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Autonomizing Outer Space: Updating the Liability Convention for the Rise of Artificial Intelligence (AI)

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Autonomizing Outer Space: Updating the Liability Convention for the Rise of Artificial Intelligence (AI)

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The rapid rise of artificial intelligence (AI) is reshaping numerous industries, and the Outer Space sector is no exception. This Article examines the transformative implications that AI technologies will have on this domain's liability framework as established by the Liability Convention.

The Article begins with an in-depth overview of this international treaty, followed by an exploration of how AI technologies can enhance various space activities through autonomous decision-making. It then examines how these advancements are challenging Outer Space's existing liability regime. Here, the Article spotlights how incidents caused by AI-driven space objects can raise complex accountability issues. Specifically, it identifies critical gaps, including ambiguities in the concept of the "launching State," the suitability of the "absolute liability" regime, and the applicability of "fault-based liability" standards to AI systems.

To address these complexities, this Article proposes reforms to the Liability Convention in preparation for this AI space age, including (i) expanding the "launching State" definition to include broader stakeholders, (ii) reexamining the "absolute liability" regime in light of AI autonomy, and (iii) reforming the "fault-based" liability system by establishing standards of care tailored for AI systems.

Through these adaptive measures, this Article hopes that the liability framework governing Outer Space can evolve to accommodate AI's role in space exploration, ensuring fairness, accountability, and the continued advancement of humanity's cosmic endeavors.

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I. THE DAWN OF THE AI SPACE ERA

"*Newton's Third Law: The only way humans have ever figured out of getting somewhere is to leave something behind.*"[1] – TARS, *Interstellar*

With a humor level of sixty percent,[2] TARS, the artificial intelligence (AI) robot in the cinematic space odyssey *Interstellar*, brought a touch of comic relief to the plot. But TARS's role extended far beyond that of a mere comedian. Despite lacking human-like physical features, TARS proved to be an exceedingly capable member of the *Endurance* crew;[3] the movie depicted several instances where TARS

1. *Interstellar Best Movie Quotes*, MOVIEQUOTESANDMORE, https://www.moviequotesandmore.com/interstellar-quotes/ [https://perma.cc/W727-6AUR] (last visited Oct. 18, 2024).

2. See *Bill Irwin: TARS—Interstellar (2014)*, IMDB, https://www.imdb.com/title/tt081 6692/characters/nm0410347 [https://perma.cc/FJ2D-ULPR] (last visited Oct. 18, 2024), (indicating that Cooper had changed TARS' humor setting to 60%).

3. *Endurance*, INTERSTELLAR WIKI, https://interstellarfilm.fandom.com/wiki/Endurance

played a pivotal role in rescuing other explorers from near disaster or certain death.[4]

But, as sophisticated as TARS was in the movie, it still remains a product of a fictional universe. When *Interstellar* was first released in 2014,[5] AI technologies were still in their nascent stages of development.[6] While there were noteworthy breakthroughs, the realization of AI systems akin to TARS—capable of replicating human intelligence—remained a distant objective on the technological horizon.[7]

But fast-forward a decade to today, the arrival of artificial general intelligence no longer seems way off in the cosmic horizon.[8] Over the last few years, advancements in AI technologies have made incredible strides.[9] The progression of AI technologies has been nothing short of extraordinary—transitioning from the early days of nascent algorithms meant for simple tasks to today's highly sophisticated systems with the capacity for autonomous decision-making and operations.[10] Thus, AI's capabilities, once confined to the realms of academic research and speculative fiction, have begun to permeate various aspects of human life.[11]

With the ability to transform the societal order, AI and its recent rise represent a monumental shift to the existing technological paradigm.[12] Influencing the minutia of daily life to dilemmas of grand scale, AI technologies possess the

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[https://perma.cc/XC3A-FAPV] (last visited Oct. 18, 2024).

4. Mighty Mayhem, *TARS, CASE, & KIPP [Robot Review!] Interstellar (2014) | TARS Analysis*, YOUTUBE at 6:45 (Jun. 23, 2017), https://www.youtube.com/watch?v=CAhjivap0Lg&t=405s [https://perma.cc/JRP7-D3Q9].

5. *Interstellar Release Info*, IMDB, https://www.imdb.com/title/tt0816692/releaseinfo/ [https://perma.cc/Z9X9-AZJH] (last visited Oct. 18, 2024).

6. Tom Simonite, *2014 in Computing: Breakthroughs in Artificial Intelligence*, MIT TECH. REV. (Dec. 29, 2014), https://www.technologyreview.com/2014/12/29/169759/2014-in-computing-breakthroughs-in-artificial-intelligence/ [https://perma.cc/8ELM-Y9DX].

7. *Id.*

8. *See* Benj Edwards, *Elon Musk: AI Will Be Smarter Than Any Human Around the End of Next Year*, ARS TECHNICA (Apr. 9, 2024, 10:25 AM), https://arstechnica.com/information-technology/2024/04/elon-musk-ai-will-be-smarter-than-any-human-around-the-end-of-next-year/ [https://perma.cc/KTH9-F7RJ] ("Creating artificial intelligence at least as smart as a human (frequently called 'AGI' for artificial general intelligence) is often seen as inevitable among AI proponents.").

9. *See* Kevin Roose, *We Need to Talk About How Good A.I. is Getting*, N.Y. TIMES (Aug. 24, 2022), https://www.nytimes.com/2022/08/24/technology/ai-technology-progress.html [https://perma.cc/E85P-BV3K] ("Over the past 10 years — a period some A.I. researchers have begun referring to as a 'golden decade' — there's been a wave of progress in many areas of A.I. research. . . .").

10. *See* Pranshu Verma & Kevin Schaul, *See Why AI Like ChatGPT Has Gotten So Good, So Fast*, WASH. POST (May 24, 2023, 7:45 PM), https://www.washingtonpost.com/business/interactive/2023/artificial-intelligence-tech-rapid-advances/ [https://perma.cc/GP8M-DF3L] ("A confluence of innovations has spurred growth. Breakthroughs in mathematical modeling, improvements in hardware and computing power, and the emergence of massive high-quality data sets have supercharged generative AI tools.").

11. Brian Kennedy, Alec Tyson & Emily Saks, *Public Awareness of Artificial Intelligence in Everyday Activities*, PEW RSCH. CTR. (Feb. 15, 2023), https://www.pewresearch.org/science/2023/02/15/public-awareness-of-artificial-intelligence-in-everyday-activities/ [https://perma.cc/B7XB-R5N8] ("Artificial intelligence is fast becoming a regular part of daily life.").

12. *See* Maren Thomas Bannon, *How AI is Changing the Future of Work*, FORBES (Jun. 22, 2023), https://www.forbes.com/sites/marenbannon/2023/06/22/how-ai-is-changing-the-future-of-work/ [https://perma.cc/B68J-YCU7] (noting the profound impact that AI could have on human society).

capability to reshape entire industries, revolutionize traditional practices, and offer novel solutions to age-old problems.[13] Its impact can be felt across a myriad of sectors. In the realm of finance, AI can quickly analyze outliers to identify fraudulent activities;[14] in the field of healthcare, AI can surgically scan medical images to detect the presence of cancerous cells;[15] in the domain of urban planning, AI can broadly improve the flow of traffic.[16] The list of industries that this technological advancement will eventually touch appears to be boundless.

The limitless potential of AI technologies is particularly relevant to frontier fields where they can offer new perspectives and solutions that were previously unattainable or unimaginable. Nowhere is this transformative impact more pronounced than in Outer Space. In this domain, AI technologies are not only enhancing existing capabilities but also pioneering new methods of discovery. With applications ranging from autonomous navigation to predictive management, AI has emerged as a gravity-defying technology that can drive advancements in how humanity navigates, studies, and utilizes the expanse beyond Earth.[17] In the harsh and unpredictable environment of Outer Space, AI technologies have the capacity to unlock ambitious and complex space missions that presently lie beyond the scope of human capabilities.[18] Hence, AI technologies will likely revolutionize space activities and push the boundaries of human knowledge and achievement in this cosmic expanse.

Nevertheless, the integration of AI technologies into Outer Space is not without its legal difficulties. The existing Outer Space governance model was established in a pre-advanced AI era and, thus, is ill-equipped to handle the nuanced challenges introduced by AI-assisted space activities.[19] Consequently,

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13. *See, e.g.*, Darrell M. West & John R. Allen, *How Artificial Intelligence is Transforming the World*, BROOKINGS (Apr. 24, 2018), https://www.brookings.edu/articles/how-artificial-intelligence-is-transforming-the-world/ [https://perma.cc/J9KS-WHYQ] (summarizing how AI "is a wide-ranging tool that enables people to rethink how we integrate information, analyze data, and use the resulting insights to improve decision making").

14. *Id.*

15. *Id.*

16. *Can AI Fix Traffic Jams?*, NBC BAY AREA (Jan. 9, 2024), https://www.nbcbayarea.com/news/california/ai-traffic-jams/3417932/ [https://perma.cc/EQ5N-NF2P].

17. *See* discussion *infra* Part III.

18. *See* Bernard Marr, *Artificial Intelligence in Space: The Amazing Ways Machine Learning is Helping to Unravel the Mysteries of the Universe*, FORBES (Apr. 10, 2023 5:19 EDT), https://www.forbes.com/sites/bernardmarr/2023/04/10/artificial-intelligence-in-space-the-amazing-ways-machine-learning-is-helping-to-unravel-the-mysteries-of-the-universe/ [https://perma.cc/TZ5M-QJCP] (indicating that AI "can predict features of the universe beyond the limitations of what we can currently see due to the speed of light (observable universe)").

19. *See* Rockwell Anyoha, *The History of Artificial Intelligence*, SCIENCE IN THE NEWS (Aug. 28, 2017), https://sitn.hms.harvard.edu/flash/2017/history-artificial-intelligence/ [https://perma.cc/DZ9V-KAYK] (noting that AI technologies did not experience exponential growth until the 1980s); *see also* Alex S. Li, *The Five Core United Nations Treaties Related to Outer Space*, #THESPACEBAR (Nov. 26, 2017), https://alexsli.com/thespacebar/2017/11/26/the-five-core-un-treaties-related-to-outer-space [https://perma.cc/3FRM-3QCF] (indicating that the core international treaties related to Outer Space were executed in the 1960s and 1970s); *see also* Ugo Pagallo, Elonora Bassi & Massimo Durante, *The Normative Challenges of AI in Outer Space: Law, Ethics, and the*

these legal instruments now have to confront a new reality where AI is not a mere auxiliary component but a central element of many spacecrafts.[20]

In this up-and-coming era, one of the emerging issues pertains to the resolution of incidents caused by AI-controlled space objects. This scenario presents a complex legal quagmire that traditional Outer Space liability laws cannot address adequately.[21]

Ironically, this inadequacy arises from the very advantage that AI technologies bring to space activities: autonomous actions. In these instances, a legal conundrum arises because liability would traditionally be assigned to the State-party responsible for the space object that caused the incident.[22] But, AI's capacity for autonomous actions challenges this model by disrupting the typical chain of causation.[23] Consequently, AI technologies introduce a fundamental question concerning the fairness and applicability of the conclusions dictated by the traditional liability regime.[24] This issue is further compounded by the fact that Outer Space is no longer exclusively explored by governmental entities. Increasingly, multinational commercial entities are the primary drivers of certain space activities and often are the first ones deploying AI technologies.[25]

Although some legal scholars have started to identify certain liability gaps introduced by AI technologies in Outer Space,[26] the focus has largely been on a general identification of the issue.[27] Additionally, while some solutions have been proposed,[28] there has not been any in-depth discussion about how to reconfigure the liability regime to ensure equitable resolutions for incidents involving AI-operated space objects.[29] However, this will eventually become a necessity.

Realignment of Terrestrial Standards, 36 PHIL. & TECH. 1, 6 (2023), https://link.springer.com/article/10.1007/s13347-023-00626-7 [https://perma.cc/C2UT-N8TS] ("Since the mid-2010s, the speed of AI innovation, however, has suggested several scholars and institutions to increasingly pay attention to the disruptive effect of such innovation vis-à-vis rules and principles of space law.").

20. *See* discussion *infra* Part III.

21. *See How Can Space Law Address Artificial Intelligence in Space?*, SPACEWATCH.GLOBAL (May 7, 2021) ("These interactions between humans and intelligent 'things' raise new issues relating to responsibility and liability in case of damage, as well as questions about transparency, level of autonomy, and human control.").

22. *See* discussion *infra* Section II.B.2.b.

23. *See* discussion *infra* Section IV.A.

24. *See* discussion *infra* Sections IV.B-C.

25. *See* discussion *infra* Section IV.A.

26. *See* Ioana Bratu, Arno R. Lodder & Tina van der Linden, *Autonomous Space Objects and International Space Law: Navigating the Liability Gap*, 18 INDONESIAN J. INT'L L. 423, 424–25 (2021) ("[T]his paper analyzes whether existing legal frameworks dealing with liability for damages caused by space objects are capable of dealing with incidents caused by AI, specifically, by autonomous space objects.").

27. *See generally id.* at 433–37 (identifying how "liability gaps" might exist with certain legal terms and concepts within existing liability regime governing Outer Space).

28. *See id.* at 437 ("Several solutions can be proposed for mitigating the challenges posed by the autonomous space objects to the liability regimes . . . . [T]hese proposals are mentioned here for the purpose of avoiding situations in which liability cannot be attributed, in other words a liability gap.").

29. *See id.* at 435 ("In what concerns the absolute liability . . . we do not envisage any particular difficulties in relation to attributing this type of liability. States are to be held absolutely liable for the

Assessing a State's liability under the current framework is particularly difficult when the harm stems from the autonomous actions of an AI system developed by a commercial entity that is not domiciled in such State. In this instance, on the one end, the State could avoid liability by arguing the autonomous nature of such actions meant that the State could not have breached any standard of care.[30] On the other end, the State still might find itself accountable solely because it provided the launch facilities for such AI-driven space object.[31] But both results raise fairness concerns with the State either avoiding liability for autonomous actions it had directed or bearing liability for autonomous actions that it had no control over.

This Article seeks to bridge this gap. In the face of AI's increased utilization in Outer Space, the Article analyzes how the liability regime should be modified to ensure an equitable outcome. In Part II, it provides an overview of how international treaties currently address liability and responsibility for incidents involving space objects. After this background, Part III surveys the transformative impact that AI technologies could have on various aspects of space exploration and utilization. Then in Part IV, this Article continues this discussion by explaining how the increased use of these AI technologies can challenge the existing liability framework for Outer Space. With a particular focus on the Liability Convention, this Part highlights the weaknesses of this treaty in addressing incidents involving AI-controlled space objects. After identifying these legal issues, Part V then proposes concrete recommendations to address these shortcomings.

By promoting this discourse, it is my hope that the liability framework governing Outer Space activities continues to evolve in tandem with technological advancement. Such an evolution is paramount to ensure that the laws pertaining to Outer Space can effectively address the challenges and harness the opportunities presented by the emergence of AI technologies in the realm of Outer Space exploration.

II. RESPONSIBILITY AND LIABILITY UNDER EXISTING LEGAL DOCTRINE

The rise of artificial intelligence is propelling a wave of disruption across numerous industries.[32] The Outer Space sector is no exception.[33] Before diving into

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damages caused by their space objects on the surface of the Earth *irrespective of* their autonomous capabilities.") (emphasis added)*; see also id.* at 442 ("The launching state's responsibility also applies in cases where it is not the state itself that is involved in the launching, but a New Space private party – [sic] as there is not yet in the Treaties a provision to hold a private company liable for damages caused in space.").

30. *See* discussion *infra* Section IV.A.

31. *Id.*

32. *See* Paul Sallomi, *Artificial Intelligence (AI) Goes Mainstream*, DELOITTE, https://deloitte.wsj.com/cio/artificial-intelligence-goes-mainstream-1438142473 [https://perma.cc/W4Y3-QCP6] (last visited Oct. 19, 2024) ("But it is only recently that AI appears on the brink of revolutionizing industries as diverse as health care, law, journalism, aerospace, and manufacturing, with the potential to profoundly affect how people live, work, and play.").

33. *Artificial Intelligence in Space*, EUR. SPACE AGENCY (last updated Aug. 3, 2023), https://w

how AI technologies can disrupt the prevailing governance model for Outer Space, this Part will first provide an overview of the existing liability framework for this arena. It will start by examining how the seminal Outer Space Treaty establishes a foundation for addressing issues related to responsibility and liability for one's space activities. Then, this Part will provide a comprehensive overview of the Liability Convention through an in-depth analysis of its history, text, and application.

A. The Outer Space Treaty Setting the Stage

The examination of any legal issues related to Outer Space has to begin with the United Nations Treaties on Outer Space. These landmark treaties are widely considered the bedrock principles of legal doctrine related to this domain.[34] While comprising of five treaties, only four of the United Nations Treaties on Outer Space have gained global acceptance.[35] Among these four, the Outer Space Treaty—officially known as the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies[36]—has played a pivotal role in shaping the direction for Outer Space-related international laws.

Ratified on October 10, 1967,[37] the Outer Space Treaty emerged during an era of rapid advancements and heightened interest in space exploration; this interest was primarily driven by the intense rivalry between the United States and the Soviet Union.[38] Recognizing the need for a set of principles that would govern Outer Space activities, the international community came together to forge an agreement that would not only promote the exploration and use of Outer Space for the benefit of all humankind but also deter its militarization.[39] Although crafted more than fifty-five years ago, the Outer Space Treaty still remains remarkably pertinent. As of end of November 2024, 115 countries have ratified

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ww.esa.int/Enabling_Support/Preparing_for_the_Future/Discovery_and_Preparation/Artificial_intelligence_in_space [https://perma.cc/H9RG-PPFY].

34. Alex S. Li, *Ruling Outer Space: Defining the Boundary and Determining Jurisdictional Authority*, 73 OKLA. L. REV. 711, 714 (2021) (noting these agreements "have laid the seminal foundation for doctrinal law in this sector.") [hereinafter Li, *Ruling Outer Space*].

35. *See* Alex S. Li, *Opening Outer Space: Safety and Stability through Open Standards and Open Source*, 126 PENN. ST. L. REV. 667, 673 (2022) (indicating that all but the Moon Agreement has been ratified) [hereinafter Li, *Ruling Outer Space*].

36. Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, *opened for signature* Jan. 27, 1967, 18 U.S.T. 2410, 610 U.N.T.S. 205 [hereinafter Outer Space Treaty].

37. Alex S. Li, *Unifying Outer Space: Creating a Cohesive Structure Surrounding Mining on the Moon*, 55 ARIZ. ST. L. J. 1165, 1172 (2024) [hereinafter Li, *Unifying Outer Space*].

38. *See* Li, *Ruling Outer Space*, *supra* note 34, at 715 ("While these two leading nations of the time were on the opposite sides of the first Space Race, both had recognized the dangers and catastrophic effects of a potential war in Outer Space.").

39. *See* Li, *Unifying Outer Space*, *supra* note 37, at 1172 ("[T]his treaty ensures that Earth-based geopolitical tensions do not extend into Outer Space by mandating that only peaceful pursuits can take place in this realm.").

the Agreement with an additional twenty-one countries having signed the treaty.[40]

One of the most remarkable aspects of the Outer Space Treaty is its forward-thinking nature. For example, while the Outer Space Treaty was drafted and negotiated at a time when activities in Outer Space were driven exclusively by governmental entities, it nevertheless set guidelines related to commercial activities in Outer Space.[41] These inclusions were the result of arduous negotiations between the Soviet Union and the United States.[42] While the Soviet Union originally wanted to restrict Outer Space activities to governmental entities only, the United States wanted to retain commercial enterprises' ability to participate in this expansive arena.[43] Eventually, a compromise was reached that enabled commercial enterprises to engage in Outer Space activities as long as they are first authorized by a State-party who will be responsible for all such entities' actions.[44]

Thus, beginning with the seminal Outer Space Treaty, State actors have always had responsibility for its national activities, whether these activities are carried out by governmental agencies or private enterprises. Article VI of the Outer Space Treaty unequivocally treats all such activities the same, stipulating that the nation in question bears "international responsibility" for these actions.[45] Therefore, a sovereign state must oversee and ensure that all of its national activities, even those undertaken by its commercial corporations, adhere to the principles enshrined in the Outer Space Treaty.[46]

But a nation-state's burden for its national activities in Outer Space extends beyond mere "international responsibility." According to Article VII of the Outer Space Treaty, a nation is also "internationally liable" for any damages resulting from an object it launches or procures to launch into Outer Space.[47] This liability encompasses damage that occurs on Earth, in air, or anywhere in Outer Space.[48] In addition, the Outer Space Treaty also previews the concept of "joint and several liability" by making both the State that is responsible for the launch and the State procuring such launch liable for any damages caused by the launched

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40. Comm. on the Peaceful Uses of Outer Space, Status of Int'l Agreements Relating to Activities in Outer Space as at 1 January 2024, U.N. Doc. A/AC.105/C.2/2024/CRP.3, at 10, (Apr. 15, 2024) [hereinafter U.N. Treaties Status]; U.N. OFF. FOR OUTER SPACE AFFS., *Status of the Int'l Agreements Relating to Activities in Outer Space*, https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/status/index.html [https://perma.cc/ZZS3-AHB8].

41. Alex S. Li, *Touring Outer Space: The Past, Present, and Future of Space Tourism*, 71 CLEV. ST. L. REV. 743, 749 (2023) ("But while pure commercial activities did not exist during the early days of the first Space Age, it was nevertheless contemplated.") [hereinafter Li, *Touring Outer Space*].

42. *See* Li, *Ruling Outer Space*, *supra* note 34, at 716 (indicating that a compromise was reached between the United States and Soviet Union on commercial activities in Outer Space).

43. *See* Li, *Touring Outer Space*, *supra* note 41, at 750 (describing the two different positions of the United States and Soviet Union on commercial activities in Outer Space).

44. Outer Space Treaty, *supra* note 36, at art. VI.

45. *Id.*

46. *Id.*

47. *Id.* at art. VII.

48. *Id.*

object.[49] In practical terms, if the State conducting the launch is different from the nation that procures such launch, then the injured country retains the option to seek compensation from two distinct State actors.

In order to effectuate the liability provisions and identify the owner of an object, the Outer Space Treaty also lays the groundwork for establishing a registration system for such objects.[50] This concept is further detailed in a subsequent treaty, the Convention on Registration of Objects Launched into Outer Space,[51] which includes processes on how a State can register its space-bound objects.[52]

Thus, in dictating the foundational principles for Outer Space, the Outer Space Treaty provides an overarching framework that delineates how responsibility and liability would be borne for different space activities. However, as the first international agreement governing this sector, the Outer Space Treaty paints many of these principles in broad strokes. Recognizing that these generalities could hinder the practical resolution of incidents,[53] the international community took further steps to clarify the Outer Space Treaty's liability principle in a subsequent agreement:[54] the Liability Convention, formally known as Convention on International Liability for Damage Caused by Space Objects.[55] The next section will provide an in-depth exploration of the Liability Convention through its history, text, and real-world application.

B. Drilling into the Liability Convention

While the Outer Space Treaty laid down broad principles to govern activities in Outer Space, subsequent United Nations Treaties on Outer Space sought to solidify and elaborate on these concepts.[56] The Liability Convention stands as a

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49. *See id.* arts. VII and XIII (indicating that both the state doing the launch and the state procuring such launch would be responsible as a joint activity).

50. *See id.* art. VIII ("A State Party to the Treaty on whose registry an object launched into outer space is carried shall retain jurisdiction and control over such object . . . .").

51. Convention on Registration of Objects Launched into Outer Space, *opened for signature* Jan. 14, 1975, 28 U.S.T. 695 [hereinafter Registration Convention].

52. *See* Li, *Ruling Outer Space*, *supra* note 34, at 721 ("[T]he Registration Convention lays the foundation for a registration system to account for objects in space."); *see also* Li, *Opening Outer Space*, *supra* note 35, at 675 ("This treaty established a catalog of objects in Outer Space that are updated and kept by the United Nations.")

53. *See* Herbert Reis, *Some Reflections on the Liability Convention for Outer Space*, 6 J. SPACE L. 125, 125 (1978) (noting certain countries "recognized that a principle of international legal responsibility and financial liability of so high a level of generality, however useful, could not secure the objective of assuring to a person suffering damage . . . as result of another country's space activities a reasonable prospect of prompt and fair compensation") [hereinafter Reis, *Liability Convention Reflections*].

54. Li, *Ruling Outer Space*, *supra* note 34, at 719 ("The Space Liability Convention expands on the liability regime introduced in Article VII of the Outer Space Treaty.").

55. Convention on International Liability for Damage Caused by Space Objects, *opened for signature* Mar. 29, 1972, 24 U.S.T. 2389 [hereinafter Liability Convention].

56. *See generally* Li, *Ruling Outer Space*, *supra* note 34, at 717–22 (indicating how the four subsequent treaties all elaborate on certain articles of the Outer Space Treaty).

prime example of such efforts. This section will provide an in-depth examination of the Liability Convention, a pivotal international legal instrument that clarifies the contours of liability associated with Outer Space-related incidents. This overview will begin with a summary of the deliberations that led to the creation of the Liability Convention. Armed with this historical understanding, the journey will then explore the key components of the treaty. Finally, to analyze the effectiveness of this legal doctrine, this review will examine the only application—so far—of this international agreement. Through this multifaceted analysis, this section hopes to foster a deeper understanding of the instrumental role that the Liability Convention can play in resolving incidents arising from Outer Space-related activities.

1. Negotiation History of the Liability Convention

While the Outer Space Treaty sets a legal framework for Outer Space-related activities, its provisions are notably broad.[57] This generalization left many questions unanswered, particularly in terms of how its provisions—such as those related to liabilities—should be interpreted.[58] These lingering uncertainties were so concerning that the United Nations General Assembly passed resolutions that encourage the development of a treaty that is surgically focused on the liability aspects of Outer Space activities.[59] Following a series of negotiations among that era's spacefaring nations,[60] this goal was ultimately achieved in 1972 with the adoption of the Liability Convention.[61] As of end of November of 2024, 100 countries have ratified the treaty with an additional eighteen countries having signed the treaty and four countries having declared their acceptance.[62]

Similar to the Outer Space Treaty,[63] the Liability Convention was primarily negotiated between the Soviet Union and the United States.[64] The United States, in particular, expressed deep concerns regarding the enforceability of the generalized principles outlined in the Outer Space Treaty.[65] Thus, the United States likely pushed the Soviet Union in adopting a set of specific criteria addressing liability issues. During the subsequent discussions, several other countries played a

57. *See* Li, *Ruling Outer Space*, *supra* note 34, at 717 ("Because of this characteristic, the Outer Space Treaty is susceptible to multiple interpretations which limit its practical use.")

58. *See id.* ("[T]he Outer Space Treaty is susceptible to multiple interpretations which limit its practical use.").

59. Carl Q. Christol, *Liability for Damage Caused by Space Objects*, 74 AM. J. OF INT'L L. 346, 355 (1980) (indicating that the General Assembly passed a resolution in 1969 identifying a "need for a liability convention") [hereinafter *Liability for Damages*].

60. *See generally* Reis, *Liability Convention Reflections*, *supra* note 53, at 126–27 (reflecting on the ongoing negotiations between the different countries on the Liability Convention).

61. *See* U.N. Treaties Status, *supra* note 40, at 2.

62. *Id.* at 12.

63. *See infra* Part II.A.

64. *See* Reis, *Liability Convention Reflections*, *supra* note 53, at 125 (indicating that United States wanted to reach agreement with the Soviet Union on "the question of international liability for damage caused by the launching, fight, and re-entry of payloads and associated launch vehicles").

65. *Id.* at 125–26.

critical role in shepherding the treaty to its ultimate conclusion. Notably, the Soviet Union used Hungary as an intermediary, avoiding direct negotiations with the United States on this agreement.[66] Additionally, India and Austria made substantial contributions to the convention's development; India hosted informal in-person dialogues while Austria crafted some of the treaty's finer details.[67]

During this negotiation process, these parties focused their discussions on four primary objectives.[68] First, whether establishing a country's liability for its Outer Space activities would "require a showing of fault."[69] Second, what amount of compensation should be owed to an injured party.[70] Third, whether an injured party would need to exhaust the domestic remedies of the potentially liable State prior to submitting a claim under this treaty.[71] And lastly, how to ensure that the negotiations between the injured State and the liable State do not become indefinite.[72]

With numerous parties engaged in this process and a broad gamut of positions on the core issues, the negotiations proved to be an arduous endeavor that spanned almost a decade.[73] However, this prolonged and challenging negotiation process ultimately yielded many fruitful compromises, shaping the Liability Convention into a treaty that garnered broad-level acceptance.[74] In its final form, the agreement explicitly addressed all of the principal objectives that the negotiators had set out to clarify. These extensive deliberations molded the Liability Convention into a valuable extension of the Outer Space Treaty.

By translating the Outer Space Treaty's broad aspirational principles into concrete provisions, the Liability Convention developed processes that all parties can readily understand and implement. This, in turn, fostered responsible and cooperative Outer Space activities by ensuring the existence of effective and timely resolution mechanisms. To further explore these processes, the next section will focus on the key concepts and components of the Liability Convention through an analysis of the agreement's text.

2. Key Components of the Liability Convention

The result of an extensive negotiation process, the Liability Convention establishes a comprehensive legal framework designed to address the liability of space-faring nations when their space objects cause harm. This section will drill into the text of the treaty. Specifically, it will scrutinize its essential components, including: (a) the entities eligible to file a claim, (b) the entities that could be held

66. *Id.* at 126.
67. *Id.*
68. *Id.*
69. *Id.*
70. *Id.*
71. *Id.*
72. *Id.*
73. *Id.* at 127.
74. *See id.* at 127–28 (describing how the parties were able to come to various compromises that ensured the Liability Convention's broad level of acceptance).

liable, (c) the standards for liability, (d) the categories of eligible damages and the possible compensation, and (e) the processes governing the submission and adjudication of liability claims.

a. The Potential Claimants: State Representatives Only

In any incident involving harm, the inquiry typically begins with the identification of the injured party. A claim under the Liability Convention is no exception. In fact, the identity of the injured party is crucial for determining which State is eligible to file a claim under the treaty. Under the provisions of the Liability Convention, only a State has the right to file a claim.[75] This is not an issue when a State sustains damage because it could just submit a compensation claim on its own behalf.[76] However, a complication arises when the injured party is an individual or a non-State entity. In such instances, if the State capable of representing the injured party refuses to support the claim, then the injured party is left without a remedy under the Liability Convention.[77]

This principle even applies for an "international intergovernmental organization that conducts space activities," which is typically entitled to certain benefits under the Liability Convention.[78] An illustrative example of such an organization is the European Space Agency.[79] To avail itself of the Liability Convention, the European Space Agency must have accepted the rights and obligations of the Liability Convention and a majority of its members must be State-parties to both the Liability Convention and the Outer Space Treaty.[80] However, even under these circumstances, the European Space Agency can only submit a compensation claim through one of its member-States that has ratified the Liability Convention.[81]

Therefore, it is of paramount importance for a non-State injured party to ascertain which States can assert a claim on its behalf. According to the Liability Convention, there are three States that can file the claim on behalf of the injured party. The first State that is eligible is the one that the injured party belongs to as a natural or juridical person;[82] this essentially corresponds to the State that the

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75. *See* Liability Convention, *supra* note 55, art. VIII (listing the specific categories of States that can present a claim under the Liability Convention).

76. *Id.* art. VIII(1).

77. Dan St. John, *The Trouble with Westphalia in Space: The State-Centric Liability Regime*, 40 DENV. J. INT'L L. & POL'Y 686, 696 (2012) ("But, if no state chooses to advance an individual's claim, that individual has no recourse in international law.") [hereinafter St. John, *Westphalia Trouble*].

78. Liability Convention, *supra* note 55, art. XXII(1).

79. *See European Space Agency (ESA)*, INT'L ASTRONAUTICAL FED'N, https://www.iafastro.org/membership/all-members/european-space-agency-esa.html [https://perma.cc/P8UX-PPGR] (last visited Oct. 19, 2024) ("ESA is an intergovernmental organisation, created in 1975, with the mission to shape the development of Europe's space capability and ensure that investment in space delivers benefits to the citizens of Europe and the world.").

80. Liability Convention, *supra* note 55, art. XXII(1).

81. *Id.* art. XXII(4).

82. *Id.* art. VIII(1).

injured party is either a citizen of or domiciled within.[83] The second State that is eligible is the one that exercises control over the territory where the injured party suffers the damage.[84] The third and final State that is eligible is the one in which the injured party holds permanent residency.[85] Consequently, for a non-State injured party to pursue a claim under the Liability Convention, it is imperative for this party to secure representation from one of these three States.

If the non-State injured party cannot get one of these three States to support the claim on its behalf, then it is regrettably left without a remedy under the Liability Convention. In this way, the Liability Convention operates exclusively through State-party interactions.[86] But the treaty does not preempt a non-State injured party from seeking alternative remedies. Specifically, the convention indicates that such party could still pursue a damage claim by using the local remedies—such as domestic courts, administrative tribunals, or agencies—of the State that allegedly caused the harm.[87]

With the potential claimants under the Liability Convention identified, the next question naturally shifts to the other side of the equation: Who could be liable under this treaty? The following section tackles this topic.

b. The Liable Parties: The Launching States

Once the injured parties and their potential State representatives have been identified, the subsequent question focuses on who could be held accountable for such damages. The Liability Convention offers a straightforward answer to this inquiry: Only a "launching State" can be liable.[88]

The treaty defines a "launching State" to encompass four distinct categories.[89] First, it could be the State that launches the space object that causes the damage.[90] Second, it could be the State that procures the launch of such space object.[91] Third, it could be the State that controls the territory such space object is launched from.[92] And fourth, it could be the State who controls the facility such space object is launched from.[93] Thus, a claimant could potentially submit a compensation claim to several States.

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83. *See* St. John, *Westphalia Trouble*, *supra* note 77, at 696 (indicating that this is the "natural state" of the natural or juridical person).

84. Liability Convention, *supra* note 55, at art. VIII(2).

85. *Id.* at art. VIII(3).

86. *See* St. John, *Westphalia Trouble*, *supra* note 77, at 696 ("But, if no state chooses to advance an individual's claim, that individual has no recourse in international law.").

87. Liability Convention, *supra* note 55, art. XI(2).

88. *See id.* arts. II-III (noting that a "launching State" would be liable for damages with the standard of liability based on where the damage occurs).

89. *Id.* art. I(c).

90. *Id.*

91. *Id.*

92. *Id.*

93. *Id.*

Apart from these four explicit categories of launching States, an implicit category can also be inferred from the Liability Convention. Under this treaty, an "international intergovernmental organization which conducts space activities"[94] could also be a potentially liable party.[95] Consequently, a group of launching States would not be able to evade liability simply by creating an organization to conduct all of their space activities.

Furthermore, the Liability Convention's definition for "launch" also includes attempted launches as well.[96] Hence, damages from a failed launch would also be covered under the treaty. As a result, it is immaterial whether the space object successfully reaches Outer Space; as soon as the object is launched, its launching State is accountable for any damage such object causes.

However, the standard of liability for such damages is dependent upon the location where the harm occurs. The next section will explore the two distinct standards established by the Liability Convention.

c. The Liability Standards: Absolute and Fault-based

The Liability Convention applies two different standards of liability based on where the damage occurs. For harm "on the surface of the Earth" or "to an aircraft in flight," the treaty establishes a standard of absolute liability.[97] Consequently, in such cases, the launching State would be unconditionally liable for any damage inflicted by any space objects it is accountable for. But the launching State does possess a defense against this standard of absolute liability. If the launching State can prove that the damage was the result of gross negligence or an intentional act or omission of the claimant—or those represented by the claimant, then the launching State will not be held absolutely liable.[98] However, this defense only applies if the launching State's activities were in compliance with international law, with the Liability Convention explicitly referencing the Outer Space Treaty as a critical reference.[99]

For damages that occur to another space object or to those within such space object in a location that is not on/in those locations, the Liability Convention prescribes a fault-based liability standard.[100] Accordingly, in such scenarios, the launching State would only be held liable "if the damage is due to its fault or the fault of persons for whom it is responsible."[101] But, it is worth noting that many legal scholars are critical of this fault-based standard. This skepticism

94. *See infra* Part II.B.2.a.

95. *See* Liability Convention, *supra* note 55, art. XXII(3) (indicating that "an international intergovernmental organization" could be "liable for damage by virtue of the provisions of this Convention").

96. *See id.* art. I(b).

97. *Id.* art. II.

98. *Id.* art. VI(1).

99. *Id.* art. VI(2).

100. *Id.* art. III.

101. *Id.*

stems from the convention's lack of a "standard of care."[102] Without this standard of care, it is difficult to objectively measure when a party's actions or omissions have reached the level of "fault" needed to constitute a breach.[103] Its absence has led to criticisms about the effectiveness of this liability standard.[104]

Aside from these standards of liability, the Convention also contemplates scenarios where multiple parties are involved. In an incident where multiple parties could be held accountable, then all such parties would be held "jointly and severally liable."[105] Under the "joint and several liability" doctrine, the claimant would be able to file a claim against any one of the liable parties for the entirety of the damages it has suffered.[106] This approach ensures that the injured party can flexibly pursue its claim against any one of the accountable parties, simplifying its process for seeking compensation.

Just as in cases involving a single liable party, the location where the damage occurs remains crucial. Thus, when the damage occurs on the Earth's surface or to an aircraft in flight, then all responsible parties would be held absolutely liable.[107] However, for damages that occur to an injured party's space object or persons or properties within such object while not on/in those locations, then all accountable parties would be subject to fault-based liability.[108] In these cases, each party will be apportioned its "burden of compensation" according to its "extent of fault."[109] If such apportionment cannot be clearly established, then the compensation for such damage will be evenly divided upon all liable parties.[110]

By extension, this also means that if one of the liable parties paid for all of the damages caused, then that party retains the right to seek "a claim of indemnification" from all other parties who are jointly and severally liable for such damages.[111] But to streamline the compensation process, the Liability Convention allows the liable parties to agree amongst themselves how to divide up the damages that they are collectively responsible for.[112] The only caveat is that such agreements cannot materially impact the claimant from seeking compensation from any or all of the parties who are jointly and severally liable for the total damage caused.[113]

102. *See, e.g.*, St. John, *Westphalia Trouble*, *supra* note 77, at 701 ("The problem with the space law liability regime is that there is no standard of care against which a state's conduct can be measured."); Yun Zhao, *The 1972 Liability Convention: Time for Revision?*, 20 SPACE POL'Y 117, 120 (2004) ("While requiring proof of fault, the Convention does not provide a clear obligation to act or to abstain.").

103. Zhao, *supra* note 102, at 120.

104. *Id.*

105. Liability Convention, *supra* note 55, art. IV(1).

106. *Joint and Several Liability*, LEGAL INFO. INST. (last updated July 2023), https://www.law.cornell.edu/wex/joint_and_several_liability [https://perma.cc/LV33-YNZ9].

107. Liability Convention, *supra* note 55, at art. IV(1)(a).

108. *Id.* art. IV(1)(b).

109. *Id.* art. IV(2).

110. *Id.*

111. *Id.* art. V(2).

112. *Id.*

113. *Id.*

But even under the Liability Convention, there are certain types of damages that are excluded from compensation claims. Additionally, the treaty establishes parameters on the type of compensation that would be due. The next section will explain these aspects in detail.

d. Damages and Compensation: Victim-oriented

Under the Liability Convention, the liable parties must compensate the injured party for the harm caused.[114] The treaty defines damage to include "loss of life, personal injury or other impairment of health; or loss of or damages to property of States or of persons, natural or juridical, or property of international intergovernmental organizations."[115] Thus, if a launching State is held liable, it could be accountable for a significant amount of compensation.

Nevertheless, there are two categories of damages that are excluded from such compensation.[116] The first category comprises any damage that is caused to the liable State's own nationals.[117] This exemption was likely written in as such damages are internal to the liable State itself and, thus, do not concern the claimant. The second category encompasses damages suffered by any foreign nationals who are either participating in the activities that caused the damage or present within the "planned launching or recovery area" as a result of them accepting an invitation.[118] This exemption was likely included because such individuals have voluntarily assumed the risk of these activities.[119]

For all damages that are eligible for compensation under the Liability Convention, the amount of compensation that an injured State can recover is "determined in accordance with international law and the principles of justice and equity."[120] The goal of this compensation is intended to "restore [the injured party] to the condition which would have existed if the damage had not occurred."[121] This emphasis on "restoration" and "the principles of justice and equity" suggests that the convention's compensation scheme is "victim-oriented."[122] In fact, even the compensation's form of currency is deferential to the injured party: The default option is whatever form of currency that the claimant uses or selects.[123]

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114. *Id.* art. XII.
115. *Id.* art. I(a).
116. *Id.* art. VII.
117. *Id.* art. VII(a).
118. *Id.* art. VII(b).
119. *See* Definition of Assumption of Risk, LEGAL INFO. INST. (last updated Jun. 2022), https://www.law.cornell.edu/wex/assumption_of_risk [https://perma.cc/U3T5-Z7EP] (noting that this is a common law doctrine where a plaintiff is unable to recover for damages when "the plaintiff voluntarily accepted the risk of those actions").
120. Liability Convention, *supra* note 55, art. XII.
121. *Id.*
122. *Liability for Damages*, *supra* note 59, at 359 ("The convention has been characterized as victim oriented.").
123. Liability Convention, *supra* note 55, art. XIII.

But the presence of the phrase "principles of law and equity" has also ignited debates on the types of damages that should qualify for compensation under this international framework. While there is growing consensus that direct damages should be a part of the calculation,[124] opinions vary on the inclusion of indirect damages.[125] However, given that "moral damages"—damages associated with "injury to the dignity or sovereignty of a state"[126]—would be recoverable under the Liability Convention,[127] it is likely that some form of indirect damages may also be included.[128] Meanwhile, as to nominal and punitive damages, the prevailing perspective is that such damages are irrelevant because the compensation is not capped.[129] Thus, such damages might have already been accounted for as part of the overall calculation.[130]

Once the claimant sorts out how much compensation it would seek, it must file a claim under the Liability Convention. To do this, such State must adhere to specific procedures established by the treaty. The following section will examine these processes in depth.

e. Processes and Procedures: Ensuring Timeliness

To file a claim under the Liability Convention, the injured State must follow specific procedures set out in the treaty. For starters, compensation claims must be presented through diplomatic channels.[131] This can be accomplished either directly or indirectly through a third State if there is no diplomatic relationship between the claimant and the liable party.[132] Furthermore, the injured party can also utilize the office of the Secretary-General of the United Nations to present its claim if all parties involved are United Nations members.[133] Importantly though, the injured State does not need to exhaust any local remedies of the defendant

124. *See, e.g.*, *Liability for Damages*, *supra* note 59, at 360 ("Undoubtedly the clearest . . . case for recovery of damages is where there is a direct relationship between the cause of the harm and the harmed individual or property."); Edward R. Finch, Jr., *Outer Space Liability: Past, Present and Future*, 14 INT'L LAWYER 123, 126 (1980) ("Actual damages costs should certainly be recoverable from the launching State.").

125. *Compare Liability for Damages*, *supra* note 59, at 362 ("[I]t may be anticipated that the convention will be interpreted as covering both direct and indirect damage . . . .") *with* Finch, Jr., *Outer Space Liability: Past, Present and Future*, *supra* note 124, at 126 (noting that Liability Convention "does not include . . . indirect damages").

126. *Liability for Damages*, *supra* note 59, at 363.

127. *See id.* at 363–64 (recounting that during the negotiations of the Liability Convention, various countries appear to agree that moral damage would be recoverable).

128. *See* CARL Q. CHRISTOL, SATELLITE POWER SYSTEM (SPS) INTERNATIONAL AGREEMENTS 152 (1978) ("To the extent that indirect damages fall under the heading of moral damages they would be included.").

129. *Liability for Damages*, *supra* note 59, at 365 ("Since liability for a space object accident is unlimited, there was no need to impose either nominal or punitive damages.").

130. *Id.* at 368 (noting that an award "might take the indicated conduct into account without characterizing the award as punitive").

131. Liability Convention, *supra* note 55, art. IX.

132. *Id.*

133. *Id.*

State prior to submitting its claim.[134] But, if the injured State elects to pursue such remedies, it cannot simultaneously file a claim under the Liability Convention.[135]

To ensure timely legal proceedings, the Liability Convention stipulates that all claims must be brought within one year of the later of (i) the date of the incident or (ii) the date when the liable State is first identified.[136] If the claimant does not possess all of the information needed to file a claim, this one-year period does not commence until the date when such State should have reasonably become aware of the missing information.[137] Nonetheless, this one-year period will not pause merely because the injured State is unaware of the full extent of the damage.[138] In these instances, the claimant should still file the claim and subsequently amend the claim with additional details within one year of acquiring the missing information.[139]

Following the submission of a claim, the Liability Convention encourages the parties involved to engage in negotiations to settle the claim.[140] However, the treaty does include provisions for the establishment of an arbitration panel if the claim is not resolved within a one-year period.[141] This arbitration process entails the formation of a Claims Commission composed of a designated representative from each party along with a neutral member jointly chosen by the parties.[142] This Claims Commission will establish its own procedures for the resolution of the claim.[143] The decision of the commission is binding only if the parties mutually consent to this condition;[144] otherwise, the parties are required to seriously consider the "final and recommendatory award" of the commission in good faith.[145]

By clarifying the key aspects of the liability principle set out in the Outer Space Treaty, the Liability Convention can play an instrumental role in resolving incidents related to Outer Space activities. Through this treaty, spacefaring nations can have a better understanding of the type of liability they may face for the damages caused by their space objects. Simultaneously, entities harmed by such activities have a structured process at their disposal to ensure they receive appropriate compensation.

Nonetheless, the effectiveness of such a legal framework can only be assessed through its practical application. Thus, the following section will analyze

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134. *Id.* art. XI(1).
135. *Id.* art. XI(2)
136. *Id.* art. X(1).
137. *Id.* art. X(2).
138. *Id.* art. X(3).
139. *Id.*
140. *See id.* art. XIV (indicating that the parties should first settle through "diplomatic negotiations").
141. *Id.*
142. *Id.* art. XV.
143. *Id.* art. XVI.
144. *Id.* art. XIX(2).
145. *Id.*

an actual claim filed under the Liability Convention: the Cosmos 954 incident.

3. An Application of the Liability Convention: Cosmos 954

The result of many years of careful negotiations,[146] the Liability Convention was envisioned to streamline the resolution process for Outer Space-related incidents. The framers of this comprehensive treaty wanted to furnish the international community with a practical instrument that is capable of effectively assessing liabilities and redressing any harm caused by a space object.

As of end of November of 2024, only one formal claim has been made under the Liability Convention. This particular claim was submitted by the Canadian government seeking redress for damages it incurred from the crash landing of the Soviet Union's nuclear-powered satellite, Cosmos 954.[147] Although Cosmos 954 had a few weeks of normal operations subsequent to its launch on September 18, 1977, it rapidly succumbed to malfunctions.[148] By January 1978, a mere few months after its deployment, the satellite uncontrollably reentered Earth's atmosphere.[149] During this descent, the satellite disintegrated, scattering radioactive debris over a wide swath of area in Canada's Northwest Territory.[150] Faced with the threat of contamination, Canada swiftly began clean-up efforts that lasted until mid-October 1978.[151] These operations carried a significant financial burden, ultimately costing about fourteen million Canadian dollars.[152]

The crash landing of Cosmos 954, a Soviet space object, on Canadian territory exemplified the type of incident that prompted the Liability Convention's creation. Because this satellite caused damages to the surface of the Earth, Cosmos 954's launching State would be absolutely liable for all damages that result.[153] In this instance, the Soviet Union recognized its ownership of Cosmos 954, which eliminated any uncertainty surrounding the identity of the accountable launching State.[154] But even in the absence of such an admission, it would have been easy to identify the liable State because the Soviet Union owned, launched, and operated Cosmos 954.[155] Hence, in January 1979, the Canadian government presented the Soviet Union with a compensation claim for damages caused by

146. *See* Reis, *Liability Convention Reflections*, *supra* note 53, at 125 (indicating that the Liability Convention was "the result of one of the most difficult and lengthy treaty negotiations since 1945").

147. Li, *Ruling Outer Space*, *supra* note 34, at 720.

148. Bryan Schwartz & Mark L. Berlin, *After the Fall: An Analysis of Canadian Legal Claims for Damage Caused by Cosmos 954*, 27 MCGILL L. J. 676, 677 (1982) [hereinafter Scwartz & Berlin, *Cosmos 954 Analysis*].

149. *Id.*

150. *Id.*

151. *Id.*

152. *Id.* at 678.

153. Liability Convention, *supra* note 55, art. II.

154. Edward G. Lee & D. W. Sproule, *Liability for Damage Caused by Space Debris: The Cosmos 954 Claim*, 26 CAN. Y. B. INT'L L. 273, 275-76 (1988) [hereinafter Lee & Sproule, *Cosmos 954 Facts*].

155. Scwartz & Berlin, *Cosmos 954 Analysis*, *supra* note 148, at 677.

Cosmos 954.[156] The lodging of this claim saw Canada and the Soviet Union become the first parties to leverage the Liability Convention in a practical setting. Although the negotiations still took over two years to complete,[157] the treaty played a pivotal role in facilitating the formal resolution of this incident between Canada and the Soviet Union.

The Liability Convention enabled Canada to specify the amount of compensation it sought to recover from the Soviet Union. While the recovery and clean-up operations had cost Canada about fourteen million Canadian dollars, Canada ultimately submitted a claim for only the incremental costs of these activities, which totaled $6,041,174.70 Canadian dollars.[158] This result was largely because of Canada's strict interpretation of Article XII of the Liability Convention.[159]

Although Canada read the provision narrowly, this claim could have precedential value, serving as a model for the sorts of damages that could be pursued. For instance, while no entity suffered "direct" damage from the debris, the Canadian claim demonstrated that the cost associated with containment and mitigation efforts to prevent future harm or consequences could be included.[160] This logic appears to be in line with the Liability Convention's provision that restorative efforts should be compensated.[161] In addition, even though the Canadian government had declined Soviet Union's offer of assistance in clean-up efforts, Canada argued that this was not a bar to a compensation claim.[162] This position can also find support through the Liability Convention's stipulation that such assistance is upon the injured party's "request" and such request will not "affect the [parties'] rights or obligations."[163] Thus, even if an injured party declines the liable party's assistance—a possibility provided for in a related Outer Space treaty, the Rescue Agreement[164]—it would not legally preclude a compensation claim.

Because Cosmos 954 caused harm to an area of the Earth under Canadian

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156. Lee & Sproule, *Cosmos 954 Facts*, *supra* note 154, at 274.

157. *See id.* (noting that the claim was presented in January 1979 and formally resolved in April 1981).

158. Scwartz & Berlin, *Cosmos 954 Analysis*, *supra* note 148, at 678.

159. Lee & Sproule, *Cosmos 954 Facts*, *supra* note 154, at 274 n. 3.

160. *See id.* at 276 (indicating that the Canada's position for claiming the clean-up efforts was based on the fact that although no entity was damaged directly, the clean-up efforts were necessary for mitigation purposes).

161. *See* Liability Convention, *supra* note 55, art. XII ("[P]rovid[ing] such reparation . . . as will restore [the entity] to the condition which would have existed if the damage had not occurred.").

162. *See* Lee & Sproule, *Cosmos 954 Facts*, *supra* note 154, at 278 ("Canada asserted that, notwithstanding that it had not accepted the type of assistance offered to it by the Soviet Union under the Rescue and Return Agreement, it was not precluded from seeking compensation under the Liability Convention.").

163. Liability Convention, *supra* note 55, art. XXI.

164. Formally, Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space, art. XXII, Apr. 22, 1968, 19 U.S.T. 7570, 672 U.N.T.S. 119 [hereinafter Rescue Agreement]. Under the Rescue Agreement, the responsible State should assist with the retrieval of its space object. *See* Li, *Ruling Outer Space*, *supra* note 34, at 717.

control, the Liability Convention also enabled Canada to bypass the need to prove fault. According to the treaty, the launching State would be held strictly liable for such damages.[165] As a result, the two parties did not have to invest significant resources in determining whether the Soviet Union had breached a certain standard of care that led to Cosmos 954's crash-landing. Instead, they could devote all of their attention to the main issue—how much compensation should be due to Canada from the Soviet Union—and come to a quicker resolution.

By simplifying and eliminating certain complexities, the Liability Convention streamlined the negotiation process between Canada and the Soviet Union. After several working sessions, the Soviet Union ultimately agreed to compensate Canada with about three million Canadian dollars.[166] This outcome helped to solidify the Liability Convention's practical role in facilitating diplomatic resolutions to incidents caused by Outer Space-related activities. Thus, the Cosmos 954 incident underscored the importance of this treaty.[167] Specifically, the incident demonstrated that the Liability Convention can be successfully implemented to quickly ascertain liability and provide an effective remedy for a State that has been injured by Outer Space-related activities.

However, the Cosmos 954 incident was a relatively straightforward case for the Liability Convention to resolve. The incident occurred during an era when Outer Space was still "the exclusive province of governmental agencies."[168] As such, the identities of the liable State and the injured State were easily discernible. Moreover, because the harm was caused to the surface of the Earth, there was no need to assess the degree of fault. But as Outer Space becomes increasingly commercialized,[169] the next claim under the Liability Convention might not be so clear-cut. In fact, even the framers postulated that the current version of the Liability Convention, by itself, might not be adequate to resolve all liability disputes.[170]

As interest in Outer Space continues to grow, the emergence of artificial intelligence technologies is likely to further accelerate this sector's expansion. Moreover, the proliferation of AI-enhanced tools and techniques may give rise to legal complexities that will challenge the effectiveness of the Liability Convention.

But before exploring how these AI technologies could impact the existing liability framework for space activities, it is beneficial to provide some context on the ways artificial intelligence can transform the Outer Space industry. The subsequent Part will do this by exploring how AI-related innovations could be

165. *Supra* Part II.B.2.c.

166. Li, *Ruling Outer Space*, *supra* note 34, at 720.

167. Reis, *Liability Convention Reflections*, *supra* note 53, at 128.

168. Li, *Touring Outer Space*, *supra* note 41, at 747.

169. *See* Li, *Opening Outer Space*, *supra* note 35, at 675 ("In fact, commercial companies will launch more objects to Outer Space in the next few years than humanity has in the first sixty-year history of the Space Age.").

170. *See* Reis, *Liability Convention Reflections*, *supra* note 53, at 127 ("The negotiators recognized that it may eventually prove desirable to have a separate additional treaty on space-sustained damage when the presence of human beings in space becomes frequent and numerous.").

applied to various aspects of Outer Space exploration and utilization.

III. AI'S IMPACT ON OUTER SPACE

As an environment that is naturally inhospitable for human life, Outer Space has always been a challenging arena for crewed operations. But recent advancements in artificial intelligence have the potential to revolutionize humanity's forays into its current final frontier. AI tools and processes can unravel the complexities of Outer Space exploration and enhance the effectiveness of Outer Space utilization. Thus, the integration of AI technologies into Outer Space-related activities could rapidly facilitate advancements in this sector. This Part will examine several areas in Outer Space where AI technologies are poised to have a paradigm-shifting impact.

A clarification note before starting, this Part will focus solely on AI implementations that are directly related to space activities. It will exclude any discussions of AI used in areas that are tangentially related to Outer Space. For instance, AI applications aimed at optimizing Earth observations and analysis will not be covered because these advancements primarily pertain to improvements in data analysis.[171] Similarly, the implementation of AI-capable computer systems that are hardened for Outer Space is also excluded because the advancement there is more rooted in material science and not directly related to AI's impact on Outer Space activities.[172]

Therefore, this Part will examine the ways in which AI advancements are directly influencing key areas within the space domain, namely, (1) Autonomous Navigation, (2) Predictive Maintenance, (3) Constellation Management, (4) In-situ Servicing, and (5) Health Monitoring.

A. Autonomous Navigation

Artificial intelligence, with its ability to make intelligent and autonomous decisions in complex environments, holds the potential to revolutionize Outer Space navigation. This transformation will be powered by AI's remarkable capability to rapidly process and analyze vast amounts of environmental sensory data.[173] Thus, space objects equipped with integrated AI technologies can navigate

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171. *See, e.g.*, *Vision & Objectives*, AI4COPERNICUS, https://ai4copernicus-project.eu/vision-objectives/ [https://perma.cc/FH55-3PBU] (last visited Oct. 19, 2024) (discussing the implementation of AI for Earth data analysis).

172. *See, e.g.*, *Hewlett Packard Enterprise Accelerates Space Exploration with First Ever In-Space Commercial Edge Computing and Artificial Intelligence Capabilities*, HEWLETT PACKARD ENTERPRISE (Feb. 11, 2021), https://www.hpe.com/us/en/newsroom/press-release/2021/02/hewlett-packard-enterprise-accelerates-space-exploration-with-first-ever-in-space-commercial-edge-computing-and-artificial-intelligence-capabilities.html [https://perma.cc/K8LP-EUL4] (noting the deployment of AI computing system that is hardened for the Outer Space environment).

173. *See e.g.*, Marcos Avilés, *Executive Summary Report: ATENA*, 1 GMV INNOVATING SOLUTIONS 1, 8 (2022), https://nebula.esa.int/sites/default/files/neb_study/2609/C4000133932ExS.pdf [https://perma.cc/V9Z6-UUKP] (indicating how the team designed an AI capable of rapidly

autonomously through uncharted terrains by quickly responding to Outer Space's ever-changing conditions.[174]

AI-assisted navigational systems will be able to quickly manage tasks such as obstacle detection and avoidance as well as navigational route analysis.[175] Without the need to frequently transmit environmental data and wait for remote commands, these navigational systems can make real-time course adjustments. This reduced reliance on Earth-based guidance will enable space objects to venture deeper into Outer Space and perform more thorough investigations of complex celestial regions. Such a shift can significantly accelerate the pace of Outer Space exploration by enhancing mission efficiency and reducing space-based risks.

A recent illustration of this AI technology is AutoNav, the AI-integrated automatic navigational system deployed on NASA's Perseverance rover.[176] This innovative technology uses imaging and sensory systems to construct 3D maps of the Martian terrain, enabling the rover to identify and navigate around hazards autonomously.[177] Consequently, Perseverance is able to traverse the Martian surface faster than previous rovers with reduced reliance on remote instructions.[178] This advancement not only enabled researchers to gather data faster but also accelerated the achievement of various scientific goals.[179]

B. Predictive Maintenance

Artificial intelligence can also play a transformative role in ensuring the integrity and success of various Outer Space missions. Utilizing sophisticated machine learning models, AI algorithms can diagnose the datasets generated by a space object's various systems.[180] This real-time analysis can enable AI systems to quickly detect patterns and anomalies that indicate potential equipment failures.[181]

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processing image data for navigational purposes).

174. *See e.g.*, *id.* ("Space missions benefit greatly by the capability of the on-board GNC system to adapt rapidly to unknown environment.").

175. *See* Daniela Girimonte & Dario Izzo, *Artificial Intelligence for Space Applications*, 12 EUR. SPACE AGENCY 235, 243 (2007) ("Autonomous systems for enhanced situation self-awareness are therefore a very important research topic in spacecraft engineering.").

176. Pat Brennan, *NASA's Self-Driving Perseverance Mars Rover 'Takes the Wheel'*, JET PROPULSION LABORATORY (July 1, 2021), https://www.jpl.nasa.gov/news/nasas-self-driving-perseverance-mars-rover-takes-the-wheel [https://perma.cc/V7HC-49AQ].

177. *Id.*; *see Perseverance AutoNav Avoids a Boulder*, JET PROPULSION LABORATORY (Sept. 21, 2023), https://science.nasa.gov/resource/perseverance-autonav-avoids-a-boulder/.

178. *7 Things to Know About the NASA Rover About to Land on Mars*, JET PROPULSION LABORATORY (Jan. 6, 2021), https://www.nasa.gov/solar-system/7-things-to-know-abou t-the-nasa-rover-about-to-land-on-mars [https://perma.cc/3XF6-9P66].

179. *See id.* (suggesting that Perseverance is NASA's most advanced rover to-date).

180. *See* Antonia Russo & Gianluca Lax, *Using Artificial Intelligence for Space Challenges: A Survey*, 12 APPL. SCI. 5106, 5113 (2022) [hereinafter Russo & Lax, *AI for Space*] (noting several studies where "deep learning approach" is used as a way of "integrating a fault-diagnosis system into a space vehicle to isolate, detect, and classify faults in the system").

181. *See id.* (discussing how researchers have envisioned an AI architecture made up of modules "for automatic feature extraction anomaly detection, and telemetry prediction.").

Hence, AI systems could proactively identify potential malfunctions before they occur, allowing for prompt preventative measures.

This AI-powered predictive maintenance capability could be a game-changer for deep space operations. These missions' remote and challenging conditions often make traditional repair and maintenance methods infeasible. However, implementing AI diagnostic technologies could facilitate swifter adjustments or preventative measures before issues become severe; this would reduce the risk of catastrophic failures and mission losses. Thus, AI technologies could transform spacecraft maintenance operations, shifting it from a reactive approach to a proactive stance. This enhanced level of anticipation and readiness can elevate the reliability standards of various Outer Space missions, promoting greater assurance in the longevity and resilience of various space objects.

Predictive maintenance, though still relatively new, is undergoing active testing and demonstrations in Outer Space. One notable example is SoundSee, an audio analyzer developed by Bosch that is currently being tested on the International Space Station (ISS).[182] Attached to a free-moving robot, the SoundSee system is designed to gather and analyze a broad spectrum of acoustic noises throughout the space station.[183] Using its deep-learning AI algorithms, SoundSee can alert ISS personnel to unusual sounds that may indicate potential issues.[184]

Another noteworthy development is NASA's Research in Artificial Intelligence for Spacecraft Resilience (RAISR) software.[185] RAISR is an AI-capable software that can perform real-time diagnostics of various spaceflight systems.[186] This predictive AI monitoring system can continually evaluate outputs from a spacecraft's various systems and look for signs of potential issues in life support systems, power distribution, or structural integrity.[187] The analysis conducted by AI algorithms like the RAISR could provide spacecraft personnel with early warnings of impending failures, enabling the crew to troubleshoot and resolve problems more efficiently.

C. Constellation Management

As the orbits around Earth become increasingly crowded with a burgeoning

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182. Neel V. Patel, *NASA Will Use a Robot to Listen Out for Danger on the ISS*, MIT TECH. REV. (Oct. 30, 2019), https://www.technologyreview.com/2019/10/30/65100/nasa-will-use-a-robot-to-listen-out-for-danger-on-the-iss/ [https://perma.cc/JX3X-J2VZ].

183. *Id.*

184. *Id.*

185. Karl B. Hille, *NASA AI Technology Could Speed Up Fault Diagnosis Process in Spacecraft*, NASA (May 18, 2021), https://www.nasa.gov/technology/nasa-ai-technology-could-speed-up-fault-diagnosis-process-in-spacecraft/ [https://perma.cc/V6KT-9T4K].

186. *Id.*

187. *See id.* ("The artificial intelligence (AI) might even be able to connect the spacecraft's decreased temperature with a malfunction in its internal heat regulation system: an example of a more catastrophic fault.").

number of constellation satellites,[188] artificial intelligence can also play a pivotal role in orchestrating effective constellation management. Through the use of sophisticated machine learning algorithms and swarm intelligence, AI systems can optimize the performance of these satellite constellations in real-time.[189] AI-augmented management processes can help to coordinate complex tasks such as maintaining optimal satellite spacing, ensuring effective communication links, and balancing bandwidth allocations.[190] This automated intelligent approach could become essential in an era of mega-constellations, when hundreds to thousands of satellites must operate harmoniously to provide global coverage.[191]

Furthermore, AI management of satellite constellation can also extend to functions such as collision avoidance and space debris tracking.[192] With the low Earth orbits becoming increasingly congested with space objects,[193] AI-driven systems can not only ensure the safety and longevity of satellite constellations but also uphold the sustainability of operations in this environment. Thus, AI's ability to process vast amounts of orbital data as well as make rapid and accurate decisions is revolutionizing how Outer Space operators manage and safeguard the orbital environment.

Although this AI-assisted management technique is still in its early days, NASA has already begun to test this concept. In July 2023, NASA launched four CubeSats

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188. *See* Alex S. Li, *Broadband in the Space Wide Web: Satellite Internet Heating Up*, #THESPACEBAR (June 4, 2019), https://alexsli.com/thespacebar/2019/6/4/broadband-in-the-space-wide-web-satellite-internet-heating-up [https://perma.cc/B9VX-CZ53] ("While SpaceX will likely have the early lead in this new Space Race to become the dominant satellite internet service provider in Low-Earth Orbit (LEO), it will not be the only player.").

189. *See* Phil Goldstein, *Swarm Intelligence: What is It and How Are Agencies Using it?*, FEDTECH (Feb. 23, 2022), https://fedtechmagazine.com/article/2022/02/swarm-intelligence-what-it-and-how-are-agencies-using-it-perfcon [https://perma.cc/JG65-QJ8N] (noting that NASA is starting to test swarm intelligence, "a field of AI that focuses on the use of artificial intelligence software to enable individual units . . . to act in a coordinated way," on satellites).

190. *See Denmark's Gomspace and 2Operate to Use AI for Constellation Management*, SPACEWATCH.GLOBAL, https://spacewatch.global/2019/03/denmarks-gomspace-and-2operate-to-use-ai-for-constellation-management/ [https://perma.cc/V2QB-AQ54] (last visited Oct. 20, 2024) (explaining that AI models can automate certain constellation management tasks); *see also* John Loeffler, *New Lockheed Martin System will Manage Satellite Constellation from the Cloud Using AI*, SPACE.COM (Sept. 26, 2023), https://www.space.com/lockheed-martin-manage-satellite-constellations-cloud-artificial-intelligence [https://perma.cc/65B7-ALEK] ("Lockheed Martin might very well have developed a system with minimal human interaction that can manage the maddeningly complex trajectories of tens of thousands of satellites in real time.").

191. *See* Li, *supra* note 188 (indicating that these constellations contains "hundreds or thousands of satellites").

192. *See* Sarah Wells, *AI Battles the Bane of Space Junk*, IEEE SPECTRUM (July 1, 2023), https://spectrum.ieee.org/space-junk-ai-cleanup [https://perma.cc/F5JK-LKG9] ("AI models can be trained using historical data to identify space-debris motion patterns and predict their future trajectories. . . . This allows collision-avoidance maneuvers to be more effectively planned for active space missions and orbiting satellites.").

193. *See* Alex S. Li, *Up in the Air: Turning Space Debris into Opportunities*, #THESPACEBAR (Aug. 13, 2017), https://alexsli.com/thespacebar/2017/8/up-in-the-air-turning-space-debris-into-opportunities [https://perma.cc/UJW5-U9JG] (indicating "that there are approximately 24,000 objects, 10-cm or greater in size, circling earth").

into low Earth orbit to further explore swarm navigational techniques.[194] Through this mission—named Starling—NASA has successfully evaluated the benefits and limitations of these technologies in enabling spacecrafts to operate collectively and autonomously without relying on remote ground-based support.[195] The insights gained from Starling will enable NASA to fine-tune AI-assisted constellation management techniques.[196] Thus, this mission has the potential to revolutionize future satellite constellations by making them more scalable and financially feasible.[197]

D. In-Situ Servicing

Artificial intelligence-driven robotic systems can also forge new frontiers in the field of in-situ servicing. These robots, guided by sophisticated AI systems, can autonomously perform a wide array of tasks that are crucial for the development and maintenance of Outer Space infrastructure.[198] By enabling in-situ servicing capabilities in Outer Space, these systems can extend the operational life of various space objects. This would eliminate the need for repeated launch-and-reentry cycles that can weaken these objects' structural integrity.[199] These AI-servicing modules can also operate continuously in the challenging and unpredictable environment of Outer Space.[200] This ability enables them to be less Earth-dependent and lay the foundation for more sustainable and permanent Outer Space operations.

Furthermore, these autonomous servicing operations could eliminate some of the risks that humans would have to otherwise face in Outer Space; AI-controlled robots could take over complex repair or installation projects that currently require humans to spend hours to perform as a part of dangerous spacewalks.[201] With the ability to make key decisions independently and adapt to unforeseen challenges,[202] these intelligent robots are also particularly well-suited

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194. Justin Kruger, *News: Successful Launch and Development of Starling*, STAN. SPACE RENDEZVOUS LAB'Y (July 18, 2023), https://slab.stanford.edu/news/news-successful-launch-and-deployment-starling [https://perma.cc/49KD-VHWQ].

195. *Swarming for Success: Starling Completes Primary Mission*, NASA, https://www.nasa.gov/directorates/stmd/swarming-for-success-starling-completes-primary-mission/ [https://perma.cc/HKH9-EN9Y] (last visited Oct. 20, 2024).

196. *What is Starling?*, NASA, https://www.nasa.gov/smallspacecraft/what-is-starling/ [https://perma.cc/8D6Q-4CSH] (last visited Oct. 20, 2024).

197. *Id.*

198. *See* Boyu Ma, Zainan Jiang, Yang Liu, & Zongwu Xie, *Advances in Space Robots for On-Orbit Servicing: A Comprehensive Review*, 5 ADVANCED INTELLIGENT SYS. at 1 (Aug. 2023), https://onlinelibrary.wiley.com/doi/epdf/10.1002/aisy.202200397 [https://perma.cc/7WEK-RXTG] ("[S]pace robots can assist or replace astronauts in completing various missions, such as aiding astronauts in repairing the Hubble Space Telescope, constructing space stations, and maintaining satellites.").

199. *See* Li, *Opening Outer Space*, *supra* note 35, at 705 (indicating that space objects undergo a lot of stress during launch and reentry activities).

200. *See* Li, *Touring Outer Space*, *supra* note 41, at 805 (noting that Outer Space is "naturally inhospitable to human life").

201. Jason Caffrey, *What Could Possibly Go Wrong on a Spacewalk?*, BBC (Dec. 22, 2015), https://www.bbc.com/news/magazine-34810412 [https://perma.cc/FNQ6-DB7R].

202. *See* Zhihong Jiang, Xiaolei Cao, Xiao Huang, Hui Li & Marco Ceccarelli, *Progress and Development Trend of Space Intelligent Robot Technology*, 2022 SPACE: SCI. & TECH. at 5 (Jan. 2022),

for servicing space objects residing in more distant orbits and locations. As a result, AI-guided robots could facilitate more expansive and transformative activities in Outer Space.

While still considered science fiction by some, in-situ servicing operations are slowly becoming a reality. For instance, the European Space Agency, in collaboration with commercial partners, is in the advanced stages of planning its first ever in-orbit service mission.[203] While the details of this technology demonstration are still under development,[204] this mission draws parallels to NASA's previously planned but ultimately cancelled "On-orbit Servicing, Assembly, and Manufacturing" mission: OSAM-1.[205] In the case of OSAM-1, AI technologies were expected to play a pivotal role in enabling robotic components to autonomously capture and refuel the Landsat-7 satellite.[206] Consequently, it stands to reason that AI technologies will similarly be integral to the European Space Agency's mission design. The successful execution of this technology demonstration could chart a new path for orbital repair. AI-controlled servicing missions could become a cost-effective way to extend the lifespans of existing satellites.[207] These missions can also help to mitigate the issue of space debris by capturing defunct objects and altering their trajectories for disposal burn via atmospheric reentry.[208]

E. Health Monitoring

In the field of Outer Space medicine, artificial intelligence could

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https://spj.science.org/doi/epdf/10.34133/2022/9832053 [https://perma.cc/3VR3-H7M9] ("In 2002, the United States launched a project . . . [whose] main purpose . . . is to develop a space robot that docks with spacecraft in orbit and to verify the ability to *automatically* dock, capture, refuel, and repair noncooperative space targets without docking interface.") (emphasis added).

203. *ESA Moves Ahead with In-Orbit Servicing Missions*, EUR. SPACE AGENCY (July 14, 2023), https://www.esa.int/Enabling_Support/Preparing_for_the_Future/Discovery_and_Preparation/ESA_moves_ahead_with_In-Orbit_Servicing_missions2 [https://perma.cc/N9MM-FQZA].

204. *Id.; see also ESA to Build First In-orbit Servicing Mission with D-Orbit*, EUR. SPACE AGENCY (Oct. 14, 2024), https://www.esa.int/Space_Safety/ESA_to_build_first_in-orbit_servicing_mission_with_D-Orbit (noting that the mission is still in demonstrate stage and ESA needs to verify "that [the mission] meets all the performance standards").

205. *On-orbit Servicing, Assembly, and Manufacturing 1 (OSAM-1)*, NASA, https://www.nasa.gov/mission/on-orbit-servicing-assembly-and-manufacturing-1/ [https://perma.cc/2FHM-5RG8] (last visited Oct. 20, 2024).

206. *See* Robert K. Ackerman, *The Sky is No Limit for NASA Robotics*, SIGNAL (July 1, 2020), https://www.afcea.org/signal-media/sky-no-limit-nasa-robotics [https://perma.cc/F2WL-U9FU] ("The spacecraft's mission profile calls for it to autonomously rendezvous and capture the Landsat-7 satellite, which it then will refuel telerobotically.").

207. *See ESA Moves Ahead with In-Orbit Servicing Missions*, EUR. SPACE AGENCY (July 14, 2023), https://www.esa.int/Enabling_Support/Preparing_for_the_Future/Discovery_and_Preparation/ESA_moves_ahead_with_In-Orbit_Servicing_missions2 [https://perma.cc/N9MM-FQZA] ("ESA has conducted extensive work on IOS, including as part of its Clean Space initiative for the removal and prevention of space debris.").

208. *See, e.g., clearspace-1*, EUR. SPACE AGENCY, https://www.esa.int/Space_Safety/ClearSpace-1 [https://www.esa.int/Space_Safety/ClearSpace-1] (last visited Oct. 20, 2024) ("Clearspace-1 will [be] the first-ever mission to remove an existing derelict object from orbit through highly precise, complex, close proximity operations, all in the name of cleaning up space.").

revolutionize the way human health is being managed. Equipped with diagnostic capabilities, AI systems can continuously monitor health data, swiftly detect deviations, and automatically issue early warnings of potential medical issues.[209] This health management system could be crucial in Outer Space, where conventional medical facilities are inaccessible. Furthermore, personnel in Outer Space have to contend with unique challenges like microgravity and radiation.[210] Therefore, an AI's ability to offer real-time health assessments and diagnostic support could usher in a new era in Outer Space healthcare. This could lead to more ambitious and extended deep space missions.

AI's transformative influence in Outer Space extends beyond physical health management to encompass mental well-being as well. The solitude of Outer Space can lead to feelings of "magnificent desolation."[211] This effect will undoubtedly be amplified during extended deep space missions, potentially resulting in mental health issues such as anxiety or depression.[212] These conditions could have dire consequences in Outer Space where a small mistake can be fatal. But through interactive applications that utilize machine learning and natural language processing, AI technologies could offer personalized psychological support.[213] The incorporation of highly developed AI systems capable of engaging in conversation, providing coping strategies, and even delivering therapy sessions could prove indispensable. Hence, AI advancements in Outer Space could lead to the promise of a more holistic approach to health management, ensuring that crews on long-durational missions remain both physically fit and mentally resilient.

Although the use of AI-assisted technologies for monitoring health is still in its nascency, there are several prominent examples. Concerning physical health, sensors in NASA's spacesuits can continuously collect biometrics data about their wearers.[214] This data is then transmitted to mission control where AI-assisted

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209. *See* Ethan Waisberg, Joshua Ong, Phani Paladugu, Sharif Amit Kamran, Nasif Zaman, Andrew G. Lee & Alireza Tavakkoli, *Challenges of Artificial Intelligence in Space Medicine*, 2022 SPACE: SCI. & TECH. at 6 (Jan. 2022), https://spj.science.org/doi/epdf/10.34133/2022/9852872 [https://perma.cc/BUH7-VP3P] ("Over time, AI systems will . . . becom[e] more data-driven, personalized, and preventative to improve the health outcomes of astronauts.")

210. Zarana S. Patel, Tyson J. Brunstetter, William J. Tarver, Alexandra M. Whitmire, Sara R. Zwart, Scott M. Smith & Janice L. Huff, *Red Risks for a Journey to the Red Planet: The Highest Priority Human Health Risks for a Mission to Mars*, 6 NPJ MICROGRAVITY at 1 (Nov. 2020), https://www.nature.com/articles/s41526-020-00124-6 [https://perma.cc/8RFN-ALL6] ("The major health hazards of spaceflight include higher levels of damaging radiation, altered gravity fields . . . . ").

211. John Loeffler, *Deep Space Missions Will Test Astronauts' Mental Health. Could AI Companions Help?*, SPACE.COM (Oct. 6, 2023), https://www.space.com/astronauts-artificial-intelligence-companions-deep-space-missions [https://perma.cc/KXZ3-TL32].

212. *See id.* ("A road trip through a cold, lifeless void that is one loose seal away from sucking you out into certain doom? Astronauts need all the help they can get to stay mentally healthy.").

213. *See id.* ("Given the prolonged and extreme isolation of a future Mars mission, an AI social support tool, if proven to be effective, could serve as part of a toolkit of countermeasures available to future crew venturing on a mission to Mars . . . .").

214. Loura Hall, *Astronaut Artificial Intelligence Monitors Patients at Home*, NASA (Sep. 30, 2020), https://www.nasa.gov/technology/tech-transfer-spinoffs/astronaut-artificial-intelligence-monitor

technologies can proactively monitor the astronauts' vitals for warning signs.[215] In the realm of mental well-being, an AI-powered robot called CIMON-2—short for the second iteration of the Crew Interactive Mobile Companion—has been undergoing demonstration testing on the ISS.[216] Developed by European Space Agency's partners, CIMON-2 relies on IBM's Watson AI technology and functions as an astronaut's robotic assistant and companion in Outer Space.[217] Capable of recognizing emotions, CIMON-2 is designed to act as an "empathetic conversational partner."[218] This aspect is particularly important for human beings who inherently require social interactions for their mental well-being.[219] Although further research and development is needed before something akin to TARS becomes a reality,[220] emotionally intelligent AI robots could be a solution in maintaining the spacefarers' mental well-being on extended missions.

Hence, advancements in artificial intelligence are poised to reshape the landscape of Outer Space at an ever-accelerating pace. AI technologies stand as a revolutionary force capable of ushering in a new era of Outer Space exploration and utilization. This transformation could herald a new future where humanity's more ambitious celestial aspirations are not merely within reach but could soon become tangible realities.

But, the widespread adoption of these paradigm-shifting technologies in Outer Space could strain the interpretation and application of this domain's existing legal framework. This challenge is particularly pronounced in the realm of incident resolution, where the established liability framework has its roots in a different era. The next Part will examine how these advancements in AI technologies may disrupt the existing paradigm set by the Liability Convention.

IV. AI'S CHALLENGES TO THE EXISTING LIABILITY REGIME

As artificial intelligence finds applications in various aspects of Outer Space exploration and utilization, its transformative power will not only reshape technological capabilities but will also challenge existing legal structures. One such

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s-patients-at-home/ [https://perma.cc/BS82-N37D].

215. *Id.*; Satta Sarmah Hightower, *Startup Adapts AI Used in Space to Advance Healthcare on Earth*, FORBES (Apr. 6, 2021), https://www.forbes.com/sites/awsstartups/2021/04/06/startup-adapts-ai-used-in-space-to-advance-healthcare-on-earth/?sh=2bd199945355 [https://perma.cc/A7E Q-8S3H].

216. Tereza Pultarova, *Astronauts in Space Will Soon Resurrect an AI Robot Friend called CIMON*, SPACE.COM (Sep. 7, 2021), https://www.space.com/space-station-ai-robot-cimon-upgrade-for-astronauts [https://perma.cc/LM4U-DHNZ].

217. *Id.*

218. Mike Wall, *New, Emotionally Intelligent Robot CIMON 2 Heads to Space Station*, SPACE.COM (Dec. 5, 2019), https://www.space.com/cimon-2-artificial-intelligence-robot-space-station.html [https://perma.cc/JV2W-3HKC].

219. John Loeffler, *Deep Space Missions Will Test Astronauts' Mental Health. Could AI Companions Help?*, SPACE.COM (Oct. 6, 2023), https://www.space.com/astronauts-artificial-intelligence-companions-deep-space-missions [https://perma.cc/KXZ3-TL32].

220. Business Insider, *'MythBusters' Adam Savage Explains Why Interstellar's TARS is the Perfect Robot*, YOUTUBE at 2:25 (July 17, 2019), https://www.youtube.com/watch?v=0UoOhdvQYmo&t=145s [https://perma.cc/Q3EG-8W2M].

challenge is to the framework set by the Liability Convention. The emergence of AI as a key player—one that is capable of autonomous navigation, active monitoring, passive operations, and even comprehensive management[221]—in various Outer Space activities introduces novel scenarios that were unimaginable when this treaty was first drafted. Therefore, traditional methods of identifying and assigning liability may become outdated in the face of AI's autonomous capabilities. This inadequacy could stymie the resolution of incidents involving AI technologies.

Thus, AI technologies could have a significant impact on the Liability Convention's effectiveness in resolving Outer Space-related incidents. Within this treaty, AI's increasing use is poised to have a significant effect on three particular legal issues: (1) the pool of liable parties, (2) the applicability of absolute liability, and (3) the accountability of fault. This Part will explore each of these topics in turn.

A. The Pool of Liable Parties

In the realm of space-related activities, the Liability Convention has long stood as a pivotal framework governing the attribution of liability for damages from a space object.[222] Historically, this treaty hinges on the principle that only launching States or State-like intergovernmental organizations can bear liability.[223] However, the increasing use of artificial intelligence in various Outer Space activities presents a profound challenge to this established paradigm; this is particularly true when it comes to identifying the parties that could be held liable. Hence, AI's emerging role in this sector should warrant a reexamination of the Liability Convention's definition for a "launching State."

Currently, when a space object causes harm, it is relatively straightforward to identify the parties that could be held liable. The Liability Convention stipulates that only "launching States" or state-like "international intergovernmental organizations" can bear such liability;[224] this group is narrowly defined to include only States or State-like entities that launch, procure the launch, or whose territory or facility is used for the launch of the space object in question.[225] While the definition is clear-cut, this framework substantially reduces the types of parties that could be held accountable. However, this limitation made sense for the era in which this framework was originally conceived: a period when space missions were predominantly driven by States or State-like organizations.[226] In the rare instance when a mission was run by a commercial enterprise, it was still under a State-entity's ultimate

221. *See generally supra* Part III.
222. *See generally supra* Part II.B.
223. *See supra* Part II.B.2.b.
224. *Id.*
225. *Id.*
226. *See* Li, *Touring Outer Space*, *supra* note 41, at 747 ("Outer Space started as essentially the exclusive province of governmental agencies . . . .").

control.[227] Thus, without fail, the attribution of liability was an easy task and the narrow definition made sense.

However, the landscape of Outer Space exploration and utilization is on the cusp of a paradigm shift with AI technologies' increasing use. AI systems, characterized by their capacity for autonomous decision-making, introduce a novel and challenging scenario. In cases where damages are directly caused by the autonomous actions of an AI-driven space object, the question of liability becomes more nuanced. In such instances, it might not be appropriate to limit the pool of liable parties to only those States or State-like entities that launched, procured the launch, or whose territory or facility was used for the launch of such an object.

This is because these launching States might not have direct control, or even indirect influence, over the AI's decision-making process. These launching States then might be able to avoid liability by arguing that they did not breach any duty of care; there was nothing that they did or did not do that caused the incident. The harm was completely attributable to the fault of an autonomous AI system and these launching States are too far removed from the chain of causation to be liable.

In these cases, the claimant might then try to petition the State responsible for the "faulty" AI technology for compensation. Arguably, it would be justifiable to hold such a State accountable for the damages caused; even if it does not have complete oversight, this State could have asserted some influence over the development of the AI technologies and their autonomous decision-making processes. Thus, it would be equitable to hold such a State accountable because it is not that far removed from the incident's chain of causation.

But under the Liability Convention, these AI-responsible States do not qualify as launching States. The current definition for a launching State does not cover a State that is accountable for procuring an AI *component* of a space object.[228] The Liability Convention only covers a State that is responsible for procuring the *whole* space object for launch.[229] It could very well be the case that these are two different States. If this is true, then the injured party could be left without a remedy.

This issue is further compounded by the rise of the commercial space industry.[230] Many private enterprises are at the forefront of developing and deploying AI technologies for Outer Space.[231] Consequently, these commercial corporations will play a more direct role in influencing the operation and control of many AI-assisted space objects and missions. However, none of these

227. *Id.* at 749 ("Even in entrepreneurial-oriented societies as the United States, there was a prevalent feeling that these enormous endeavors were not feasible for private companies to lead and accomplish.").

228. *See supra* Part II.B.2.b.

229. *Id.*

230. Li, *Opening Outer Space*, *supra* note 35, at 668–69.

231. David Cotriss, *AI in Space Exploration and AI Space Stocks to Watch*, NASDAQ (Feb. 15, 2023), https://www.nasdaq.com/articles/ai-in-space-exploration-and-ai-space-stocks-to-watch [https://perma.cc/K8PE-TNU6].

companies could be considered a launching State—as the Liability Convention only covers nation-states or State-like intergovernmental organizations.[232] Therefore, under the treaty, even though they are more directly linked to an AI-enhanced space object, these private enterprises could not be held directly liable by the injured State.

While some might argue that these commercial corporations could still become indirectly liable outside of the Liability Convention, the remedies there are not well-defined. Specifically, an injured State would have to make a claim to these companies' "State-sponsors" based on the Outer Space Treaty's "responsibility" provision.[233] Under this framework, all States "bear international responsibility for [their] national activities in outer space" including those by their "*non-governmental entities*."[234] Hence, the States where the liable companies are domiciled would be held accountable for any damages caused.

However, in such cases, the Outer Space Treaty lacks the details needed to file a claim or to determine the appropriate compensation.[235] This weakness underscores the primary reason why the Liability Convention was created; the convention established clear and structured procedures to make the Outer Space Treaty's liability provision effective.[236] But by pursuing liability against commercial entities indirectly via the "responsibility" clause of the Outer Space Treaty, the injured State has to now bypass the concrete processes established by the Liability Convention. And as discussed earlier, the claimant also could not proceed under the Liability Convention to avail itself of these processes as the commercial entities are not called out as a type of launching State.[237] This catch-22 means that the injured State might be left without a remedy.

Furthermore, AI's autonomous decision-making process introduces an additional independent link in the liability chain. Consequently, it might not be equitable to place all of the blame solely on the various country-sponsors. While member-States are expected to, and generally do, enact effective commercial space regulations to ensure their enterprises do not take unnecessary risks or evade their liabilities,[238] when it comes to AI technologies, this oversight power becomes less effective. With AI's autonomous decision-making ability, these States may no

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232. *See supra* Part II.B.2.b.

233. *See supra* Part II.A.

234. Outer Space Treaty, *supra* note 36, art. VI (emphasis added).

235. *See* Adrian Taghdiri, *Flags of Convenience and the Commercial Space Flight Industry: The Inadequacy of Current International Law to Address the Opportune Registration of Space Vehicles in Flag States*, 19 B. U. J. SCI. & TECH. L. 405, 415-16 (2013) [hereinafter Taghdiri, *Flags of Convenience*] (noting that the Outer Space Treaty lacks enforcement or settlement processes for damages).

236. *See supra* Part II.B.1.

237. *See supra* Part II.B.2.b.

238. *See* Taghdiri, *Flags of Convenience*, *supra* note 235 at 412 ("As a result, it is often in a signing party's best interest to adopt effective legislation to avoid unexpected liability for damages caused through a launch failure or a mishap in outer space.") (internal citations omitted); *see also* Li, *Unifying Outer Space*, *supra* note 37, at 1198 (indicating that Luxembourg passed national legislation holding its domestically domiciled corporations liable "for any damages that their activities might cause").

longer have the capability to exercise direct control or influence. In a case where the harm is caused by an AI's indirect and independent downstream decision rather than the actions of an entity that a State is directly overseeing, it may no longer be fair or appropriate to attribute such damages to that State-party.

The emergence of AI technology and its growing autonomy in decision-making processes is revolutionizing the Outer Space environment. Yet, AI's increasing integration into various Outer Space activities is also reshaping this sector's legal landscape, particularly concerning the attribution of liability. The Liability Convention's traditional focus on launching States or State-like organizations as the only liable parties may no longer make sense. Therefore, it is very likely that the types of parties that could be held liable need to be redefined to ensure equitable accountability. This modification will ensure the availability of an effective remedy in the event of damages caused by AI-assisted space objects.

But this gap in the pool of parties that can be held liable is just one of the challenges facing the Liability Convention in this new AI space age. The next section will explore another issue confronting this treaty amidst the AI revolution in Outer Space: the imposition of absolute liability in cases involving autonomous decisions.

B. The Applicability of Absolute Liability

Artificial intelligence's growing incorporation into various Outer Space activities heralds the arrival of a new era of exploration and technological advancements for this sector. However, AI's advanced capabilities also present a challenge to the "absolute liability" concept within the Liability Convention. Under this treaty, a liable party would be held "absolutely liable" for any damage caused by its space objects on Earth's surface or to an aircraft in flight.[239] But the ascension of AI technologies, characterized by autonomous decision-making capabilities,[240] may necessitate a reevaluation of this principle.

There are several reasons why holding launching States to an absolute liability standard for certain damages was the right choice when the Liability Convention was ratified. During that frontier era, Outer Space activities were dominated by governmental agencies and organizations;[241] with the exploration of Outer Space in its infancy, it was an activity that was still extremely dangerous, unknown, and unpredictable.[242] Given these characteristics, it made sense that the burden of responsibility and liability for such space objects should be fully borne by their launching States when harm was inflicted upon unwitting victims.[243] This

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239. *See supra* Part II.B.2.c; Liability Convention, *supra* note 55, art. II.

240. *See generally supra* Part III.

241. Li, *Touring Outer Space*, *supra* note 41.

242. Sarah Pruitt, *The 5 Deadliest Disaster of the Space Race*, HISTORY, https://www.history.com/news/the-5-deadliest-disasters-of-the-space-race [https://perma.cc/9XXV-57DL] (last updated Oct. 20, 2018).

243. *See* St. John, *Westphalia Trouble*, *supra* note 77, at 699-700 (indicating how the doctrine of "dangerous things" put the safety burden on the launching States).

standard was intended to incentivize launching States to take all measures needed to protect innocent bystanders. Moreover, if harm results, crucial information associated with such incidents would likely be known only to the launching States.[244] Thus, the absolute liability standard also ensured that these bystander parties' claims would not fail simply because they could not meet the "impossible burden [of proving] faulty or negligent action."[245] Lastly, as the fruits of these high-risk, high-reward activities were reaped completely by the launching States, it was only fair that they should shoulder all of the repercussions from such activities.[246]

Furthermore, this absolute liability approach is based on the premise that launching States have direct control over their space missions. This assumption was also reasonable for its time when space activities were primarily envisioned to be managed and supervised by sovereign nations.[247] Thus, these launching States had full control over the mechanisms that should be implemented to reduce risks to all nonparticipants. Given this absolute position of power, these launching States should have no objections to being held accountable through an absolute liability regime. This mechanism would provide injured States with a straightforward, unobjectionable, and equitable means of seeking compensation for damages suffered without the need to navigate the complexities of fault-determination.

However, AI's expanding role in space missions introduces a new dimension to this approach. One of AI's primary advantages is its capability to make independent operational decisions. These decisions might include navigational adjustments for reentry or landing, data analysis prioritizations, or spatial traffic management.[248] Based on real-time data and analysis, AI systems onboard various space objects can make critical operational decisions autonomously.[249] Rather than being a drawback, this autonomy is an intentional benefit of AI systems; these AI decisions can facilitate better adaptations to unforeseen circumstances by quickly adjusting different systems to counter any potential issues.

But when autonomous decisions made by AI systems malfunction and result in incidents causing damage to Earth's surface or an aircraft in flight, a dilemma arises. In such cases, the traditional concept of absolute liability becomes problematic: It might not be fair or practical to hold a launching State absolutely liable for actions taken autonomously by an AI system. This is particularly noteworthy given that these actions are likely to stem from intricate algorithms and learning processes that operate independently from the launching States' direct control or influence.

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244. Kirsten Schmalenbach, *Convention on International Liability for Damage Caused by Space Objects*, *in* CORPORATE LIABILITY FOR TRANSBOUNDARY ENVIRONMENTAL HARM, 523, 533 (Peter Gailhofer, David Krebs, Alexander Proelss, Kirsten Schmalenbach & Roda Verheyen eds., 2022).

245. *Id.*

246. *Id.*

247. Li, *Touring Outer Space*, *supra* note 41.

248. *See generally supra* Parts III.A-III.C.

249. *See generally supra* Parts III.A-III.D.

The growing potential for such incidents necessitates a reevaluation of how liability should be approached in space activities involving AI technologies. The principle of absolute liability, when first introduced for Outer Space, was predicated on the premise of launching States' direct involvement.[250] However, AI's autonomous nature undermines this foundation. In these circumstances, the incentives that an absolute liability regime would have on launching States are diminished given these entities' limited control over AI's independent and near-instantaneous decision-making processes.

Furthermore, another initial justification for implementing an absolute liability regime was the information asymmetry between the injured States and the launching States. As the Outer Space sector matures, this may no longer be the case. Information technologies related to this domain have rapidly advanced, making incident details more accessible to State-parties representing those harmed on Earth's surface or in an aircraft in flight.[251] Additionally, with private enterprises—rather than nation-states—taking the lead on AI technologies, information about the AI systems integrated into space objects is becoming more readily available.[252] These enterprises are also more transparent about incidents involving their technologies.[253] Thus, it no longer appears implausible for injured States to meet the burden of proof. Therefore, the information asymmetry concern that led to the implementation of the absolute liability regime may have weakened over time.

Hence, the proliferation of AI technologies in Outer Space presents a significant challenge to the principle of absolute liability established by the Liability Convention. As AI takes on more autonomous space-related roles, launching States will likely have less direct control over the factors that could lead to damages on Earth's surface or to an aircraft in flight. Hence, the effectiveness of an absolute liability regime in ensuring safe operations may be diminished.

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250. *See supra* note 244.

251. There are various sites containing up-to-date information about various Outer Space technologies and activities. *See, e.g.*, Gunter D. Krebs, *Gunter's Space Page*, GUNTER'S SPACE PAGE, https://space.skyrocket.de/index.html [https://perma.cc/NN5Q-QQSH] (last visited Oct. 20, 2024); Everyday Astronaut, *Bringing Space Down to Earth for Everyday People*, EVERYDAY ASTRONAUT, https://everydayastronaut.com/about-us/ [https://perma.cc/2ZX2-KDXG] (last visited Oct. 20, 2024).

252. *See, e.g.*, Russo & Lax, *AI for Space*, *supra* note 180 (This AI technology survey suggests that information about the latest AI systems is becoming easier to access by all).

253. *See, e.g.*, Rocket Lab, *Rocket Lab Completes Anomaly Review, Next Mission on the Pad in July*, ROCKET LAB, https://www.rocketlabusa.com/updates/rocket-lab-completes-anomaly-re view-next-mission-on-the-pad-in-july/ [https://perma.cc/JE8D-M9LA] (last visited Nov. 20, 2023); Federal Aviation Administration, *FAA Closes SpaceX Starship Mishap Investigation*, FEDERAL AVIATION ADMINISTRATION (Sep. 8, 2023), https://www.faa.gov/newsroom/faa-closes-spacex-star ship-mishap-investigation [https://perma.cc/7E9Z-UULV]; Federal Aviation Administration, *FAA Closes Blue Origin Mishap Mishap Investigation*, FEDERAL AVIATION ADMINISTRATION (Sep. 27, 2023), https://www.faa.gov/newsroom/faa-closes-blue-origin-mishap-investigation [https://perma.c c/TK5J-CLLY]; Rocket Factory Augsburg (@rfa_space), X (Aug. 24, 2024, 2:10 AM), https://x.co m/rfa_space/status/1827030581986611696 [https://perma.cc/R8JE-FBHY].

Furthermore, as information regarding incidents becomes more widely dispersed and readily available, the balance of fairness between the injured States and the launching States may no longer justify how the absolute liability regime was originally constructed. Consequently, as this new era of space exploration continues, the absolute liability regime will need to be reevaluated.

While the absolute liability regime is only applicable to damages caused to Earth's surface or to an aircraft in flight, the Liability Convention also established a fault-based system to govern damages occurring elsewhere. However, AI's emergence is introducing complexities to the resolution of disputes under this system as well. The following section will examine this issue in greater detail.

C. The Accountability of Fault-Based Liability

The integration of artificial intelligence into the sphere of Outer Space activities will also present new challenges for the Liability Convention's fault-based liability standard. Historically, this standard requires a claimant to prove that, in any location other than on the Earth's surface or to an airplane in flight, the damages caused by a launching State's space objects were due to such State's negligence or fault.[254] However, the rising importance of AI technologies, with their inherent autonomous characteristics, in Outer Space brings nuanced complexities that will further strain this already-contentious standard.

The fault-based liability framework was conceived during a time when Outer Space activities were primarily under direct human control. As a result, this liability model was predicated on the basis of a relatively clear chain of events from cause to effect, enabling a straightforward attribution of fault in the event of damage caused by space objects outside the scope of the absolute liability regime.[255] While this approach appears simple and elegant, the Liability Convention does not explicitly define a standard of care; this leaves room for subjective interpretation of when a State should be held accountable.[256] A recurring point of contention since the treaty's inception,[257] this absence of a standard has led to concerns that the Liability Convention might be insufficient to resolve these types of incidents.[258]

Nevertheless, the lack of a standard of care in the convention was a deliberate choice made by its drafters.[259] During the negotiations for the Liability

254. *See* discussion *supra* Part II.B.2.c.

255. *See* St. John, *Westphalia Trouble*, *supra* note 77, at 700–01 ("Assuming the space object causing the damage is identified and the launching state is at fault, it is then responsible for the damage.").

256. *See id.* at 701 ("This is a fundamental flaw in the Liability Convention because fault cannot be measured without the yardstick of standard of care. Several theories, however, have been put forward.").

257. *See, e.g.*, St. John, *Westphalia Trouble*, *supra* note 77, at 701 (calling it a "fundamental flaw"); *Liability for Damages*, supra note 59, at 368 ("The failure to define 'fault' also has been seen as a defect in the convention.").

258. *See* James P. Lampertius, *The Need for an Effective Liability Regime for Damage Caused by Debris in Outer Space*, 13 MICH. J. INT'L L. 447, 456-57 (1992) (indicating that the lack of as standard creates the issue with providing "a rule of decision").

259. *Id.* at 453–54.

Convention, activities in Outer Space were still in their infancy.[260] Thus, the likelihood of incidents was still relatively minimal. To the drafters, this meant that the potential for causing a lengthy delay in the convention's adoption outweighed the immediate benefits of establishing a clearly defined standard.[261] Consequently, the drafters decided to defer this matter for another day.[262]

Yet, AI technologies' increasing adoption into various Outer Space activities means that this discussion can no longer be delayed. AI systems, operating with a high degree of autonomy, introduce a new layer of complexity to the already vague fault-based liability framework. Operating independently from direct human intervention, AI technologies make decisions based on their algorithms and the results of their data analysis. These autonomous operations pose a significant challenge to the traditional mechanism of attributing fault. If damages occur in Outer Space because of an AI-driven autonomous decision, the conventional approach of attributing fault based on human error or oversight may become irrelevant.

Proving fault in these scenarios would likely necessitate an understanding of AI's own decision-making process. These decisions typically result from AI's own unsupervised learning capability: when the AI trains itself through its machine learning algorithms' interactions with environmental inputs.[263] Thus, these AI decisions, although founded on logical analysis, can be unpredictable and challenging to decipher, making fault determination challenging.[264] Adding to this complexity, when multiple AI-systems are involved, establishing the source of fault for an incident becomes even more difficult: Was it the AI responsible for data analysis or the AI responsible for implementing the solution? Moreover, once the source of fault is identified, the lack of a standard of care presents a further challenge. Without this standard that accounts for the dynamic nature of an AI's decision-making process, it is difficult to objectively establish that the AI had made a "faulty" decision or acted negligently in its decision-making process.

Furthermore, the growing significance of commercial companies in Outer Space will complicate the fault-based liability regime. Many emerging AI technologies being utilized in Outer Space came from private enterprises.[265] In scenarios where these private entities have the primary control over the AI

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260. *Id.* at 454.

261. *Liability for Damages*, supra note 59, at 369.

262. *See* Reis, *Liability Convention Reflections*, *supra* note 53, at 127 ("The negotiators recognized that it may eventually prove desirable to have a separate additional treaty on space-sustained damage when the presence of human beings in space becomes frequent and numerous.").

263. Visual Journalism Team, *A Simple Guide to Help You Understand AI*, BBC (July 10, 2023), https://www.bbc.co.uk/news/resources/idt-74697280-e684-43c5-a782-29e9d11fecf3 [https://perma.cc/FYN8-9CBZ].

264. Chloe Xiang, *Scientists Increasingly Can't Explain How AI Works*, MOTHERBOARD TECH BY VICE (Nov. 1, 2022), https://www.vice.com/en/article/y3pezm/scientis ts-increasingly-cant-explain-how-ai-works [https://perma.cc/D2NM-Z7A6].

265. David Cotriss, *AI in Space Exploration and AI Space Stocks to Watch*, NASDAQ (Feb. 15, 2023), https://www.nasdaq.com/articles/ai-in-space-exploration-and-ai-space-stocks-to-watch [https://perma.cc/K8PE-TNU6].

technologies used in a space mission, the State-centric liability model will likely come under strain. While the Outer Space Treaty dictates that nation-States are responsible for the activities of their commercial enterprises, it lacks any detailed enforcement mechanisms.[266] Although the Liability Convention was drafted to address this issue, the convention makes no explicit reference to private entities.[267] Thus, in cases where the damages occur in Outer Space because of an AI system developed and operated by a private enterprise, it might not be equitable to indirectly assign fault to the responsible State as opposed to directly assigning it to the accountable company.

Additionally, the collaborative nature of modern space missions adds further complexity to the process of attributing fault. These missions often involve multiple public and private actors with AI systems being one of many components in a multifaceted space endeavor. Disentangling the responsibilities and liabilities of each involved party in the event of an incident can be a nuanced and challenging task; determining which parties should be responsible in such a collaborative activity requires unraveling the contributions of various actors, including AI developers and operators.

Moreover, with multiple launching States involved, there is an increased likelihood that the liable party could be the State-representative of the injured party. In this case, the Liability Convention could be rendered toothless;[268] the liable party could simply assert that the treaty exempts these damages from compensation since such damages are to the liable party's own nationals.[269] This loophole further highlights the need for a comprehensive and adaptable framework to address fault-based liability.

Thus, the treaty's conventional fault-based liability standard will likely become inadequate to fully address the use of AI technologies in Outer Space. AI's autonomous decision-making capability, combined with the involvement of multiple actors—including private enterprises—in space missions, underscores the urgent need for a reevaluation of how fault and standards of care should be formulated within the context of Outer Space laws.

As AI continues to advance and play an increasingly autonomous role in space activities, it is necessary for the corresponding legal framework to evolve in tandem. Such an adaptation is essential to ensure that the liability model remains relevant and effective in an era where technology, particularly AI, is rapidly reshaping the contours of Outer Space exploration and utilization. This evolution will necessitate the establishment of dynamic and technology-appropriate standards of care as well as clear delineations for the roles and responsibilities of multiple State and non-State actors. Additionally, it will entail a reassessment of

266. *See* discussion *supra* Part IV.A.
267. *Id.*
268. *See* discussion *supra* Part II.B.2.d.
269. Liability Convention, *supra* note 55, art. VII(a).

the pool of liable parties and a reevaluation of the concept of absolute liability. The subsequent Part will examine these aspects in detail, offering in-depth recommendations for reshaping the Liability Convention to align with the increased use of AI technologies in Outer Space.

V. ADAPTING THE LIABILITY CONVENTION FOR THE AI ERA

The rapid advancement of artificial intelligence is reshaping the landscape for Outer Space exploration. In the face of this challenge, the existing liability framework governing activities for this sector stands at a crossroads. Consequently, there is a need to adapt the Liability Convention to better align the framework with the increasingly significant role that AI will play in Outer Space. This Part will propose several recommendations for such an adaptation. Specifically, it will focus on three areas of change to the Liability Convention: (a) redefining the "launching State" concept, (b) reevaluating the "absolute liability" principle, and (c) reforming the "fault-based liability" regime.

A. Redefining Launching State

As artificial intelligence's role in Outer Space exploration continues to expand, redefining the "launching State" categories within the Liability Convention becomes increasingly important. The current framework, primarily centered on those State-parties involved with the launch,[270] will prove inadequate in addressing the complexities of modern space missions. In some of these endeavors, it might be necessary to hold the party responsible for the AI technologies running the space object accountable as well.[271]

To adapt to this evolving landscape, it is essential to broaden the definition for a "launching State." This would first involve creating new "launching State" categories that would cover State-parties that procure or control the AI technologies responsible for the autonomous operations of a space object. Then, taking this one step further, the definition for "launching State" should be revised to include private enterprises as well. Such an expansion would enable the definition to transcend its traditional launch-oriented and state-centric focus to encompass a broad spectrum of space-related actors.

Under this redefined framework, the term "launching State" would not only encapsulate State-entities that are involved in the launch of space objects but also those entities—whether public or private—playing a critical role in controlling the AI technologies that are operating those space objects. This more inclusive approach recognizes the shared responsibility model inherent in many contemporary space endeavors; it acknowledges the collaborative nature of space operations that involve diverse public and private actors, including those that ultimately control certain aspects of an autonomous space object.

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270. *See* discussion *supra* Part II.B.2.b.
271. *See* discussion *supra* Part IV.A.

Critics might contend that holding private enterprises accountable through an international treaty contradicts established international norms. However, this traditional perspective is becoming the minority view; recent developments suggest that the global community is moving away from the position that private enterprises cannot be held liable under international treaties.[272] Under this new direction, corporations could soon find themselves fully integrated into the international legal system and held accountable for certain actions.[273] Furthermore, there are international treaties in existence where certain obligations extend directly to private corporations. For instance, in the Law of the Sea,[274] private enterprises are prohibited from claiming certain oceanic areas.[275] These precedents indicate that the modern approach is favoring the perspective that international treaties can assign certain responsibilities to private entities.

Critics may further argue that expanding the definition of "launching State" to include private enterprises represents an unnatural and unjustified extension. But such criticism overlooks the evolving dynamics of Outer Space exploration. In the modern space age, private enterprises are not merely passive participants but often active pioneers in space activities.[276] In such circumstances, limiting liability exclusively to States-members is anachronistic. This traditional view fails to recognize the significant control and influence that private entities exert over space missions, particularly those activities operated autonomously by AI technologies.

Since many space missions are now substantially developed, funded, and executed by private companies,[277] these entities have become indispensable actors whose actions could directly lead to incidents in Outer Space. Thus, it is both logical and equitable that, with such increased operational control, these entities should have increased responsibility and liability. Omitting these private enterprises from the liability equation would create a legal loophole, enabling entities that play a pivotal role in a space object's operations to evade accountability.

Incorporating the entities responsible for AI technologies into the liability framework would address a crucial gap in the current Outer Space legal system. The updated regime will ensure that those who have a direct influence over the AI

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272. *See* Emeka Duruigbo, *Corporate Accountability and Liability for International Human Rights Abuses: Recent Changes and Recurring Challenges*, 6 NW. J. INT'L HUM. RTS. 222, 224 (2008) ("[L]egal status of corporations in international law has shifted to some extent from the classical position, with corporations now considered bearers of duties under international criminal law.").

273. *See id.* ("[S]ignificant changes are occurring in the domestic and international planes that suggest that a more far-reaching shift, that would more fully integrate private business enterprises into the international legal system, will occur some time in the near future.").

274. U.N. Convention on the Law of the Sea, *opened for signature* Dec. 10, 1982, 1833 U.N.T.S. 397 (entered into force Nov. 16, 1994).

275. *See id.* at Art. 137(1) (noting explicitly that corporations, as "juridical person," cannot "claim or exercise sovereignty or sovereign rights over any part of the Area or its resources").

276. *See* discussion *supra* Part III.

277. *See* Li, *Unifying Outer Space*, *supra* note 37, at 1193 ("As a renewed public interest fuels the emergence of a new space age, it is becoming clear that—unlike the first space age—commercial entities will play a significant role in developing the new space economy.").

systems are held accountable for the outcomes of these systems' operations. This liability exposure is vital in an era where AI technologies can make autonomous decisions that could lead to complex legal and safety issues. By broadening the definition for "launching States" to directly cover liabilities for these issues, the Liability Convention can more effectively manage the risks associated with AI-assisted space activities. This will encourage more responsible conduct and due diligence among all parties involved.

While the legal and regulatory implications of this revision are profound, this is a critical step towards creating a legal framework that accounts for the autonomous nature of AI operations in Outer Space. This expanded definition for "launching State" is necessary to ensure that liability related to space activities is equitably assigned. By reflecting the diverse array of actors who contribute to and exert influence over these missions, the updated Liability Convention can remain a resilient and pertinent instrument.

But, broadening the categories for "launching State" represents only one aspect of the changes required to modernize the Liability Convention for this new era of Outer Space exploration. The following section will explore how the standard for "absolute liability" should evolve with the rise of AI technologies as well.

B. Reevaluating Absolute Liability

The evolving landscape of Outer Space, especially with the increasing utilization of artificial intelligence, also necessitates a critical reevaluation of the "absolute liability" standard defined in the Liability Convention. This standard, which currently holds the launching State absolutely liable for any harm caused by its space objects to the Earth's surface or an aircraft in flight,[278] must be reassessed in light of the growing autonomous activities in Outer Space.

When the "absolute liability" principle was first established, activities in Outer Space were still in their infancy.[279] At that time, space missions were extremely risky and accessible only to a select few highly developed nations.[280] With so few parties directly involved and fully reaping the benefits of these ultrahazardous activities, it made sense that the liability standard was more focused on protecting bystanders around the world.[281] Thus, the absolute liability standard was introduced to ensure a straightforward compensation mechanism that does not require these innocent parties to prove fault or negligence.[282] But fast-forward to today, the landscape of Outer Space has evolved significantly; it has become a more equitable playground with participation from many different countries and commercial entities.[283]

278. *See* discussion *supra* Part II.B.2.c.
279. *See* discussion *supra* Part IV.B.
280. *Id.*
281. *Id.*
282. *Id.*
283. *See* Tim Marshall, *The New Space Race*, ROYAL MUSEUMS GREENWICH, https://ww

While Outer Space-related activities still carry inherent risks, advancements in technology and accumulated experience have made the launch and reentry processes safer.[284] This progress has contributed to fewer safety concerns. Furthermore, even nations without space programs now have improved access to information and knowledge related to the space sector.[285] As a result, the seemingly "impossible burden" of proof associated with liability claims has become more manageable for all countries.[286] These factors all diminish the concerns that led to the creation of the absolute liability standard.

Moreover, AI's capacity for independent decision-making and learning implies that certain actions of space objects are no longer directly controlled, or can even be fully predicted, by their human operators.[287] Thus, when a space object equipped with AI technologies causes damage, a fundamental question arises: Is it fair to hold the launching State absolutely liable for decisions made autonomously by an AI system? This scenario becomes even more complex when considering AI's ability to adapt through machine learning and its own experience, making AI's decision-process even harder to predict over time.

In light of these evolving circumstances, the applicability of the absolute liability standard should be altered. For damages caused to Earth's surface or an aircraft in flight by an AI-controlled space object, it may not make sense for a launching State to be automatically held liable. In such incidents, instead of having the location of the harm be the determinative factor for liability, the focus should shift to whether there was an adequate level of oversight during the development and qualification processes for the AI systems in question. A State should only be held absolutely liable for damages resulting from an AI-driven space object in these locations if the onboard AI technologies were not properly certified for space operations. But this does not mean the injured party is left without a remedy if the launching State had fulfilled its due diligence in approving the AI technologies for Outer Space activities. That launching State could still be held liable for damages under the Liability Convention's fault-based standard—as revised by the next section[288]—if the AI systems' operations breached certain widely-accepted standards of care.

However, this shift in the application of the absolute liability standard

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w.rmg.co.uk/stories/topics/new-space-race-astropolitics-power-21st-century [https://perma.cc/M433-DXC5] (last visited Oct. 20, 2024) ("More than 80 countries now have a presence in space.").

284. Mike Wall, *Will Human Spaceflight Ever Truly Be Safe?*, SPACE.COM (Jan. 27, 2011), https://www.space.com/10698-human-spaceflight-safety.html [https://perma.cc/JTG3-KFG E] ("Like aviation, human spaceflight will get safer and safer as the years pass and knowledge grows, according to experts.").

285. *See* discussion *supra* Part IV.B.

286. *Id.*

287. Roman Yampolskiy, *Unpredictability of Artificial Intelligence*, ORACLE AI & DATA SCIENCE BLOG (Feb. 5, 2020), https://blogs.oracle.com/ai-and-datascience/post/unpredictability-of-artificial-intelligence [https://perma.cc/8Y5M-B78E].

288. *See* discussion *infra* Section V.C.

requires the establishment of clear certification processes for AI systems used in space missions. Without these widely accepted standards in place, an injured State may find itself unable to definitively prove that the accountable party's certification process was inadequate. Consequently, before shifting the focus of the absolute liability standard, guidelines associated with AI technologies' development for and use in space activities must be implemented. These standards should encompass aspects such as safety, reliability, transparency of AI's decision-making processes, and whether there are safeguards in place to override certain autonomous decisions. By setting such standards, it then becomes feasible to decide whether a launching State met its burden of due diligence for such AI systems so that it should not be held absolutely liable for the resulting damage. Thus, until and unless these standards are introduced and gain further traction, the absolute liability standard should remain in effect as it currently stands.

Legal reforms to the absolute liability standard will likely involve a comprehensive review and amendment of the Liability Convention. Simultaneously, the recommendation to pivot the focus of the absolute liability standard for damages resulting from AI's autonomous decisions should only be considered when general standards for the use of AI technologies in Outer Space have been promulgated. Due to the complexity and multitude of stakeholders involved, implementing such a transformation may require substantial effort and collaboration. Nonetheless, the reevaluation of the absolute liability standard is a necessary step to ensure that the Liability Convention remains relevant and effective in this new era of Outer Space exploration.

However, the absolute liability standard is not the only standard discussed in the Liability Convention. The convention's current fault-based liability system will also face challenges as AI technologies become increasingly prominent in Outer Space. The subsequent section will detail the adjustments needed for this regime as well.

C. Reforming Fault-based Liability

The rapid integration of artificial intelligence technologies in various Outer Space activities also presents a significant challenge to Liability Convention's fault-based liability standard. This standard, traditionally centered on proving fault or negligence on the part of the launching State,[289] finds itself increasingly inadequate in the face of AI's complex decision-making capabilities. Operating with substantial autonomy, AI systems can make decisions in Outer Space based on advanced algorithms and independent data analysis.[290] Therefore, these decisions might not necessarily align with traditional human reasoning and predictability.[291] This, in turn, complicates the attribution of fault or negligence pursuant to existing legal norms.[292]

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289. *See* discussion *supra* Part II.B.2.c.
290. *See generally* discussion *supra* Part III.
291. Yampolskiy, *supra* note 287.
292. *See* discussion *supra* Part IV.C.

Furthermore, the Liability Convention in its current form does not specify a standard of care.[293] While this gap has been manageable for traditional space missions, it will become increasingly problematic in the age of AI-assisted space objects. Without clear standards of care, it would be difficult to determine whether the AI systems deviated from established safety and operational protocols, which is essential for assessing fault in the event of an incident.

Thus, the fault-based liability system under the Liability Convention must be reformed by establishing clear standards of care. Some of these new standards should be tailored to accommodate the distinctive operational characteristics of AI systems employed in space missions. These standards should encompass not only the technical and safety aspects of AI systems as applied to space activities but also ethical considerations, ensuring responsible and sustainable use of AI in Outer Space.

One critical area of focus for these standards of care is the establishment of a clear classification of AI levels of autonomy. This classification would provide a framework for determining the extent to which human operators can control or override AI decisions in Outer Space, a critical factor in assessing fault and liability. For instance, a high level of autonomy in an AI system, where human control is minimal, would necessitate stricter safety and operational standards for the underlying space object, while a lower level of autonomy, with substantial human control, might require a different set of safety and operational criteria. This classification system will not only aid in establishing a more precise standard of care for AI systems used in space missions but also delineate the level of responsibilities and oversight expected by their controlling entities.

Establishing these standards will fill a critical void in the existing fault-based liability framework. These standards will provide a baseline for determining the compliance of AI systems against globally accepted safety standards and operational protocols. This becomes essential for assessing fault in the event of an incident involving AI-driven space objects. Additionally, clear standards will serve as guidelines for entities involved in the development and deployment of AI systems, ensuring that all parties adhere to best practices and are held accountable for their roles.

Even with these standards of care in place, assessing whether a breach occurred in an incident involving AI-controlled space objects demands a detailed analysis. This breach assessment should consider whether the AI system's design, programming, or operation diverged from the established safety standards and operational protocols. In particular, the assessment should evaluate the AI system's responses to unanticipated environmental conditions and the effectiveness of its programming in handling unexpected scenarios. The nature of this breach assessment would vary based on the AI's level of autonomy and the degree of human involvement, offering a balanced and fair determination of fault.

While reforming the "fault-based liability" system to incorporate these

293. *See* discussion *supra* Part II.B.2.c.

standards of care will not be easy, it is necessary. The retooling of this framework, along with changes in the definition for "launching State" and the applicability of the "absolute liability" standard will create a liability framework that is adaptable, equitable, and reflective of the evolving landscape of Outer Space-related activities. Achieving such reforms will require a concerted effort among space-faring nations and stakeholders that strikes a balance between fostering innovation in space technologies and upholding the principle of accountability.

As advancements in AI technologies create a new Outer Space reality filled with autonomous activities, the Liability Convention needs this realignment. In fact, adjusting the Liability Convention to accommodate these emerging circumstances aligns with the original intent of the treaty's architects, who foresaw its eventual obsolescence.[294] Reflecting the dynamic interplay between technology and law in the realm of Outer Space, these changes will ensure the Liability Convention's continual relevancy in ensuring responsible and sustainable progress in Outer Space.

VI. TO A NEW AI HORIZON

With the advancement and increased utilization of artificial intelligence technologies in Outer Space, it is clear that the liability regime governing this sector is at a critical juncture. Propelled by necessity, much like the explorers in *Interstellar* who ventured into the unknown,[295] we too find ourselves at a crossroads related to Outer Space activities; one that requires us to set out on a mission to transform this sector's legal landscape to ensure its alignment with the emerging realities of AI-driven space missions.

In this Article, I embarked on this journey. I started by providing a comprehensive overview of the international treaties governing liability in Outer Space as well as the transformative nature that AI technologies could have on activities within this sector. With a focus on the Liability Convention, I then critically explored how the increased use of AI technologies poses challenges to the existing liability framework governing Outer Space. In response to these issues, I proposed a series of recommendations to adapt the Liability Convention to these technological advancements.

The essence of this endeavor can be aptly summarized by TARS's quote at the beginning of our journey:[296] To reach new heights in AI-assisted exploration of Outer Space, we must be willing to reassess and, if necessary, leave behind

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294. *See* Reis, *Liability Convention Reflections*, *supra* note 53, at 127 ("The negotiators recognized that it may eventually prove desirable to have a separate additional treaty on space-sustained damage when the presence of human beings in space becomes frequent and numerous.").

295. *See* A.O. Scott, *Off to the Stars, With Grief, Dread and Regret*, N.Y. TIMES (Nov. 4, 2014), https://www.nytimes.com/2014/11/05/movies/interstellar-christopher-nolans-search-for-a-new-planet.html [https://perma.cc/E6BQ-548M] ("Some kind of message seems to be coming across the emptiness of space and along the kinks in the fabric of time, offering a twinkle of hope amid humanity's rapidly darkening prospects.").

296. *Supra* Part I.

outdated legal notions. Thus, it is my hope that this Article serves as a call to action for policymakers, practitioners, and scholars to engage in the critical task of transforming the liability regime for Outer Space. By doing so, we can ensure that the legal framework governing such activities remains robust—one that is capable of fully harnessing new opportunities while effectively managing the challenges presented by the inclusion of AI technologies in everyday space activities.

In this way, this journey of legal evolution will not be just about leaving something behind; it will also be about paving the way for a future where law and technology harmoniously coexist. One in which AI technologies will be effectively empowered to guide humanity forward as we continue to explore the vastness of Outer Space and onward to a new horizon.