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New Challenges for International Space Law: Artificial Intelligence and Liability

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Abstract

Advances in Artificial intelligence (AI) and robotics will have a revolutionary impact on space operations. Utilising machine learning and deep learning techniques, AI-enabled systems are capable of both performing tasks and improving their own performance. These capabilities are powerful in the often-remote environments of outer space and will become increasingly valuable as automated space operations spread. As AI proliferates throughout the space domain, algorithms will assume many of the responsibilities traditionally overseen by humans. By exposing new satellites and orbital autonomous vehicles to new data, AI is moving from theory to application in the space environment. However, even when all initial algorithmic parameters are specified, the outputs of such systems can still be highly unpredictable, risking harm to people, property, and the environment. The operation of the Outer Space Treaty, the Liability Convention, and the Registration Convention in conjunction with AI systems encounters ambiguities that need to be clarified to ensure liability can be properly attributed in the case of damages occurring involving a space-based AI system. This paper examines the application of the United Nations space treaties, select transnational and domestic AI regulations, and various 'soft-law' instruments focused on the responsible development of AI systems to space-based AI systems. Reforms are then proposed to clarify the relationship between AI systems and the international legal regime that governs space in a practical manner as well as a 'bottom-up' regulatory approach to better facilitate the future development of regulation governing the use of AI by the global space sector.

Keywords: Artificial Intelligence, Guidelines and Technical Standards, International Law, Liability, National Law and Regulation, Responsible AI, Space Law.

1. Introduction

The AI and space industries are worth around USD 136.6 billion and half a trillion USD per year and are projected to grow to USD 1.8 trillion and USD 1-3 trillion, by 2030 and 2040, respectively.[1], [2, p. 4], [3], [4, p. 74] These industries are driving technological innovation, but regulation is struggling to keep pace with their rapid expansion. The primary challenge is creating regulation that can address risks and harms posed by these new technologies while remaining responsive to fast-moving technological and economic developments.[4, p. 76]

AI and space technology is being combined in a number of ways to enable sophisticated space operations: astronaut assistants, space healthcare,[5, p. 537] mission design and planning,[6] satellite data processing, space debris mitigation,[7] real-time condition monitoring of spacecraft parameters,[8, pp. 4–5] and automated propulsion and navigation systems, all integrate various forms of AI technologies.[9, p. 2] AI is also being used for weather and atmospheric monitoring, detection and classification of vegetation and ground cover,[9] large-scale climate modelling,[10], [11] object detection, tracking, and removal,[8, p. 3] and data downlink volume reduction (e.g. AI *in situ* recognising clouds in images and only transmitting images not containing clouds) to support terrestrial analysis of data gathered in space.[12, p. 49], [13]–[16] The potential for AI to be utilised *in situ* has expanded as 'edge computing' platforms designed for AI on board satellites have come to maturity, enabling many more possible use cases going forward.[8], [12, pp. 48–49] Some applications of space-based AI systems are shown in Figure 1.

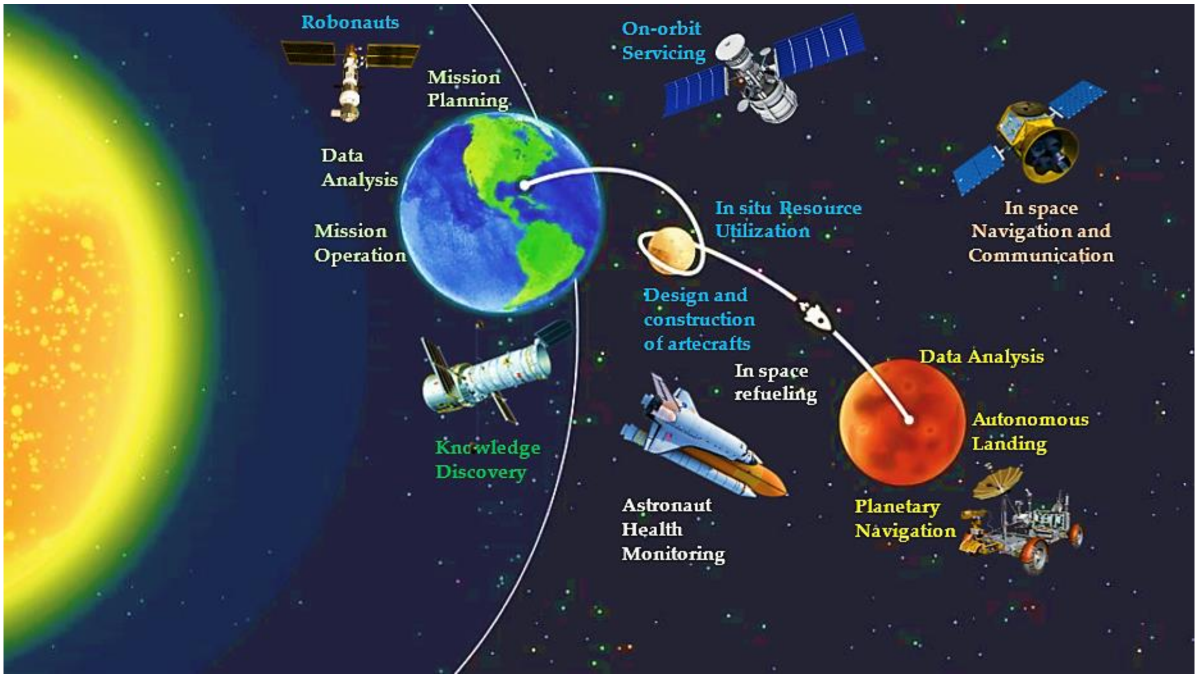

Fig. 1. AI-augmented space activities

The regulation of AI technologies will be important as they mature and become more widespread. As the value of these systems and the associated risks of harm to individuals, property, and the environment become more apparent, guidance is needed to ensure standards of quality in the development and use of space-based AI systems.[17, p. 7]

Operational standards for space-based AI systems are therefore required to maximise safe operation and prevent or mitigate potential harm to the greatest extent possible. Two specific use cases illustrate the potential harms well: Earth Observation (EO) and Space Traffic Management (STM). EO involves the potential for privacy breaches stemming from the AI-enabled insights and analysis of high temporal and spatial resolution satellite photography. STM deals with orbital traffic and space debris, including the need for automated satellite and spacecraft manoeuvring to avoid collisions as orbits become more crowded.[18]–[20] As of 2019, satellite operators were already spending 14 million euros per year to avoid collisions, despite 99% of conjunction predictions being false alerts.[21, p. 27] These examples demonstrate the potential for harm to individuals, property, and the orbital environment if space-based AI systems do not operate within the law and in a highly accurate manner.

Many different legislative and regulatory regimes may be applicable when examining the intersection of the space industry and AI technologies.[17, p. 4] International space law, domestic regimes governing space and AI, and industry guidelines and standards are all relevant to the regulation of space-based AI activities. The current lack of binding regulation has led to the development of non-binding industry approaches to guide the responsible development and use of AI. Although these approaches lack the authority of binding legal treaties, they still represent a political commitment from States and their space agencies regarding their use of AI technologies. These approaches also provide guidance and clarity regarding existing laws and regulations governing space-based AI systems while illuminating a path toward the future development of legally binding instruments.

By reviewing the existing law and regulations related to liability in the context of space-based AI systems, this paper aims to explore the existing limits of regulation governing this area and suggest options for addressing regulatory gaps going forward.

2. International Law

In order to have a discussion with the aim of informing discourse regarding the regulation of AI in space, it is necessary to review the pertinent international legal instruments. Five space treaties were negotiated and drafted under the auspices of the United Nations (UN), relevantly including the Outer Space Treaty (OST),[22] the Liability Convention,[23] and the Registration Convention.[24] These instruments were drafted in the 1960s and 1970s and focus on preventing conflict in outer space. These treaties do not directly address AI,[25, p. 16] but they form a foundational basis for regulating space activities and enjoy nearly universal adoption in the international community. Some have suggested a new space treaty to explicitly address modern developments like AI in space,[26], [27, pp. 310–311] but this seems unlikely to develop soon due to a present lack of political willpower. Instead, it may be more practical to clarify existing treaty obligations through guidelines and confidence-building measures.[4, p. 77], [27, p. 333], [28, p. 174]

The OST establishes key principles of space law such as the non-appropriation of outer space by nations,[22, Art. II] the applicability of international law to activities in space,[22, Art. III] the responsibility of States for national activities in outer space,[22, Art. VI] the liability of States to other State parties for damages caused by their space objects,[22, Art. VII] and the jurisdiction of States over objects sent into space.[22, p. VIII] Although Article III imports international law to activities in outer space, and so could recognise new norms if they reached the level of customary international law as demonstrated through *opinio juris*,[27, pp. 316–317] this cannot be interpreted as a 'catch all' provision which allows any other international legal principles to be applied to this unique domain and has not been treated as such by the international community.[4, pp. 76–77]

The Liability Convention expands on Article VII of the OST by outlining a dual-pronged liability regime, based on fault and absolute liability, depending on the location of the damage.[23, Art. II–III], [29] This treaty is important in regard to damage to space objects caused by space debris and collisions between space objects controlled by automated systems. The Liability Convention holds launching States jointly and severally liable for any damage caused,[23, Art. V] encouraging States to mitigate risks and comply with best practices and international treaty obligations. Given that liability is not limited under the Convention, this motivates States to develop appropriate national space legislation.[30, p. 4]

The Registration Convention concerns the registration of objects sent into space, with details recorded in both State-based registers and a UN-based international register.[24, Art. II–III] These registers include details of the launching State of the object(s), the name/designator of the object(s), the time and place of launch, orbital parameters, and the general function of the object.[24, Art. IV] Importantly, the Convention adopts the definitions of "launching State" and "space object" found in the Liability Convention.[24, Art. I]

2.1 Issues with AI under International Space Law

The lack of settled jurisprudence regarding liability for space-based AI systems raises many questions that cannot be addressed in one paper. This paper instead seeks to flag some limited aspects of the definitions and liability mechanisms outlined in the treaties that require clarification.

As an example, one question concerns whether AI can be considered a 'space object' for the purposes of the Liability and Registration Conventions and consequently (or rather separately) whether AI systems should be registered in a similar way to physical objects, especially given the lack of physical characteristics that AI systems possess. Definitions included in the Liability Convention highlight the uncertainty of its application to AI systems. Given "launching States" are the entities which incur liability, the definition of a "launching State" should be examined. Article I(c) articulates that a "launching State" means "A State which launches or procures the launching of a space object" or "A State from whose territory or facility a space object is launched".[23, Art. I(c)] No specific definition or example of "space object" is provided in the OST, but a generally accepted definition is that a "space object" is "any man-made object, launched or intended to be launched in outer space, including any non-functional objects, especially space debris."[31, p. 3] Continuing, the definition provided by the Liability Convention of "space object" "includes ***component parts*** of a space object as well as its launch vehicle and parts thereof" [emphasis added].[23, Art. I(d)] Component parts is not defined in the document, and no examples are provided, making it a highly ambiguous term.[32, p. 6] Looking to authoritative dictionaries, "component part" is defined as a compound phrase meaning "something (as a building or part of a building) that cannot be removed without ***substantial damage*** to itself or to the immovable property to which it is attached" [emphasis added].[33] This definition is aligned with the interpretation of other authors who have focused on the physical structure of the 'greater' space object, where the lack of a "component part' would render the 'greater' object incomplete.[34, p. 607] In the context of AI in space, this could be interpreted to mean that an AI system that could not be removed without causing substantial damage to the object on which it resides could in itself constitute a space object for the purposes of the Liability Convention and thus attract liability to a State which procures the launching of the AI aboard said object, in addition to the other States involved.[23, Art. V] This would be relevant where a State not otherwise involved in launching a Space object could be considered to have procured the AI on board, making it a launching State through procurement of a space object, and thus this could have serious implications regarding liability, licensing, and insurance arrangements for parties involved in *in situ* AI deployments.

Aside from the limited scope of application imposed by the vague terminology regarding "substantial damage", the interpretation outlined above is dependent on either a 'purposive' interpretation of the definition of "component part", with damage being done to the ability of the space object to perform its task, or a broad interpretation of 'object' beyond traditional physical and tangible notions. The distinction is relevant as scholars are divided as to whether the term "space object" should be taken to mean only physical objects, or also intangible objects (such as electromagnetic signals).[32, p. 6], [35, p. 434] Given that AI is a form of software composed of code, and that code is a particular configuration of matter which is then read by hardware, it could be considered to have a physical form, thus avoiding the distinction. However, this logic would also apply to non-AI enabled software, making this argument much broader and consequently more difficult to justify as regular software (regardless of its importance in contributing to the function of the 'greater' space object to which it belongs) is unlikely to be considered an independent space object.[31, p. 3] The literal approach to defining "space object" has so far gained the most support,[32, p. 6] and in the case of *in situ* AI systems, the lack of physical independence from the 'greater' space object to which it is attached can be used to argue that AI itself (without the hardware on which it sits) should not be considered an independent space object.[36, p. 165]

As such the broad interpretation of "space object" above would be by no means universally accepted, nor would its operation be clear.[32, p. 7] However, it does illustrate one instance of the unclear application of the Liability Convention to AI systems operating in space and the need for clarification as the capabilities of actors within the space industry evolve. The Liability Convention's ambiguous and untested provisions on damages and claims have therefore made contractual and insurance arrangements of central importance in space mission planning due to commercial actors' preference for private risk allocation to avoid issues of double insurance and disputes.[37, p. 22], [2, p. 20], [31, p. 7] It is worth noting that the European Union has moved to provide their own definition of "space object", meaning "any man-made object in outer space". [38, Art. 2(2)] This is a similarly vague definition which will likely also require clarification in the future.

Separately, as others have noted, the Liability Convention does not directly contemplate the operation of AI systems in space, leading to confusion surrounding issues of causation and the attribution of fault and liability in the event of damage caused by AI-enabled space objects.[2, pp. 7–8], [35, p. 437], contra [31, p. 6] These issues are broader in scope and potentially more cumbersome to overcome than the definitional issues discussed above, and are largely beyond the scope of this paper. Some have proposed that launching States should be held liable for damage caused by AI enabled space objects, as the liability system is based on the launching State(s) of an object.[2, p. 8] This suggests that launching States must authorise and supervise all "intelligent" space objects launched they are responsible for, ensuring they exercise due diligence in taking steps to prevent potential damage.[2, pp. 9–10], [17, p. 6] Such a proposal could meet resistance in the form of launching States that do not wish to be held jointly and severally liable for damage they claim to be caused by a poorly designed AI system procured by another launching State beyond their control.

2.2 Potential International Law Solutions

The international legal framework governing space activities is currently insufficient to address AI-related damage claims in space and could be improved through amendments or new multilateral treaties.[2, p. 20] One potential solution is a supplemental binding protocol to the Liability Convention that clarifies concepts such as "space object", "damages", "fault" and "gross negligence", and clarifies links between the OST and the Liability Convention which muddy the application of existing international space law norms to AI systems.[32, p. 7], [35, p. 440] For example, a revised definition of "space object" could include "any item launched or attempted to be launched physically into outer space. It includes all its tangible and intangible components, such as software, hardware, equipment, installations, launch vehicles, and other parts thereof, without which, the full operation of the space object would not be construed as possible".[32, p. 7] This would provide greater clarity and certainty for those dealing with AI-related damages while remaining compatible with the existing definition of space object under the Liability Convention.

The idea of creating a special registry to track the details of AI-enabled space objects has been proposed as a way to increase transparency in AI-related space activities.[17, p. 7], [39, p. 144] The registry could record information such as the type of AI model used, the purpose of the system, who created it and who licenses/operates it, a general description of the type of data used to train the relevant AI models, and the launching State associated with the objects. While such a system could help clarify the design, operation, and ownership of AI systems, it may face resistance due to organisations' reluctance to publicly disclose sensitive information and open themselves to potential legal and financial obligations in the event of an accident. The design and implementation of such a registry would need to be carefully considered and negotiated to ensure widespread adoption.[17, p. 7]

Separately, it has been suggested that principles of international law could be imported to the space domain through Article III of the Outer Space Treaty to clarify States' obligations under Article IX regarding due diligence and fault.[35, pp. 441–442] While this approach has appeal, the unique legal and technological context of outer space should be taken into account and international legal principles should be tailored to the domain to avoid future regulatory issues.[40, p. 15]

While the above propositions would be constructive, reforming international space law to address AI-related issues may be difficult as evidenced by the lack of new treaties since the 1979 *Moon Agreement* and the difficulties in amending existing treaties.[41], [31, p. 1], [35, p. 443] Further, any supplemental protocols would only apply to States which choose to ratify said protocols, potentially leading to a fractured international regulatory landscape. The international space law community is also currently focused on issues surrounding space debris and space traffic management, so it is unlikely that there will be significant international regulation of AI in space beyond these issues in the near future. Gaps in the current framework will likely need to be addressed through national AI legislation, insurance, and industry standards and guidelines for the foreseeable future.

3. Transnational and Domestic Regulation

The fact that States retain jurisdiction over their space objects suggests that national law applies to them,[30, p. 4] and as such any AI onboard a space object would be controlled by national legislation even in space.[42] Many nations have laws governing their space activities as required by Article VI of the OST, but they generally do not directly address automated systems. Direct inclusion of provisions intended to cover the gaps and ambiguities of international space law represents a clear way to create certainty for organisations operating within their jurisdiction.[30, p. 9] However, this is unlikely to occur in the near future as general AI regulations are still nascent in almost all jurisdictions.

It is therefore important to examine national laws governing AI systems outside the space domain. These laws often aim to balance the interests of private sectors and States, protect the public, and promote innovation. Examining the approaches of other sectors can provide insight into the direction global AI regulation is moving in and the rules that space industry actors must follow based on the location of their operations.[30], [43]

3.1 The European Approach

The European Union's proposed Artificial Intelligence Act (EU AI Act) aims to regulate AI by categorising systems into four risk categories ranging from "minimal or no risk" to "unacceptable risk" and implementing governing mechanisms accordingly.[44] Systems deemed to present an "unacceptable risk" will be prohibited,[44, Tit. II, Art. 5] while those assessed to present higher risk must meet certain requirements.

The Act will likely be adopted later in 2023 and will require high-risk systems to have risk management systems, data governance mechanisms, technical documentation, and record keeping systems.[44, Tit. III, Ch. 2, Art. 9-12] Further they must be designed to allow for transparency and provision of information to users, effective human oversights, and accuracy, robustness, and cybersecurity throughout their lifecycle.[44, Tit. III, Ch. 2, Art. 13-15, see also Tit. IV, Art. 52] The providers of such systems must also ensure they have an appropriate quality management system in place to ensure compliance with this regulation, in addition to drawing up technical documentation, undergoing conformity assessments, and automatically generating logs from their systems as required.[44, Tit. III, Art. 17-20, see also Ch. 5, Art. 43] After deployment of a system, providers must also establish and document a post-market monitoring system,[44, Tit. VIII, Ch. 1, Art. 61] and share information relating to any incidents and malfunctioning of their system that breach their legal obligations.[44, Tit. VIII, Ch. 2, Art. 62]

The Act will also grant compliant AI systems a declaration of conformity and a mark of conformity to communicate the quality of their systems to the market.[44, Tit. III, Ch. 5, Art. 48-49] It also provides regulatory sandboxes for testing AI systems with safeguards,[44, Tit. V, Art. 53-54] and gives small and medium-sized enterprises (SMEs) priority access to support measures to ensure market access and foster growth.[44, Tit. V, Art. 55]

The Act has faced some criticism for its narrow definition of AI and its potential impacts on human rights,[44, Tit. I, Art. 3(1)], [45], [46, pp. 14–15] but its penalties (up to €30 million or 6% of annual turnover) and scope (applying to any AI provider that implements or develops an AI system in the EU) make it significant,[44, Tit. X, Art. 71] even for large multinational corporations.

The EU AI Act is complemented by two additional directives. The first updates the general product liability directive to include AI standards and make those who provide software or services that affect the AI product or make changes to it through updates or machine learning liable, as well as the manufacturer.[47, p. Ch. II, Art. 7(4); see Ch. I, Art. 4] This provides certainty for businesses and allows EU manufacturers to seek redress from importers or foreign manufacturers.[47, Ch. II, Art. 7(2)] It also requires manufacturers to disclose evidence and makes it easier for victims to prove causation and liability in the event of harm occurring.[47, Ch. II, Art. 8-9; Ch. III, Art. 14; p. 5] The second directive aims to address AI liability by providing a system for seeking compensation where normal liability rules do not apply and requires access to evidence from companies in cases of harm caused by high-risk AI systems.[48, Art. 3], [49] It also changes the burden of proof by adding a rebuttable "presumption of causality" to avoid the need to explain the details of an AI system's inner workings.[48, Art. 4] This is of particular importance given the long-standing issues surrounding causation and its links to the concept of 'foreseeability' as related to the actions of AI systems and liability.[30, p. 3]

The EU AI Act is relevant for space mission operators based in the EU or using Earth observation systems with imagery of the EU, as the data would be considered personal data and an output of the system,[2, p. 12] bringing it within the Act's jurisdiction. There may also be an argument that certain AI systems used in space could be classified as "high risk" depending on their use in the event they manage or operate critical infrastructure, though this is unclear.[44, p. Annex III, Art. 5(c)]

Separately, the European Parliament's Regulation 696/2021 directs the Copernicus mission to incorporate AI into its operations and suggests considering the Commission's white paper on "excellence and trust" in AI systems.[38, Para. 72], [50] This suggests that considerations of ethics and trust in AI may become important in the space industry's AI development. It would be ideal for future legislation to include explicit reference to space AI systems and their risk-based governance classification under European law.[30, p. 10]

3.2 United States of America

The U.S. has several laws related to private space activities, but they do not address AI systems.[51]–[53] Currently the US does not have federal legislation regulating AI systems. However, the Algorithmic Accountability Act of 2022 (AAA) has been proposed at the federal level.[54] It would require companies to assess bias and effectiveness when using automated decision-making systems. The AAA is similar to the EU AI Act but takes a high-level approach and leaves implementation to the Federal Trade Commission (FTC).[55, p. 2]

The AAA requires organisations to assess the impact of automated decision-making systems before and after their deployment,[54, Sec. 3] similar to the conformity assessments found under the EU AI Act.[55, p. 2] Contrastingly, the AAA focuses on regulating "critical decision processes" and has a broader scope than the EU AI Act,[54, Sec. 2] requiring conformity assessments for all automated decision-making systems with significant effects on consumer's access to the types of services listed in the Act (compared to only 'high risk' systems in the EU).[54, Sec. 2(8)] Because of this, it could be argued that the AAA is more technology agnostic and is better prepared for the future of AI development compared to the EU AI Act.[55, p. 3], [45]

However, the AAA only applies to "large companies" with an annual turnover over USD 50 million, equity value over USD 250 million, or that process the information of over 1 million users.[54, Sec. 2(7)] This limits its ability to protect individuals and may lead to complicated legal and accounting arrangements by large organisations to avoid regulatory oversight.[55, p. 4] The EU AI Act has a better model of placing consistent requirements on all organisations while providing support to SMEs to enable compliance without disadvantaging them compared to larger competitors.[44, Tit. V, Art. 55], [55, p. 4]

Unfortunately, legislation regulating technology is difficult to pass in the U.S. and proposed Acts are unlikely to progress soon.[55, p. 6], [56] However, initiatives such as the White House's "Blueprint for an AI Bill of Rights" and the NIST's development of AI standards and the "Trustworthy and Responsible AI Resource Centre" indicates an increasing awareness of the need for AI regulation in the U.S.[57], [58]

Specific to space AI, NASA has released an AI ethics framework outlining ethical principles for the development and use of AI in space activities.[59] NASA has also committed to promoting responsible AI in response to Executive Order 13960,[60], [61] though the specifics of the commitment have not yet been fully developed. This move by NASA signals the direction in which AI regulation is likely headed and the culture that space industry players should adopt in order to align with NASA and its supply chain.

3.3 Australia

The Australian regulatory situation, lacking modern AI laws but recognising the need for reform, is similar to many jurisdictions around the world. Australia has a space agency and a growing space industry, but its space legislation, the Launches and Returns Act 2018, does not have provisions related to AI systems.[62] The country relies on traditional consumer and privacy laws to address potential issues with AI, but these laws do not specifically address AI.[63], [64] In 2019, the Australian government released "Australia's Artificial Intelligence Ethics Framework" which consists of eight principles to ensure the safety, security, and reliability of AI systems developed in the country.[65] The Australian Human Rights Commission also released a report with recommendations for the use of automated decision making, including the creation of an "AI Safety Commissioner" and a statutory cause of action for serious invasions of privacy.[66, pp. 193–199] The recent New South Wales AI Assurance Framework requires reviews of government AI projects under certain conditions and takes into account ethical AI principles when determining the risks and benefits of a project.[67] While many AI guidelines and principles are intended for widespread use, there has been opposition to industry agnostic certification standards for AI, with industry arguing that different sectors may have different needs for regulation.[66, p. 93], [68, p. 1] Recently, the Australian government has agreed to consider using international space standards such as those used by the European Space Agency and NASA for all Commonwealth space procurements.[69, pp. 10, Rec. 15(3.146)] It has also agreed to lead the implementation of the Guidelines for the Long-Term Sustainability of Outer Space Activities,[69, pp. 15, Rec. 26(5.66)] and which relevantly encourages the adoption of international technical standards.[70, R. A.2(f)] The government has also agreed to participate in international forums to develop norms of behaviour in outer space.[69, pp. 15, Rec. 28(5.68)] These statements show that the government is considering and accepting the need for safety and certainty in outer space activities.

3.4 The Brussels Effect – A Path to Consistent Regulation

Several other countries, including the United Kingdom, Canada, Japan, China, South Korea, and Singapore have also begun to introduce measures to regulate AI systems, though their efforts vary in terms of maturity.[43, Sec. 2.2] These frameworks do not typically match the scope and scale of those in the EU or US, and there is no consistent "State practice" between jurisdictions that could be considered *opinio juris* and recognised as international law under the OST.[22, Art. III] This underscores the need for regulatory convergence between jurisdictions to avoid many fragmented approached to AI regulation occurring that would create a complex and inefficient regulatory environment for those operating across multiple jurisdictions.

To this end, nations should seek to harmonise their regulation and policies with existing regulatory initiatives such as the EU AI Act to create an interoperable system of controls and redress schemes.[30, p. 10] It is imperative that in developing regulations to govern space-based AI globally, non-western space actors should be included in ongoing discussions to avoid a bifurcation of regulatory policies that could enable harm or damage to individuals, property, or the environment in the future. The importance of maintaining a safe and conflict free space domain for economic, scientific, and environmental purposes necessitates that all States (regardless of technical capability or diplomatic position) be engaged to ensure they are all working in concert to preserve the outer space environment for the peaceful use of all humankind.[22, Art. I]

The EU AI Act has the potential to set a global standard for AI regulation through a "Brussels Effect" similar to that associated with the EU's General Data Protection Regulation.[71] The legislation's requirements may make it more feasible for organisations to create a single EU-compliant system for their products and services, rather than maintaining multiple standards within their organisation. The EU's ability to negotiate and enforce complex regulatory regimes also lends it credibility to become a leading actor in regulating AI in space,[39, pp. 134, 142] this is especially so given the negotiation process involved in drafting the EU AI Act reflects the ideals of consultation and consensus in international space law development within the UN Committee on the Peaceful Uses of Outer Space (COPUOS).[72, Para. 4] The "Brussels Effect" and extraterritorial nature of the EU AI Act make it applicable to space-based AI systems, which often operate across multiple jurisdictions. For instance, EO systems usually image large swathes of the planet, with orbital paths covering multiple geographic regions and the legal jurisdictions within them. It is likely easier for those using AI systems that process EO data to create a single system that adheres to the strict requirements of the EU AI Act (as opposed to many systems conforming to different regulatory frameworks), leading the EU AI Act to potentially set the standard for space-AI systems globally.

The EU AI Act is more comprehensive and far-reaching than the US AAA and is more likely to become a quasi-standard due to its thoughtfully constructed nature.[55, p. 5] While the US AAA may not produce a comparable "Washington Effect", the US economy and technological leadership could still influence AI governance practices.[55, p. 5] An agreement between the EU and US to cooperate on the development of a roadmap for trustworthy AI and risk management, along with a lack of coordinated regulatory strategy in the US, makes a bifurcation of regulatory approaches between the two major western markets unlikely.[73]

4. International Guidelines, Standards, and other 'Soft-Law' Guidance

'Soft-law' instruments, such as guidelines, standards, and confidence-building measures, can be useful in shaping a mature environment for the regulation of space and AI activities in the absence of clear international and national law. Widespread adoption of these standards can facilitate the negotiation of binding legal documents and potentially influence the development of customary international law.[25, p. 17]

Documents such as the *Space Debris Mitigation Guidelines* and the *Long-Term Sustainability Guidelines* from COPUOS provide guidance for responsible space activities, with a focus on safety and debris mitigation.[70], [74] The Long-Term Sustainability Guidelines also encourage the use of international technical standards, including those from the International Organization for Standardization (ISO), in developing regulatory frameworks for outer space activities, including for space AI systems.[70, R. A.2(f)]

International standards organisations such as the ISO and the Institute of Electrical and Electronics Engineers (IEEE) are creating level playing fields between jurisdictions by developing and implementing performance and safety standards and conformity assessments for products and processes. These organisations are now focusing on AI standardisation and have formed dedicated committees to produce AI standards and assessment models. The ISO has formed a Subcommittee on AI (SC42) to develop standards for technical aspects of AI development and conformity assessments and is also publishing guidelines for AI management systems.[75] The IEEE is creating AI standards on trustworthy AI, ethics, bias, and system quality, including the Standard for Transparency of Autonomous Systems.[76] International standards can be used to determine fault and liability for damages in the event of collisions under the Liability Convention,[77] particularly in the context of AI-enabled systems in space. A commitment to standards combined with a lack of compliance can indicate fault, as a State that has voluntarily agreed to use the standard should be aware of the risks associated with its planned space activities.[78, p. 297] The incorporation of voluntary international standards for AI development and deployment by States as part of their national regulatory frameworks for space could also assist in resolving questions about fault in relation to AI systems under Article III of the Liability Convention for the same reasons.

Additionally, several international organisations have published documents on responsible AI development. The United Nations Chief Executives Board (UN CEB) has emphasized the importance of "ethical" AI in its discourse,[79] and UNESCO's 193 member States have adopted a global agreement on ethical AI development.[80] The Organisation for Economic Co-operation and Development (OECD) has also endorsed principles for robust, safe, fair, and trustworthy AI, which have been adopted by 42 countries,[81] and the World Economic Forum (WEF) has released a white paper regarding public sector procurement of trustworthy AI systems.[82] These initiatives reflect a shift in the way AI development is discussed and may influence future regulation and expectations within the industry.

4.1 A bottom-up approach to the regulation of space-based AI

Due to the difficulty of negotiating new legally enforceable instruments at the international level, it is likely that the most effective way to reach an agreement on the international level on the regulation of AI in space will be through the use of guidelines and standards. This process would begin with non-binding non-governmental guidance documents, before moving to enforce these documents through national regulation, then finally negotiating binding international agreements, thus working from the 'bottom-up' on a scale of substantive international commitment and norm creation. Initial guiding documents could take the form of "Guidelines for Automated Activities in Space," akin to the *Long-Term Sustainability Guidelines*,[70] and could lead to the development of more substantive rules in the future.[17, p. 7] There is concern that non-binding guidelines for regulating AI in space guidelines for regulating AI may not provide sufficient protections and can be difficult to enforce.[39, p. 141], [83, p. 50] Therefore, it is preferable to transition to traditional, enforceable legislative approaches to ensure safety and predictability in space operations.[66, p. 88]

In addition to promoting such initiatives through traditional forums such as COPUOS, a practical step towards enforceable regulation is through the introduction of requirements to adhere to technical standards and guidelines under national laws. States should enforce "best practices" such as explainability measures, model certification, documentation of training protocols, and other responsible AI governance behaviours to reduce the potential for failures and incidents caused by space-based AI systems that could expose them to liability under the Liability Convention.[84], [30, p. 10] Regulatory requirements could include a requirement to submit an 'Artificial Intelligence Impact Assessment' (AIIA) to demonstrate the responsible and safe operation of AI systems incorporated into a payload through the licensing process under national legislation. AIIA's or other certificates indicating compliance with standards are emerging as key regulatory tools in the AI governance field.[85] Enforcing such regulatory requirements can help create a more certain regulatory environment for organisations operating across jurisdictions while enabling States to exercise control over their national space sector in compliance with their obligations under the OST and other treaties.[39, p. 143]

Enforcement of new regulations and standards could also happen by proxy due to financial factors. Regardless of national regulation, insurance companies may request potential customers submit detailed AIIAs or compliance certificates to ensure that the risk in insuring them is low enough to justify exposure to significant liability in the event of a claim. This is especially so given the increasing risk of conjunction events in orbit, and the difficulty of insurers in maintaining profitable business models as space debris proliferates.[86, p. 25]

While this approach does not immediately resolve the aforementioned issues at the international law level, enforcing technical standards and guidelines can reduce the chances of poorly designed and operated AI systems causing harm or damage in outer space, which may mitigate the need to consult the international liability framework. This gives the international community time to propose, debate, negotiate, and implement reforms to the existing liability framework. Further, as more nations adopt similar regulatory practices, a form of international custom may emerge,[87, Art. 38(1)(b)] enabling greater potential for binding agreement at the international level, allowing for potential reforms to international law to gain momentum. This 'bottom-up' approach to regulating AI in space, which involves the negotiation of non-binding guidance documents with the aim of harmonising approaches to AI regulation between jurisdictions and preventing fragmentation and disparity between different national legislative frameworks, and implementing the negotiated guidelines through national legislation, is currently favoured by the international community. This process can help create multilateral agreements to clarify the obligations of actors using automated systems in outer space and promote adherence to the core treaty framework and principles of the OST.[39, pp. 137, 140]

5. Conclusions

The development of AI systems for use in outer space will bring many opportunities and applications both *in situ* and to benefit life on Earth. The international legal framework governing space raises many questions as to the operation of existing international space law and the determination of liability in the event of damage occurring due to AI systems.

The international space law framework provides a system for allocating liability in the event of damage occurring but was not designed to accommodate the advent of AI systems and their growing role in space activities, creating ambiguities in the application of the framework to AI systems. While multiple solutions have been put forward to remedy the international regime, they are unlikely to progress soon due factors such as the lack of political willpower and requirement of consensus within COPUOS. Because of this, answers should be sought through the development of domestic level regulations.

Individual nations should implement AI regulation to govern the use of such systems on Earth, taking guidance from jurisdictions with advanced frameworks (namely the EU) to create a consistent set of rules across jurisdictions. This will enable more certain and consistent business practices for organisations involved in developing and using AI systems across jurisdictions, such as those potentially used in the space industry. Beyond this, countries should look to integrate elements of AI policy, strategy, and regulation into their space industries by making conformity with AI guidelines and technical standards a condition of licensing under their national space legislation.

Ideally, a document containing guidelines for automated activities in space should be negotiated between States which can clarify standards and legal rules for the safe operation of AI in space, while also serving as a multilateral touchstone for national regulation and the negotiation of future binding international space instruments.

By utilising a 'bottom-up' approach to regulating space-based AI systems, a scaffold of increasingly substantive and enforceable multilateral documents can be negotiated and integrated into domestic regulatory frameworks, providing a clear path for international custom to form and future binding multilateral agreements to be created. This avoids wasting time and effort trying to immediately negotiate a binding multilateral instrument and instead enables interim rules to be espoused and integrated into activities throughout the space sector, minimising potential harms and maximising the safe operation of space-based AI systems.

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