed by panels of outside experts and environmentalists who enforced and supervised the plan with cooperation from participating nations. Individual signatory nations were responsible for regulating themselves but cooperated with others to share information. The Med Plan was considered a success because, in 1976, 33% of beaches were considered unsafe for swimming by the World Health Organization, but by 1996, only 20% were deemed unsafe. In addition, from 1972 to 1982, France drastically reduced its production of suspended solids, hydrocarbons, phenols, and mercury by above 90% (Haas, 1989).

<u>Hybrid Verification Programs</u>

While hybrid verification programs are new, several programs include data sharing and verification elements. Hybrid verification programs include the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), the Antarctic Treaty, the Convention of International Trade in Endangered Species of Wild Fauna and Flora (CITES), and the Long-Range Transboundary Air Pollution (LRTAP). These programs use a mix of government and private sector-supplied data and verification. NPT compliance is verified by the International Atomic Energy Agency, which subjects nation-states with nuclear programs to verification, and states can voluntarily sign on to additional verification agreements, making them a multilateral verification program from an outside body, an option in the SSR rating structure (International Atomic Energy Agency, n.d.). In the last 56 years since the NPT, new countries have been prevented from acquiring nuclear weapons, and the US and Russia have decreased their nuclear weapons inventories by almost 90%. Although several nations have acquired nuclear weapons or near nuclear weapons since the signing of the NPT, it has been largely successful (Brookings Institution, 2020).

The Antarctic Treaty has a strong, open, and compliant verification process. The treaty ensures that signatory nations only use the Arctic for peaceful cooperation and scientific advancement, prohibiting militarization and nuclear testing in Antarctica. Outside specialized non-governmental bodies assist in helping facilitate cooperation amongst signatory parties. Verification is open for any nation or outside organization to inspect, and any noncompliance will be handled through negotiation or the International Court of Justice (The Nuclear Threat Initiative, n.d.). The treaty and cooperation have led to scientific advancements and the discovery of seasonal ozone depletion. The Arctic remains undisturbed because of this treaty (British Antarctic Survey, n.d.).

CITES works similarly to SSR and ORBIT, where a standing committee reviews cases for noncompliance, but the responsibility to adhere to CITES requirements lands on the signatory nations (Altherr, n.d.). Data is provided by each nation individually (World Wildlife Fund, n.d.). CITES impacts include making trade violations visible and increasing or stabilizing wild populations. For example, the number of Vicunas in the Andean region increased by 400,000 due to effective CITES management (CITES, 2022).

Finally, the LRTAP is a cooperative framework that uses flexible enforcement and data provided by signatory countries, which is then made publicly available (World Resources Institute, 2020). LRTAP is a joint program that monitors the long-range transmission of air pollutants in Europe through monitoring devices presented by organizations. LRTAP has prevented 600,000 premature deaths in Europe annually and has dropped sulfur emissions by 30-80% since 1990. LRTAP has become the model for effective international cooperation between governments and scientists (EUR-Lex, 2020).

APPENDIX V

The Objective and Responsible Behavior Indicator for Transparency (ORBIT) Framework

Framework Goals

The goal of this framework is to use the elements of a transparency and confidence-building measure (TCBM) to establish responsible behaviors in space, reduce misperceptions and calculations, and thereby prevent military escalation and promote global security (Group of Government Experts, 2013) (Johnson, 2011). This framework's definition of responsible behavior in space includes exchanging national security policy goals, allowing for observation or inspection into space activities, sharing launching information, and mitigating intentional and accidental debris creation. In addition, it focuses on coordinating responses in high-risk scenarios such as possible conjunctions, space hazards, high-risk re-entries, and maneuvers (Johnson, 2011).

Key Sources

<u>Space Laws</u>

- The Outer Space Treaty (United Nations Office for Outer Space Affairs, 1963)
- The Rescue Agreement (United Nations Office for Outer Space Affairs, 2017)
- Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (United Nations Office for Outer Space Affairs, 2010)
- Safety Framework for Nuclear Power Source Applications in Outer Space (United Nations Office for Outer Space Affairs, 2017)
- Convention on Registration of Objects Launched into Outer Space (United Nations Office for Outer Space Affairs, 2010)
- UN International Space Law Synthesis Document (United Nations Office for Outer Space Affairs, 2010)

<u>Space Voluntary Commitments</u>

- Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space (United Nations Office for Outer Space Affairs, 2010)
- Group of Government Experts on TCBMs (Group of Government Experts, 2013)
- Long-Term Sustainability Guidelines (United Nations Office of Outer Space Affairs & Committee on the Peaceful Uses of Outer Space, 2018)

<u>Outside Reports</u>

- Best Practices for the Sustainability of Space Operations (Space Safety Coalition, 2023)
- Ships Passing in the Night (Dickey, 2023)

Framework Definitions

Launching State	A country that launches or from whose territory or facility a space object is

	launched.
Space Object	Components, parts, or objects launched into space, including launch vehicles, debris, satellites, etc….
State of Registry	The launching country from where the space object is registered.
Space Actor	A country (government or military space program) and the civilian space programs operating out of the country's territory or area of control. Civilian space programs include corporations, academic, and non-profit space launches not necessarily funded by the country's government. Per the Outer Space Treaty, all actions by civil and government space programs operating inside a country's territory are that country's legal obligation.

Convention on Registration of Objects, Articles I and II (United Nations Office for Outer Space Affairs, 2010)

Scoring

The default score is a "1" for responsible behavior. If a country or a civil space program operating in that country's territory did not engage in responsible behavior in the past year, the country would be given a "0" for that question.

According to the UN Liability Convention, a country is liable for actions taken by any space program operating out of its territory or area of control (United Nations Office for Outer Space Affairs, 2010). Therefore, even though the overall evaluation is of a country, all actions from civil space programs operating out of a country's territory will be attributed to the country's overall score.

Quantitative Verification

<u>Safety (1 pt.)</u>

Detectability Score

Detectability Score = 0.5 * Optical Score + 0.5* Radar Score

Optical Score	1 if a space object has a visual magnitude of 15. 0.5 if it does not meet the 15 visual magnitude threshold.
Radar Score	1 if an object is above 75% detection probability rate. 0.5 if it meets 50% and 0 if it is below 50%.

(Space Sustainability Rating, n.d.)

<u>Sustainability (1pt.)</u>

Mission Index

$I = P_C * e_C$

I	Mission Index, or risk indicator, scored between 0-1 (with a less responsible impact on the environment closer to 0)
P_C	the probability of collision = $1\text{-}e^{-p.\Delta v.A.\Delta t}$
e_C	the severity of fragments increasing the risk of collisions for operational satellites

(Aschbacher, n.d.)

Qualitative Verification

Safety (27 pts.)		
Communication, Cooperation, Visibility, and Trust *(14 pts.)*		
Question	Scoring	Citation
In the past year, has the space actor registered payloads and associated objects with the United Nations?	1: Yes 0: No	(Space Sustainability Rating, n.d.), (United Nations Office of Outer Space Affairs & Committee on the Peaceful Uses of Outer Space, 2018)
In the past year, has the launching state provided the UN within one day of launching a space object with the following: 1. Nature of operation and function of space object 2. Name of launching state/states 3. Object Registration number 4. Date, territory, and location of launch 5. Basic orbital parameters (Nodal period, inclination, apogee, perigee, Geodetic coordinates, vector speed, ephemeris data) 6. Current orbit and future orbit 7. Object dimensions 8. Wet and dry mass	1: Yes 0: No	(United Nations Office for Outer Space Affairs, 1963, Article XI), (United Nations Office for Outer Space Affairs, 2010, Registration of Objects: Article IV), (Group of Government Experts, 2013), (United Nations Office of Outer Space Affairs &

In addition, was this information provided with the standardization requirements of the UN?		Committee on the Peaceful Uses of Outer Space, 2018) , (Author interview with internal stakeholders), (Author interview with scientists)
In the past year, have all civil space objects originating from the country included transponders for accurate tracking purposes?	1: Yes 0: No	(Dickey, 2023), (Author interview with scientist)
In the past year, has the government space actor kept a public national registry of space objects?	1: Yes 0: No	(Group of Government Experts, 2013)
In the past year, has the space actor provided pre-launch notification of all space objects to the UN and relevant actors?	1: Yes 0: No	(Group of Government Experts, 2013)
Does the government space actor currently publish information on national space policies and strategies publicly?	1: Yes 0: No	(Group of Government Experts, 2013)
In the past year, has the space actor refused to engage with requests to observe space object launches and visits to launch sites and facilities, flight command and control centers, and other operation facilities of outer space infrastructure?	1: No 0: Yes	(United Nations Office for Outer Space Affairs, 1963, Article X), (Group of Government Experts, 2013)
Does the government space actor publish current major outer space research along with military and other national security expenditures related to space?	1: Yes 0: No	(Group of Government Experts, 2013)
In the past year, has the space actor refused access to stations, installations, equipment, or vehicles in space when there was due notice to increase safety and limit normal operations?	1: No 0: Yes	(United Nations Office for Outer Space Affairs, 1963, Article XII)
In the past year, has the space actor restricted access to or prevented other countries from exploring space in a way that restricts equal use?	1: Yes 0: No	(United Nations Office for Outer Space Affairs, 1963, Article I)

Has the government space actor actively prevented another country or corporation from accessing or exploring space, the moon, or celestial bodies?	1: No 0: Yes	(United Nations Office for Outer Space Affairs, 1963, Article I)
In the past year, has the government space actor returned objects from space that collided inside its territory to the originating country or corporation?	1: Yes 0: No	(United Nations Office for Outer Space Affairs, 1963) (United Nations Office for Outer Space Affairs, 2017, Article IV & V)
In the past year, has the space actor failed to properly compensate for any damage inflicted by space objects in accordance with the UN Liability Convention?	1: No 0: Yes	(United Nations Office for Outer Space Affairs, 2010)
In the past year, has the space actor allowed fellow space actors to use vehicles, equipment, stations, and installations for safety purposes on the moon and other celestial bodies?	1: Yes 0: No	(United Nations Office for Outer Space Affairs, 2010, Agreement Governing the Moon, Article 12)
Security & Safety *(13 pts.)*		
Question	Scoring	Citation
Has the government space actor nationally appropriated or claimed sovereignty over a celestial body, including the moon?	1: No 0:Yes	(United Nations Office for Outer Space Affairs, 1963, Article II)
Are there any military bases, installations, or fortifications on celestial bodies originating from the government space actor?	1: No 0: Yes	(United Nations Office for Outer Space Affairs, 1963, Article IV)
Has the space actor tested weapons on the moon or other celestial bodies?	1: No 0: Yes	(United Nations Office for Outer Space Affairs, 1963, Article IV)
Has the government space actor conducted military maneuvers on the moon or other celestial bodies?	1: No 0: Yes	(United Nations Office for Outer Space Affairs, 1963, Article IV)

Has the space actor placed a nuclear weapon or WMD in space or on a celestial body?	1: No 0: Yes	(United Nations Office for Outer Space Affairs, 1963, Article IV)
Do all of the nuclear-powered space objects operated by the space actor meet the requirements laid out in the "Safety Framework for Nuclear Power Source Applications in Outer Space?"	1: Yes 0: No	(United Nations Office for Outer Space Affairs, 2017)
In the past year, has the space actor conducted any purposeful physical interference with another organization's space object?	1: No 0: Yes	
In the past year, has the space actor using the radio frequency spectrum prevented other organizations from communicating with its respective satellites? Paying particular attention to developing countries so as not to box them out of space?	1: No 0: Yes	(United Nations Office of Outer Space Affairs & Committee on the Peaceful Uses of Outer Space, 2018), (United Nations Office of Outer Space Affairs & Committee on the Peaceful Uses of Outer Space, 2018)
In the past year, has the government space actor facilitated the prompt resolution of identified harmful radio frequency interference?	1: Yes 0: No	(United Nations Office of Outer Space Affairs & Committee on the Peaceful Uses of Outer Space, 2018)
In the past year, has the space actor interfered in another space actor's operation or failed to use measures of precaution when using sources of laser beams passing through outer space? This includes measuring the risk of malfunctioning of, damage to, or break-up of space objects due to lasers.	1: No 0: Yes	(United Nations Office of Outer Space Affairs & Committee on the Peaceful Uses of Outer Space, 2018)
In the past year, has the space actor informed the UN of any phenomena discovered in outer space or on celestial bodies that could endanger the life or health of astronauts or human space flight?	1: Yes 0: No	(United Nations Office for Outer Space Affairs, 1963, Article V), (Group of Government Experts, 2013)

In the past year, has the space actor provided reasonable assistance to astronauts in the event of an accident, distress, emergency landing, or when requested and kept interested parties and the UN up to date with assistance provided?	1: Yes 0: No	(United Nations Office for Outer Space Affairs, 1963, Article V), (United Nations Office for Outer Space Affairs, 2017, Article I & II)
Has the government space actor adopted, revised, and amended, as necessary, national regulator frameworks for outer space activities?	1: Yes 0: No	(United Nations Office of Outer Space Affairs & Committee on the Peaceful Uses of Outer Space, 2018)
<u>Sustainability</u> (19 pts.)		
Debris Mitigation *(Communication, Data Sharing, Maneuverability Requirements)*		
Question	Scoring	Citation
Has the space actor provided current contact information for communications regarding space objects and orbital events to the UN or other space situational awareness programs?	1: Yes 0: No	(United Nations Office of Outer Space Affairs & Committee on the Peaceful Uses of Outer Space, 2018), (Dickey, 2023)
In the past year, did the space actor fail to widely share telemetry data in the case of an emergency or if direct contact regarding a potential conjunction with the UN and other space actors?	1: No 0: Yes	(Dickey, 2023)
In the past year, did the space actor fail to share orbital data before launch, resulting in a collision in orbit?	1: No 0: Yes	(United Nations Office for Outer Space Affairs, 2010)
In the past year, has the space actor responded promptly to collision avoidance requests? (Within one day of contact)	1: Yes 0: No	(Dickey, 2023), (United Nations Office for Outer Space Affairs, 2010)

In the past year, has the space actor consulted the UN and other member countries before undertaking any activities that could cause harm or restrict the ability to peacefully explore space, the moon, or other celestial bodies?	1: Yes 0: No	(United Nations Office for Outer Space Affairs, 1963, Article IX)
In the past year, has the space actor informed the UN and the appropriate parties of any damage to a space object that could become hazardous to space operations (including intentional orbital breakups)?	1: Yes 0: No	(United Nations Office for Outer Space Affairs, 2010, Registration of Objects, Article VI), (Group of Government Experts, 2013)
In the past year, has the space actor notified the UN and relative space actors of possible conjunctions upon immediate discovery?	1: Yes 0: No	(Group of Government Experts, 2013)
In the past year, has the space actor failed to notify the UN of maneuvers that may risk the flight safety of other space objects?	1: No 0: Yes	(Group of Government Experts, 2013)
In the past year, has the space actor avoided and notified the UN of any potential uncontrolled high-risk re-entry events of space objects or residual materials that might create damage or radioactive contamination?	1: Yes 0: No	(Group of Government Experts, 2013)
In the past year, has the space actor launched any space objects that *did not* mitigate risks that could cause malfunctioning space objects or loss of control that could contribute to an increased probability of a high-risk re-entry event or collision?	1: No 0: Yes	(Group of Government Experts, 2013)
In the past year, has the space actor remained at least 1 km away in LEO or 73 km away in GEO from another organization's satellite?	1: Yes 0: No	(Author's interview with a scientist)
In the past year, has the space actor deorbited or placed end-of-life satellites into a disposal orbit promptly after its mission is complete?	1: Yes 0: No	(United Nations Office for Outer Space Affairs, 2010), (Space Sustainability Rating, n.d.)
In the past year, has the space actor passivated all spacecraft and launch vehicles after its operational lifetime? This includes the removal of all stored energy,	1: Yes 0: No	(Space Sustainability Rating, n.d.), (United

residual propellants, compressed fluids, and the complete discharge of electrical storage devices.		Nations Office for Outer Space Affairs, 2010)
In the past year, has the space actor caused any harmful contamination or adverse Earth environmental changes due to space missions?	1: No 0: Yes	(United Nations Office for Outer Space Affairs, 1963, Article IX)
In the past year, has an object launched by the space actor released debris in orbit that was not either deorbited or property placed in a disposal orbit? This includes ensuring that space objects deorbit in a controlled fashion and that space objects are placed in a disposal orbit that avoids long-term interference with or return to GEO.	1: No 0: Yes	(Space Sustainability Rating, n.d.), (United Nations Office for Outer Space Affairs, 2010)
In the past year, did the space actor experience any accidental break-ups due to failures in design, disposal, or passivation measures?	1: No 0: Yes	(United Nations Office for Outer Space Affairs, 2010)
In the past year, has the space actor engaged in any intentional destruction of space objects that caused debris creation?	1: No 0: Yes	(United Nations Office for Outer Space Affairs, 2010),
In the past year, did the space actor fail to adhere to common space maneuvering norms laid out in the maneuverability framework below?	1: No 0: Yes	(United Nations Office for Outer Space Affairs, 2010), (Space Safety Coalition, 2023)
In the past year, has the space actor participated in active debris removal?	1: No 0: Yes	(Space Sustainability Rating, n.d.)

Maneuverability Guidelines
This framework and the following guidelines show how and when space objects are obligated to move to avoid conjunction.

General Rules for Maneuverability:

1. The more maneuverable spacecraft should maneuver to avoid conjunction.
2. Spacecraft in mission orbits have the right of way.
3. Spacecraft less able to maneuver due to payload or mission should be identified and made public before launch.
4. Continued monitoring of potential conjunctions is required by all involved parties.

(Dickey, 2023)
Maneuverability Framework:

	Nonmaneuverable	**Minimally Maneuverable**	**Maneuverable**	**Automated collision avoidance**	**Crewed**
Nonmaneuverable	N/A	Minimally maneuverable S/C moves	Maneuverable S/C moves	Automated COLA S/C moves	Crewed vehicle moves
Minimally Maneuverable		Satellites moving into or out of their designated mission orbit should yield to satellites in their mission orbit. Otherwise, decided in bilateral discussion.	Maneuverable S/C Moves	Automated COLA S/C moves	Crewed vehicle moves, unless other arrangements are in place
Maneuverable			Satellites moving into or out of their designated mission orbit should yield to satellites in their mission orbit. Otherwise, (or in cases where both satellites are moving into or out of their mission orbits), decided in bilateral discussion.	Automated COLA S/C moves	Crewed vehicle moves, unless other arrangements are in place
Automated collision avoidance				Established via pre-coordinated agreement	Crewed vehicle moves, unless other arrangements are in place
Crewed					Bilateral discussion to determine who maneuvers.

(Space Safety Coalition, 2023)

Matrix for Compliance Scoring

The following matrix can be used to evaluate the compliance of responsible behavior in space. C stands for Compliant, PC stands for Partially Compliant, and NC stands for Non-Compliant.

Evaluation Matrix

Safety	Sustainability					
	0-3	4-6	7-9	10-13	14-16	17-20
26-28	PC	PC	PC	C	C	C
21-25	PC	PC	PC	PC	C	C
16-20	PC	PC	PC	PC	PC	C
11-15	NC	PC	PC	PC	PC	PC
6-10	NC	NC	PC	PC	PC	PC
0-5	NC	NC	NC	PC	PC	PC

(Freedom in the World, n.d.)

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