



Moon Dialogs

Sustainable Lunar Infrastructure

A Moon Dialogs Salon Report – October 1st 2020

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Sustainable Lunar Infrastructure Panel

The sixth Moon Dialogs Research Salon took place on Friday, October 1st, with a roundtable featuring Brent Sherwood, Vice President of Blue Origin; Dava Newman, Apollo Professor of Aeronautics and Astronautics at the Massachusetts Institute of Technology; and Alex MacDonald, NASA Chief Economist.

The panelists were asked to share their perspectives on the topic of 'sustainable lunar infrastructure', in particular, how they conceived near term settlement efforts on the Moon.

ALEX MCDONALD

Alex MacDonald shared that NASA's approach to lunar exploration comes from an operational perspective, where something is only sustainable if "you can afford to keep doing it". NASA's previous attempts to establish lunar return programs – the [Space Exploration Initiative](#) in the 1980's and the [Vision for Space Exploration](#) in the 2000's – relied on the establishment of large lunar bases, an approach, MacDonald argued, that was unsustainable. In its current form, the Artemis Program frames a return to the Moon as preparation for future missions to Mars. Therefore, while true lunar settlement remains far off, the near-term operative for NASA is to establish a "minimum viable presence" – or sustainable presence – on the lunar surface to gain operational insights transferable to future Mars missions. This minimum viable presence would rely on three main elements: a Lunar Terrain Vehicle, equivalent to the unpressurized rover used during Apollo, a pressurized rover, and a surface habitat. Functionally, the aim would be to set up the infrastructure needed to sustain visits to the Moon on the order of 30 days, once a year, every year, for 20 years (ideally, indefinitely). He also noted that NASA would have to balance expanding operations to the Moon and Mars while maintaining human presence in low-Earth orbit – as is mandated by U.S. national policy. The challenge would be to enable the "next generation" of operations in low-Earth orbit – an important economic anchor for the space industry. Ultimately, he concluded, the long-term vision for NASA is indefinite exploration everywhere, forever.

The infographic features a central image of the Moon with the Artemis logo and the title "NASA's Plan for Sustained Lunar Exploration and Development". A line connects this image to a text box that says "Read NASA's Plan for Sustained Lunar Exploration and Development for more details". Another line connects to a quote: "As an economist something is sustainable when you can afford to keep doing it". A third line connects to a paragraph: "With Artemis, we are focused on going to the Moon to lay a foundation for **sustained presence** (i.e. visiting the Moon once a year, every year, for 20 years)". A fourth line connects to a list of infrastructure pieces: "We need to ensure we can afford these three infrastructure pieces to ensure sustainable presence: • A Lunar Terrain Vehicle, equivalent to the unpressurized rover used at the end of Apollo • A pressurized rover • A surface HAB". A fifth line connects to a paragraph: "Functionally, we need to prove the ability to work on other worlds for 30 days." A sixth line connects to a paragraph: "The question of settlement is very different from 'sustained presence' - we're still far away from settlement, but NASA is focused on expanding our presence in the near-term from a **'Minimum Viable Presence'** perspective - what do we need to know in order to go to Mars?". A circular portrait of Alex MacDonald is in the bottom right corner, with a line connecting it to the text: "Alex MacDonald".

NASA's Plan for Sustained Lunar Exploration and Development

Read NASA's Plan for Sustained Lunar Exploration and Development for more details

As an economist something is sustainable when you can afford to keep doing it

With Artemis, we are focused on going to the Moon to lay a foundation for **sustained presence** (i.e. visiting the Moon once a year, every year, for 20 years)

We need to ensure we can afford these three infrastructure pieces to ensure sustainable presence:

- A Lunar Terrain Vehicle, equivalent to the unpressurized rover used at the end of Apollo
- A pressurized rover
- A surface HAB

Functionally, we need to prove the ability to work on other worlds for 30 days.

The question of settlement is very different from "sustained presence" - we're still far away from settlement, but NASA is focused on expanding our presence in the near-term from a **"Minimum Viable Presence"** perspective - what do we need to know in order to go to Mars?

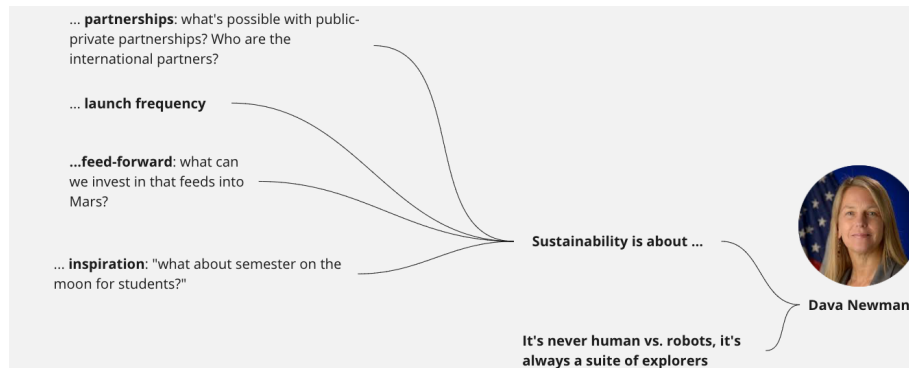
Alex MacDonald

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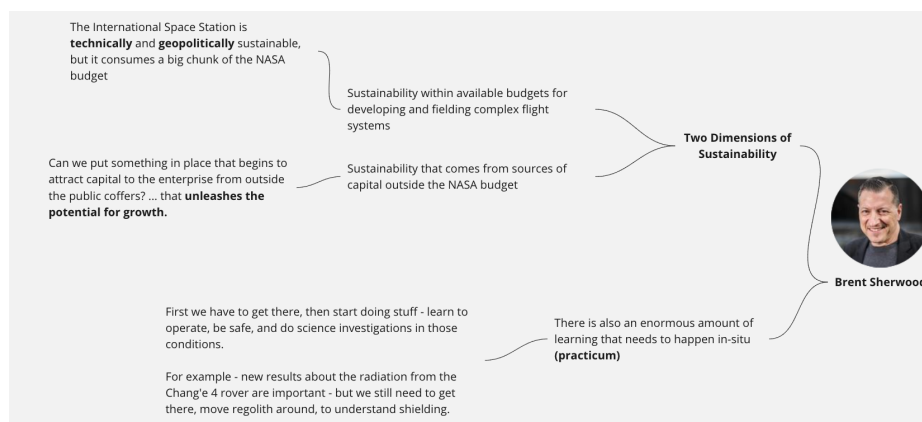
DAVA NEWMAN

Dava Newman highlighted four aspects of sustainability: partnerships with commercial players and international partners; frequent launches to enable return and resupply missions to the lunar surface; translating mission experience from lunar missions to feed forward to future Mars scenarios; and inspiring the public and next generation of explorers. In terms of critical near-term surface elements, Newman emphasized the importance of robotic precursor missions with the use of rovers, followed by human exploration. She also noted the false dichotomy between human and robot exploration, advocating for a “suite of explorers”, composed of astronauts, rovers, and newer low-cost innovations such as CubeSats.



BRENT SHERWOOD

Brent Sherwood discussed two dimensions of sustainability. Sustainability within available (government) budgets would be important for developing and fielding complex flight systems. However, he warned that programs such as the International Space Station, while technically and geopolitically stable, limited NASA by consuming large parts of the budget. In order to move past low-Earth orbit, he argued, there would have to be a “wedge” in the budget to enable new programs – something he deemed “budget sustainability”. To unleash the potential for growth in the industry and achieve genuine economic sustainability, he argued the second dimension of sustainability would have to come from sources of capital outside of the NASA budget. Ambitious visions for space exploration would be necessarily constrained by government budgets. Furthermore, building upon Alex MacDonald’s concept of the “minimum viable presence”, Sherwood emphasized that establishing an early presence on the lunar surface and a sustainable mode of transportation between Earth and the Moon would be critical. Early exploration would lead to important in-situ learning to understand how to operate in the lunar environment and further characterize lunar volatiles, which could enable future missions. Sherwood echoed MacDonald’s point regarding the importance of low-Earth, and high-Earth orbit operations, while keeping in mind Blue Origin’s ultimate vision to enable millions of people to work and live in space to benefit the Earth.



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Highlight Points Raised

DAVA NEWMAN SPOKE ABOUT SUSTAINABILITY FROM A HUMAN EXPLORATION STANDPOINT.

Newman highlighted recent and ongoing robotic missions that have already proved critical to improving our understanding of the challenges posed by the lunar environment, such as galactic cosmic radiation. While praising the sustainability of human presence in low-Earth orbit onboard the ISS, she noted that the life support systems were in need of an upgrade, and new technologies would have to be developed to enable humans to operate in the lunar environment. She also noted the importance of enabling mobility on the lunar surface – through rovers, vehicles, and humans, and sharing lessons-learned through open data-sharing policies.

BRENT SHERWOOD SHARED SOME POTENTIAL DESIGN CONSIDERATIONS, ANTICIPATING A DIVERSE NUMBER OF ACTORS ON THE LUNAR SURFACE.

Sherwood reiterated the importance of interoperability between hardware on the lunar surface. He also warned of maintaining a balance between expediency and alignment with a long-term vision: while pursuing program execution, it will be imperative to keep sight of how things feed forward.

PANELISTS DISCUSSED THE VIABILITY OF THE COMMERCIAL SPACE INDUSTRY ON THE LUNAR SURFACE.

Alex MacDonald shared NASA perspective on its own role in supporting the burgeoning space ecosystem: through designing, building, and paying for things⁽¹⁾ – and doing so in a way that enables commercial services to emerge. He highlighted certain programmatic initiatives from NASA, designed to foster the space economy, such as the Commercial Lunar Payload Services Program (CLPS) and the Volatiles Investigating Polar Exploration Rover (VIPER). MacDonald noted that there still existed an enormous aspiration-to-reality gap, which would only begin to close once NASA began to start flying ISRU demonstration flight payloads, and completing important technology demonstrations and experiments.

[\(1\) NOTE NASA'S RECENT ANNOUNCEMENT TO PURCHASE LUNAR REGOLITH FROM COMMERCIAL ACTORS.](#)

Sherwood offered his own view of commercial space, arguing that if all the funding could be traced to the NASA budget, the activity should not be classified as commercial. From Sherwood's perspective, a commercial activity is one in which someone with private capital is willing to put it at risk with the expectation of making a profit, which requires selling to customers that are not the federal government. He argued that the industry would have to start thinking about products that actors other than the government could potentially buy, but as of right now, there is no known material product from the surface of the Moon that the terrestrial economy needs.

MacDonald expanded upon that idea, suggesting that the government could fill the gap by purchasing services from industry to enable the discovery of sources of non-governmental revenue (i.e. potential services or goods).

Newman emphasized that none of this would be possible without consistency of purpose from a policy perspective: for NASA, exploration budgets shouldn't be taken for granted.

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If all the dollars are traceable to the NASA budget, it's not commercial. **Commercial means when someone with private capital is willing to put it at risk with the expectation of making a profit, which requires selling to customers that are not the federal government.**

Need to start thinking about products that actors *other than the government* can buy. Once that happens, that starts to unleash growth.

There is no known material product from the surface of the Moon that the terrestrial economy needs. Until there's something that will cause people to invest significant amounts of private capital to expand infrastructure and operations, our growth of these activities will be constrained.



Alex MacDonald

The key is figuring out what other sources of non-governmental revenue there may be into the system, NASA can purchase services to enable the discovery of that.



Dava Newman

If we want to get to the Moon, we have to stay the course. We have to have consistency of purpose for exploration. We can't take the current funding that we have for granted.

THE PANELISTS WERE ASKED TO SHARE THEIR PERSPECTIVES ON THE POTENTIAL TRADE-OFFS BETWEEN COMMERCIAL SUSTAINABILITY, WHICH NECESSITATES EXCLUSION AND CONTROL OF ACCESS, AND THE DESIRE FOR OPEN ACCESS AND OBLIGATIONS ESPOUSED BY THE INTERNATIONAL COMMUNITY AND THE OUTER SPACE TREATY.

Sherwood thought the question was premature – current visions outstrip the capability of the community, and before these questions could be addressed, there remained important technical challenges to overcome. He also noted that it would be likely that there will be a limited number of actors that will be able to deliver the capabilities being addressed.

MacDonald highlighted the importance of the Outer Space Treaty in how it established a new regime for policy and economic fundamentals for in-space activity – something he anticipated could produce some tension in the future. However, echoing Sherwood's sentiments, he noted the importance of focusing on solving problems “for our generation of activities”.

Newman suggested that the Outer Space Treaty could be updated to reflect the advances in technical capabilities since its drafting, perhaps by looking at precursors such as the Antarctic Treaty and the Law of the Seas. In her view, “minimum rules are better than no rules”.



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CONVENORS NOTE

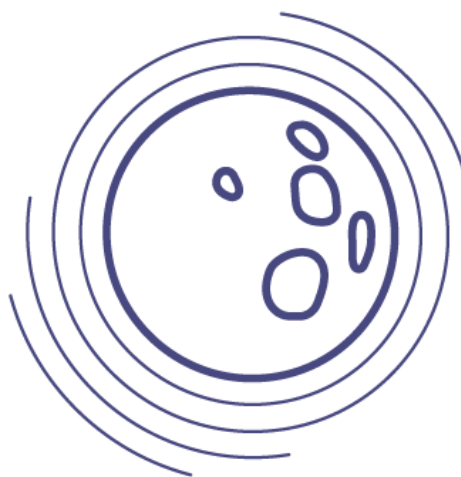
The panel highlighted the importance of establishing a viable commercial marketplace for lunar activities to enable sustainable lunar activity. They also addressed the need to toe the line between creating useful policies to encourage commercial activity while avoiding the creation of unnecessary roadblocks. In terms of near-term activities, panelists emphasized that robotic precursor missions and ground-truthing experiments during an early exploration period would be necessary to enable eventual settlement.

While it may be inevitable, the convenors note that the emergence of a natural monopoly or small group of first actors with outsized influence over the lunar ecosystem may not be the most desirable outcome. From a sustainability standpoint, single, one-off missions are unlikely to lead to the emergence of a sustainable economic marketplace, something panelists noted would be one of the early roadblocks to overcome – particularly in identifying diverse streams of capital to fund space activities.

POLICY RECOMMENDATIONS

- Sustaining funding and policy support for the Artemis program, especially to support the development of capabilities among a diverse range of actors.
- Improving international cooperation and coordination, especially to establish key interoperability standards.
- Publishing detailed architectures and plans so international and commercial partners can figure out how to contribute. Establishing confidence that plans will be sustained to reduce risk to potential partners.
- Establishing an economic and policy regime to enable the emergence of an economic marketplace.

Explore the discussion, including participants' comments, questions, and post-panel discussions, [in the associated Miro board](#), and join the conversation by adding comments to the whiteboard.



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