Space Operations

LAWN DART NETWORK UTILIZATION ON THE MOON

Liberty Shockley

The Lawn Dart program, a proliferated mesh network of security commodities staged across the lunar surface, will promote a stable and sustainable space operating environment. Lawn Darts will deploy as probes from lunar orbit around the surface of the Moon to provide an Internet of Things and a power network for other operational assets such as rovers, people, and Moon bases. This capability and its execution raises questions about international law and geopolitical concerns related to territorial claims on the lunar surface and the planned organization of space activities by conflicting parties, but the program is compliant with the current framework of law and policy. The Lawn Dart program is essential for providing security for lunar assets, protecting mission data against adversaries, and laying the groundwork for NASA and European Space Agency exploration mission success.

Space is busy, however, there is still insufficient infrastructure to support or protect assets in space, and no agreed upon coordination of space activities. Companies and governments worldwide have proposed important technologies to explore the edges of the universe, and these technologies depend on resources such as power, fuel, autonomous communication and operations, communication relay, and a place in orbit or on a celestial surface.

In an increasingly contested space environment, security is becoming critical. The United States, its Allies, and partners do not have adequately mature technology or concepts of operations to ensure safety and security against adversaries. We need commodities that provide security for mission data, communication, navigation, and power for other operations such as rovers or personnel on bases.

Lawn Darts, currently being developed by the Air Force Research Laboratory Center for Rapid Innovation, will provide a proliferated mesh network of security commodities around valuable parts of the lunar surface. Probes, or "Lawn Darts," would be deployed from orbit and lodge permanently in the ground. These probes would be composed of different sensors to perform a variety of security functions. Lawn Darts will essentially create a network that provides internet-like services and "charging stations" on the Moon.[1]

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1. Donald J. Trump, *Presidential Memorandum on Reinvigorating America's Human Space Exploration Program* (Washington, DC: The White House, December 11, 2017), https://trumpwhitehouse.archives.gov/.

Yet, deploying a physical communications network such as the one provided by the Lawn Dart program raises questions about international cooperation with regard to surveillance, resource utilization, and territorial claims on the Moon's surface pursuant to international law and US national policy. While space exploration has always had a joint and peaceful focus, securing and supporting the space domain could cause conflicts of state interests as space operations progress.

The United States seeks to lead the effort to establish cooperative norms of behavior that thwart adversarial interests, recognizing the strategic importance of the Moon to developing a cislunar econosphere. The current international framework, which primarily encourages the peaceful use of outer space, is not robust enough to guide space traffic management and will not be suited to resolve territorial claims and conflicts on the Moon. Decisionmakers must navigate what is in the realm of technical possibility and norms of behavior, and what provides the strategic advantage to accomplish their missions.

The Lawn Dart program will promote a stable and secure space operating environment on the Moon in a way that is internationally cooperative and harmonious with the current and future development of space law and policy.

Background

The Lawn Dart program is intended to protect communication, sensing, navigation, power generation and distribution on the lunar surface for connected assets. It will use unattended ground sensor nodes to conduct situational awareness information using cameras, transmit vital communications to and from any rover or sensor connected to the network in an Internet-of-Things manner, provide asset and adversary tracking, and provide power infrastructure for assets on the Moon.

The deployment method and unattended ground sensor design of Lawn Darts ensure accessibility to remote locations on the Moon. For this, individual Lawn Darts will be designed as penetrator-type spacecraft. They will deploy from another spacecraft in low lunar orbit, survive impact to the surface, power on, and connect to other nodes autonomously. The collection of nodes will provide a grid for use on the lunar surface and a communication relay back to Earth. This system will provide the required infrastructure to support future US, Ally and partner lunar missions. The concept of operation and technologies involved are illustrated in Fig. 1.

US national law directs the execution of space programs to ensure compliance with international law and minimize the spread of critical technologies to nations that could threaten US national security.[2] Myriad US laws, standards, and regulations dictate space missions and technologies and focus particularly on operational objectives, launch, space-debris creation, territorial claims on celestial bodies, and weapons. Therefore, the Lawn Dart program must be designed in a way that minimizes debris

2. National and Commercial Space Programs, 51 U.S.C. (2010), § 20102, Congressional Declaration of Policy and Purpose, https://uscode.house.gov/.

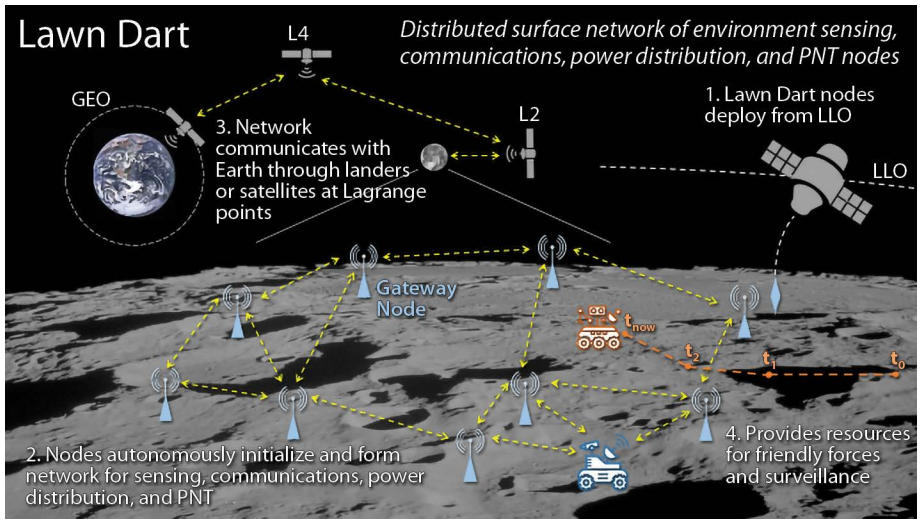

Figure 1: Lawn Darts network utilization on the lunar surface[3]

creation, does not appear to be a weapon or claim territory, and fits into both US national security and NASA interests.

Unattended ground sensor nodes and networks provide security infrastructure in the terrestrial operational domains, but this experiment extends them to the space domain. These sensors are typically used in military multidomain operations, soliciting concerns about the militarization of space. Similar hard-landing/penetrator concepts such as the Deep Space 2 mission have flown before but not for the purpose of communications infrastructure, and not with Chinese or other adversary assets in close proximity.[4]

NASA's plan for Sustained Lunar Exploration and Development and National Space Directive #1—"Lead an innovative and sustainable program of exploration . . . the United States will lead the return of humans to the Moon for long-term exploration and utilization"—generally describes how this technology will support plans for US exploration of the Moon and international participation in activities on the Moon.[5]

3. Graphic created by Charles Finely, Air Force Research Laboratory Center for Rapid Innovation, NASA Ames.

4. Suzanne Smrekar et al., "Deep Space 2: The Mars Microprobe Mission," *Journal of Geophysical Research* 104, no. E11 (November 1999), https://agupubs.onlinelibrary.wiley.com/; and National Aeronautics and Space Administration (NASA), "NASA Space Science Data Coordinated Archive," "Deep Space 2," vers. 5.1.15, October 28, 2022, https://nssdc.gsfc.nasa.gov/.

5. Smrekar et al., "Deep Space 2"; and NASA, "Deep Space 2."

Interpreting Space Law and Policy

International Law and Policy

Space Law originates principally from bilateral agreements between the United States and the former Soviet Union during the space race of the twentieth century, but soft law is currently used to supplement outdated treaties from this period.[6] Accordingly, there is a lack of legally binding international law concerning the space domain. Currently, only five treaties adopted by the UN General Assembly exist: the Outer Space Treaty (1967) the Rescue and Return Agreement (1967), the Liability Convention (1972), the Registration Convention (1976), and the Moon Agreement (1984).[7]

The Outer Space Treaty provides a legal framework for states to create unique national space laws that guide the treaty's implementation. Predominantly, the Outer Space Treaty requires space to be used for peaceful purposes and declares there can be no state sovereignty in the space domain.[8] National space law then trickles down into policy for and regulations of public and commercial space programs.

Other than these legally binding treaties, the UN has adopted formal principles through the UN Committee on the Peaceful Uses of Outer Space (UN COPUOS) and guided by the UN Office of Outer Space Affairs, although they do not influence the utilization of Lawn Darts. These include: the Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space (1963), Principles Governing the Use by States of Artificial Earth Satellites for International Direct Television Broadcasting (1982), Principles Relating to Remote Sensing of the Earth from Outer Space (1986), Principles Relevant to the Use of Nuclear Power Sources in Outer Space (1992), and the Declaration on International Cooperation the Exploration and Use of Outer Space for the Benefit and in the Interest of All States, Taking into Particular Account of the Needs of Developing Countries (1996).

The UN has also adopted documents and guidelines that are not considered legally binding. These paired with the budding establishment of norms of behavior in space collectively are also considered soft law, which guides most space activities. For Lawn Darts and the majority of other spacecraft built, the Space Debris Mitigation Guidelines of the COPUOS, the Inter-Agency Space Debris Coordination Committee

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6. Liberty Shockley et al., "Policy and Geopolitical Implications of Launch-On-Demand Capabilities," *Journal of Defense Research & Engineering*, 3, no. 1 (2020); and Frans von der Dunk and Fabio Tronchetti, eds., *Handbook of Space Law* (Northampton, MA: Edward Elgar, 2017).

7. Shockley, "On-Demand Capabilities."

8. Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (Outer Space Treaty), U.S., U.K., U.S.S.R., January 27, 1967, 18 U.S.T. 2410, arts. 2, 3, https://www.unoosa.org/; and UN, "Space Law Treaties and Principles," UN Office of Outer Space Affairs (website), n.d., accessed December 15, 2022, https://www.unoosa.org/.

(IADC) Space Debris Mitigation Guidelines, and the International Standards Organization (ISO) are the most applicable references.[9]

For legally binding guidance, Lawn Darts must adhere to the Outer Space Treaty, the Liability Convention, and the Registration Convention, though compliance is already baked into the guiding regulations described in US national space law.[10] Critically, no state that self-launches human spaceflight has ratified the Moon Agreement, meaning US national and commercial space programs are not subject to its terms.[11] Yet this agreement still worth considering since it is widely mentioned, especially as nations are planning more Moon missions and proposing more bilateral agreements on lunar activities.

Most existing space policy and regulations pertain to the creation of space debris due to its ability to clog up orbits and physically threaten space assets and space use. The definition of space debris, however, does not include any objects not in Earth orbit, so there are no international standards for the disposal of mission hardware on the Moon or other celestial bodies.[12]

The IADC Space Debris Mitigation Guidelines state debris creation "shall be minimized," but there are no further stipulations for the creation of debris on the Moon.[13] In conclusion, while there is not thorough guidance on disposal in the cislunar sphere, the Lawn Dart program intends to use the experimental nodes in the operational infrastructure once the technology is proven, along with interoperability in the LunaNet architecture, adhering to the call for responsible and sustainable actions in the space domain.

US Law and Policy

As noted above, Title 51 of US Code describes the laws applicable to national and commercial space programs in the United States. There are many administrative offices under the Executive Branch that further guide how space programs are to be conducted including NASA, the Federal Communications Commission, the Department of Defense, and the Federal Aviation Administration. The International Traffic

9. UN Office of Outer Space Affairs, *International Space Law: United Nations Instruments* (Vienna: United Nations, May 2017).

10. Convention on International Liability for Damage Caused by Space Objects, RES 2777 (XXVI), November 29, 1971, https://www.unoosa.org/; and Convention on Registration of Objects Launched into Outer Space, RES 3235 (XXIX), November 12, 1974, https://www.unoosa.org/; and 51 U.S.C.

11. UN General Assembly, Resolution 34/68, Agreement Governing Activities of States on the Moon and Other Celestial Bodies (Moon Agreement), A/RES/34/68 (1979), https://www.unoosa.org/.

12. International Standards Organization (ISO), *Space Systems and Operations including Space Data and Information Transfer Systems, and Ground Support Equipment for Launch Site Operations*, ISO 49.140 (Geneva: ISO, n.d., accessed December 20, 2022), https://www.iso.org/; and ISO, *Space Systems – Lunar Simulants*, ISO 10788:2014 (Geneva: ISO, current as of 2019), https://www.iso.org/.

13. Inter-Agency Space Debris Coordination Committee (IADC), *IADC Space Debris Mitigation Guidelines*, IADC-02-01 rev. 2 (IADC, March 2020), https://orbitaldebris.jsc.nasa.gov/.

in Arms Regulations (ITAR) also levies many requirements on the development and collaboration of space programs and their technologies.

Title 51 does not specifically regulate activities on the Moon that Lawn Darts could be subject to; it simply directs the Department of Defense, Federal Aviation Administration, and NASA to implement programs through policy directives and instructions.[14] The National Space Council's policy directive calls specifically for a program with Lawn Dart's capabilities: "To execute this vision [A New Era for Deep Space Exploration and Development] requires a secure international environment that is conducive to US commercial growth."[15] NASA's Strategic Goal 2 issues a similar call: "Extend human presence deeper into space and to the Moon for sustainable long term exploration and utilization."[16] These directives reinforce that the United States should and will be a dominant leader in lunar exploration; consequently, the Department of Defense's role is to protect and defend those missions.[17]

The Lawn Dart program falls under the US Space Force. According to the memorandum of understanding between the Space Force and NASA, "USSF organizes, trains, and equips to provide the resources necessary to protect and defend vital U.S. interests in and beyond Earth-orbit, new collaborations will be key to operating safely and securely on these distant frontiers."[18]

While Lawn Dart will function as the surface layer to help deliver vital security commodities and secure the space domain, the Space Force is currently working with NASA to address how Lawn Darts support NASA's LunaNet architecture, which plans to provide similar network and detection information.[19] This collaboration not only meets the intention of US national policy directives and memorandum of understanding, but it also mitigates concerns for space-debris creation because Lawn Darts will fully integrate with the LunaNet architecture.

Geopolitical Implications

A point of ambiguity in Lawn Dart's mission stems from the geopolitical implications of the presence of military sensors on the surface of the Moon. A Lawn Dart is a semipermanent US object on the lunar surface capable of surveillance and providing security supplied by the US military, a function typically associated with conflict prevention in the terrestrial domain. Immobile sensors and coverage also cause

14. 51 U.S.C.

15. The White House National Space Council, *A New Era for Deep Space Exploration and Development* (Washington, DC: The White House, July 23, 2020), page #, https://csps.aerospace.org/.

16. NASA, *NASA Strategic Plan 2022* (Washington, DC: NASA, 2022), 20, https://www.nasa.gov/.

17. NASA, *NASA's Plan for Sustained Lunar Exploration and Development* (Washington, DC: NASA, 2020), https://www.nasa.gov/.

18. NASA and US Space Force (USSF), "Memorandum of Understanding between the National Aeronautics and Space Administration and the United States Space Force," (Washington, DC: NASA and USSF, September 2020), 2, https://www.nasa.gov/.

19. Katherine Schauer and Danny Baird, "LunaNet: Empowering Artemis with Communications and Navigation Interoperability," NASA (website), October 6, 2021, https://www.nasa.gov/.

perceptions of territorial claims on the surface of the Moon that are prohibited by international law. But this concern is mitigated with specific guidance from the first-ever *National Cislunar Science & Technology Strategy*, published in November 2022.

The strategy outlines how the US government will focus its funding on civil, commercial, and defense on certain technologies to enable long-term growth in cislunar space.[20] It also frequently acknowledges that "a comprehensive framework for the SSA [space situational awareness] R&D needs for Cislunar space remains undeveloped" and that "SSA is essential to safe and successful . . . operations."[21] Finally, it outlines the methods the United States will use for international cooperation, including data sharing, and how a safe and predictable cislunar space is paramount for this cooperation.

To the Moon

As the only countries that self-launch human spaceflight and have soft-landed on the Moon, the United States, China, and Russia are the primary actors in space. The well-documented space race resulted in the successful landing of humans on the Moon over 50 years ago, but a new competition has begun—a quest for space superiority. "[Politicians] understand that China wants to lead the race to the moon and establish industrial - and likely military - supremacy in cislunar space with the support of Russia and other allies."[22]

China is often seen as the most active participant (and threat) in the lunar domain, though it still supports joint international ventures in accordance with international space law. In January 2019, the China National Space Administration successfully landed the first robotic, far-side lunar mission, Chang'e-4.[23] The mission's purpose was to orbit, land, and return lunar samples to Earth. In 2020, Chang'e-5 successfully launched, landed, and returned more lunar samples while also testing additional communication and landing technology. Chang'e-6, with even further objectives, is planned for 2024.[24] China has been the only state to successfully land on the far side of the moon, unseen by any terrestrial or lunar near-side observation equipment.

The China National Space Administration has its own plans for lunar scientific research stations with the goal of long-term stay of astronauts. Turkey, Ethiopia, and Pakistan are participating in China's lunar efforts, but other dominant spacefaring nations are not.[25] Incidentally, multilateral treaties and the White House-published

20. Cislunar Technology Strategy Interagency Working Group (CTSIWG), *National Cislunar Science & Technology Strategy* (Washington, DC: National Science and Technology Council, November 2022), https://www.whitehouse.gov/.

21. CTSIWG, *Strategy*, page 11.

22. Guilio Prisco, "Op-ed | SpaceX Fans Should Stand behind NASA and Support Artemis," Spacenews, November 15, 2022, https://spacenews.com/.

23. Lin Xu et al., "China's Lunar and Deep Space Exploration Program for The Next Decade (2020-2030)," *Chinese Journal of Space Science* 40, no. 5 (2020), https://www.cjss.ac.cn/.

24. Chunlai Li et al., "China's Present and Future Lunar Exploration Program," *Science* 365, no. 6450 (2019): 238–39, https://doi.org/.

25. Li et al., "Lunar Exploration Program."

Cislunar Strategy call for international cooperation, yet NASA is barred from bilateral activities with China through the Wolf Amendment.[26]

China is notably absent from the well-known Artemis Accords despite having a significant presence on the moon. This is due in part to the Wolf Amendment and because China remains highly criticized for its lack of transparency, disregard for human rights, and contempt of internationally accepted norms of behavior.[27]

While it seems "the world's space agencies are coming into surprising, if delicate, alignment about returning to the Moon and building a settlement there," questions remain as to which party will be first, and how all lunar actors will coexist.[28]

Expanded lunar exploration plans from the United States, China, and the European Space Agency include autonomous robotic support, which will require a communication network between them, and power, especially on the far side. If completed and employed by the Defense Department, Lawn Darts would likely introduce a game-changing capability that would advance US security in lunar exploration. In addition to the strategic importance of the cislunar orbit, the lunar surface has strategically advantageous elements including the South Pole, far side, subsurface, and resource concentrations.

With the prevalence of Chinese missions, particularly on the far side of the Moon, and the planned human presence on bases developed by multiple countries, a Lawn Dart capability is both necessary and urgent. The potential for a non-Allied lunar-capable nation conducting unknown science experiments in a location currently undetectable or hidden from current US-based lunar infrastructure poses a significant security risk.

If an opposing force deployed an outpost or undisclosed venture in an area currently outside the orbital coverage of existing reconnaissance satellites, the US and its Allies and partners would have to rely on the adversary being completely forthcoming about its activities. But the deployment of a Lawn Dart in the vicinity and in communication with its mesh network could relay vital information back to the United States. Moreover, anti-access, area-denial tactics inspire US lunar security strategy without compromising the UN's call to not militarize the space domain.

Ultimately, if the United States does not contest China's lunar dominance, it could lose an opportunity to make use of many lunar natural resources, including physical mission space and economic benefits of lunar materials, and see future trade and commerce opportunities compromised.

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26. Elliot Ji, Michael B. Cerny, and Raphael J. Piliero, "What does China think about NASA's Artemis Accords?," *Diplomat*, September 17, 2020, https://thediplomat.com/.

27. Makena Young, "Bad Idea: The Wolf Amendment (Limiting Collaboration with China in Space)," Defense360, December 4, 2019, https://defense360.csis.org/.

28. Eliza Strickland and Glenn Zorpette, "The Coming Moon Rush: Technology, Billionaires, and Geopolitics Will All Help Get Us Back to the Moon, but They Won't Be Enough to Let Us Live There Indefinitely," *IEEE Spectrum* 56, no. 7 (July 2019), https://doi.org/.

Concerns

The International Telecommunications Union (ITU) radio regulations contain a regulatory argument against employment of Lawn Darts, particularly on the far side of the Moon. "ITU-R RA.479 describes a shielded zone of the Moon" protected from certain lunar activities.[29] This regulatory zone protects science objectives of missions on the far side of the Moon that include measurements and observations free of radio frequency interference from the Earth. A networked communication infrastructure such as the Lawn Dart program could obstruct these missions. This ITU regulation thus impedes the space situational awareness and power capabilities Lawn Dart could provide via transmitter abilities and access to the far side of the Moon. As noted earlier, there is an insufficient framework guiding activities in cislunar space.

The Moon Agreement has not been signed by the United States, China, or Russia, likely due to its restriction regarding ownership of any part of the lunar surface or subsurface in addition to the general Outer Space Treaty restriction of claims to sovereignty. Lawn Darts would not lay claim to territory on the Moon just by their presence, as they could provide power and support functions to any nearby mission if desired. The network created would also not act as a fence; they would not restrict any movement on the surface.[30]

Often cited in discussions of future colonization of the Moon and Mars, the successfully implemented multilateral Antarctic Treaty restricts claims to sovereignty and requires use of the land and its resources to be peaceful and for scientific purposes.[31] But it is only signed by 54 states (compared to the Outer Space Treaty (112), the Artemis Accords (20), and the Moon Agreement (4)), and 7 states already had territorial (sovereign) claims on the continent that they were allowed to keep.

Another source of inspiration in terms of potential treaty language, the UN Convention of the Law of the Sea (UNCLOS) was ratified in 1982 and has since been updated due to the new practice (and economic benefits) of offshore drilling.[32]

In the same way that UNCLOS was developed in part due to economic opportunities in offshore international waters, space law must develop to allow for trade and commerce in its domain and regulate it.[33] Lawn Dart can provide critical support to such a regulatory schema. It is likely that as technologies from states accelerate the

29. Jack O. Burns et al., "A Lunar L2-Far Side Exploration and Science Mission Concept with the Orion Multi-Purpose Crew Vehicle and a Teleoperated Lander/Rover, *Advances in Space Research* 52, no. 2 (July 2013), https://doi.org/.

30. Moon Agreement.

31. Strickland and Zorpette, "Moon Rush,"; and the Antarctic Treaty, Argentina, Australia, Belgium, Chile, the French Republic, Japan, New Zealand, Norway, the Union of South Africa, U.S.S.R., U.K., U.S., December 1, 1959, https://documents.ats.aq/.

32. Convention on the Law of the Sea, December 10, 1982, 1833 U.N.T.S. 397, https://www.refworld.org/; and P. Hoagland, J. Jacoby and M. E. Schumacher, "Law of the Sea," in *Encyclopedia of Ocean Sciences*, 2nd ed., ed. John H. Steele (Cambridge, MA: Academic Press, 2008), 432–43.

33. Willem van Genugten, Daniela Heerdt, and Nico Schrijver, *Discover International Law with Special Attention for The Hague, City of Peace and Justice* (Oisterwijk, Netherlands: Wolf Legal Publishers, 2017).

ability for dominance in the beyond-Earth orbit, the international space community will have to decide if the fate of the Moon and other celestial bodies will follow the path laid by the Antarctic Treaty, UNCLOS, or a system of entirely new international law and custom design.

Conclusion

The Lawn Dart capability provides a forward-deployed, networked, and expandable solution for communication and power on the Moon. This technology furnishes infrastructure to future lunar missions, complimenting international and US plans for lunar exploration. Permanent, hardened lunar-surface unattended ground sensor nodes will integrate with future nodes like NASA's LunaNet, through a series of experimental, then operational launches. This architecture minimizes the creation of polluting space debris while still rapidly providing much-needed security for US missions.

Finally, the Lawn Dart program completes science objectives by mapping the lunar terrain and sensing the lunar environment in support of international lunar exploration goals. This complies with space law and the spirit of the community regarding the peaceful utilization of space for exploration. Despite some geopolitical concerns, Lawn Darts support scientific exploration of space and are critical for US participation in the space domain. If the United States does not provide security solutions for the further exploration of space and its celestial bodies, then other key actors in space certainly will, which may lead to the absence of US participation in these activities.

Furthermore, as lunar exploration is a joint international venture, the Lawn Darts program will strengthen US participation in this venture by complementing key technologies developed by NASA, the China National Space Administration, and the European Space Agency, such as Artemis, Chang'e missions, and the Moon Village, respectively.[34]

The current practices in emerging, challenged domains of operations like the cislunar sphere and on the lunar surface is to "bring everything you need." By providing a power, communication, and security infrastructure that feeds into larger planned network architectures like LunaNet, Lawn Darts reduce the cost and resources of missions and discourages the one-time-use mindset that can create more space debris. It supports key scientific missions, adheres to US national space directives mandating peaceful uses of outer space, and counters threat posed by US adversaries. Lawn Darts and the security they provide will enable the cooperative proliferation of lunar exploration missions and allow human presence to expand further, safer, and longer in the emerging lunar domain. ***Æ***

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34. Jan Woerner, "Moon Village: A Vision for Global Cooperation and Space 4.0," European Space Agency (website), n.d., accessed September 23, 2022, https://www.esa.int/