Moon Dialogs

Spaceports and Landing Pads

A Moon Dialogs Salon Report – Nov 2020

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Spaceports and Landing Pads

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Background

The issue of lunar dust has been discussed at length across the lunar community. Earlier in 2020, a Moon Dialog was held specifically to investigate all the details of the challenge of dust and damage, and mitigation of these issues. You can see the report and video from this session here: https://www.moondialogs.org/events/research-salon-2-lunar-dust-resource-contention.

One of the themes which was repeated frequently during that session and also afterwards was the opportunity of investing in dust-mitigating infrastructure. Many organisations around the world have addressed this in different ways, from sintering to bring-your-own landing pad solution. There is no singular solution thus far which would solve all considerations simultaneously. Thus, we set out to convene a discussion about the plural options for landing infrastructure which mitigate dust and damage, and the resultant social, economic, political and legal implications of different solution sets. Open Lunar Foundation, a co-convenor of Moon Dialogs, had completed relevant work within their research fellowship program (recruit.openlunar.org), with space architect Jeffrey Montes, whose work became the core provocation for this salon.

Speakers

This salon was grateful to host the following three subject matter experts as provocateurs and discussants:

Jeffrey Montes is a Space architect and technologist whose work on habitat designs has been awarded by NASA and exhibited in museums around the world. Jeffrey was the principal designer of Marsha, a novel design and 3D printed prototype for a Mars habitat awarded 1st place in the finale of the NASA 3D Printed Habitat Challenge. Jeffrey also co-designed Mars Ice House (2015) and Mars Ice Home (2017), two inventive designs that utilize ice as a light-transmitting shield for cosmic radiation. Jeffrey holds a Master of Architecture from the Graduate School of Architecture, Planning and Preservation (GSAPP) at Columbia University.

Dr. Ryan Watkins is a Research Scientist at the Planetary Science Institute. Her current research involves conducting boulder distribution analyses at spacecraft landing sites to assess landing site safety and boulder erosion rates on the Moon. She is also involved in landing site safety analyses for upcoming lunar missions in the lunar South Pole region. She has used Lunar Reconnaissance Orbiter images to study the effects of rocket exhaust on lunar soil reflectance and she has been studying rocket exhaust effects at the Apollo, Luna, Surveyor, and Chang'e-3 landing sites.

Dr. Philip Metzger is a planetary physicist at the University of Central Florida. He has 30 years' experience at NASA. While at NASA, Phil led the Agency's work in rocket blast effects for human-class missions. He participated in architecture studies for the Lunar Architecture Team, the Mars Architecture Team and the Lunar Exploration Analysis Group, and helped develop NASA's technology roadmap for planetary surface technologies.

Summary of the Presentation Contents

MUCH OF THIS REPORT DRAWS FROM THE PAPER AUTHORED BY JEFFREY MONTES:
HTTPS://WWW.OPENLUNAR.ORG/LIBRARY/LUNAR-SPACEPORT-ARCHITECTURES-AND-DESIGN-SPACES

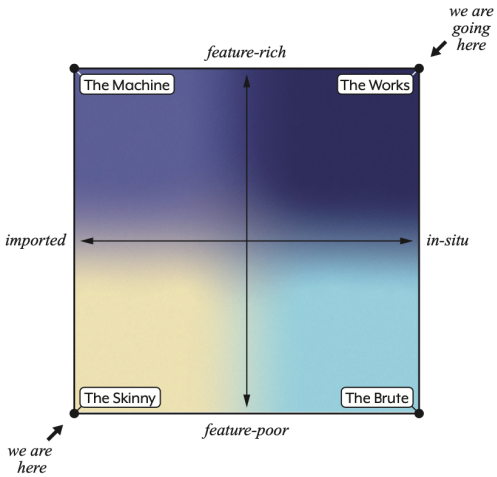
The central proposal is that a spaceport or landing pad device is useful to actors attempting to land on the Moon, and especially so for those landing within proximity of one another. A spaceport is a kind of armor for the lunar surface in that it protects the ground from the destructive force of rocket engine exhaust and prevents the ground from becoming a spray of high-velocity projectiles. In the absence of this surface armor, everything around the landing site would need to be armored and thus more massive, indiscriminately driving engineering margins. A spaceport might itself be a product of an indigenous lunar material economy, or it might, like a spacecraft, be a product of Earth and imported to the Moon. The structural, material and production differences between in situ and imported artifacts has a fundamental effect on their design.

THE USE OF THE DESIGN SPACE FRAMEWORK

The first major point made by our primary speaker Jeffrey, is that due to the array of ways to solve the landing and dust issues there is not one solution but a set of axes upon which to plot multiple solutions. The two main design considerations considered for the design space was the use of a feature-rich or feature-poor spaceport, and the decision to import the spaceport from Earth, or build the spaceport in-situ. Jeffrey argues that current spaceport designs land firmly in the realm of feature-poor, imported, but the general trend has been to move towards the feature-rich, in-situ spaceport.

Quote from Phil Metzger during the discussion:

"Way back around 2009, we came up with the idea that there is no one technology to solve the whole problem, because if you if you want to do microwave sintering, well, it gets to be too burdensome, too much energy, too much time. If you try to do polymer, then it's great for doing a fast build in the surrounding areas, but in the center of the pad, it's too hot. So we came up with the idea of a zoned approach. But then in a more recent JPL study, I started to realize it's not just breaking it down in space, but breaking it down in time. We don't have to use the same technology throughout the entire build process up on the Moon. That is what's interesting about the design space approach. There is an implied third dimension here - time. Everyone's starting here [bottom left], and everyone's talking about getting here [top right], right? But what we don't know that we don't know is the path that gets us there. I would argue you want to do this before you dive into a trade space to understand the sort of solution domain a little bit better and reduce the risk that you lose sight of that product vision."



THE FOUR DESIGNS

The main presentation went on to provide an overview of four designs for spaceports of landing pads. Each of which are a representation of the extremes of each pole or axis.

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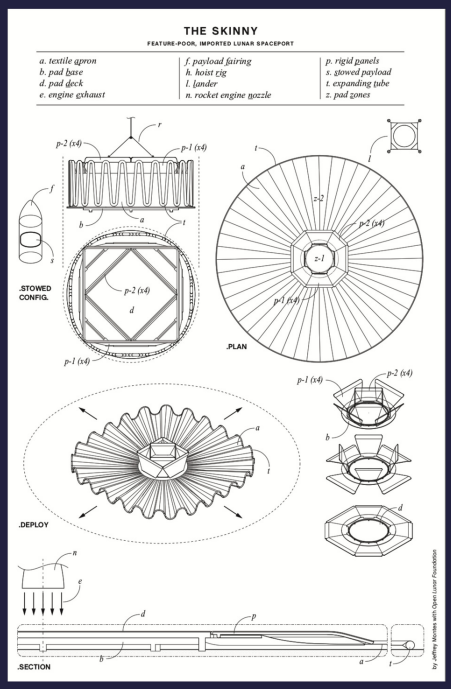
THE SKINNY

"The Skinny is a lightweight spaceport imported from Earth and deployed on the lunar surface. It performs only the essential function of a spaceport" states Jeffrey Montes. It is an unfolding design which would be delivered to the lunar surface as a payload, where it is designed to be lowered to the ground to then receive a lander.

THE MACHINE

The machine is one of the more detailed designs presented, Montes describing it as "a spacecraft onto itself." It includes refueling systems, battery charging stations, and an exhaust duct. It is designed to be taken to the surface of the Moon in a stowed format, and then deployed and assembled.

The Skinny



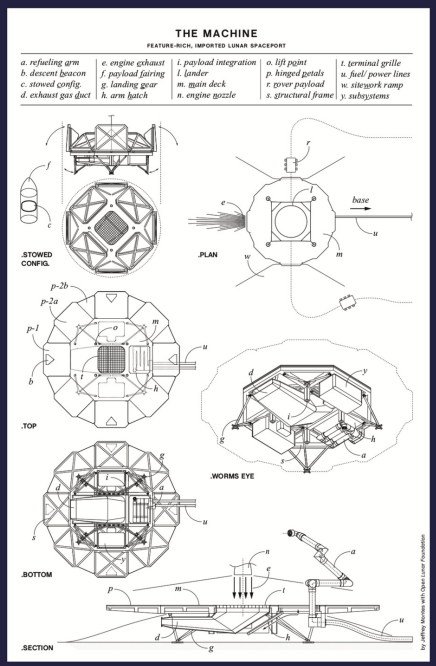
Design Considerations

Feature poor and/imported

Deployed on prepared/flattened surface

Policy Considerations

The Machine



Design Considerations

Feature rich/imported

Legs allow for a less prepared site

Removes the risk and time for getting closer to other vehicles for refueling

Policy Considerations

Is there a risk that the ejecta beneath the Machine puts other infrastructure at risk?

Is there a risk of the landing pad moving with the ejecta being blown out?

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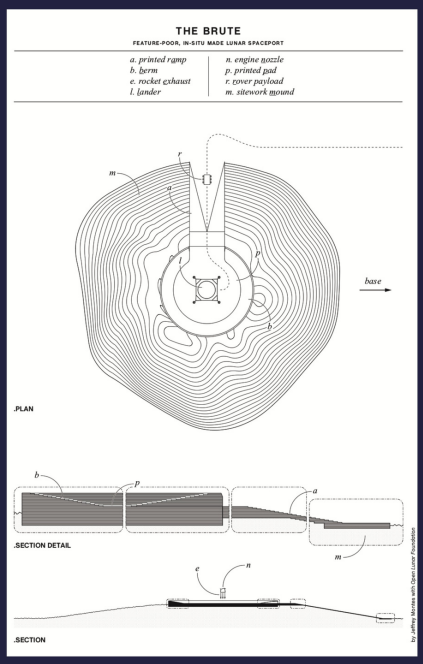
THE BRUTE

Made from in situ resources, “The Brute consists of a printed pad elevated on a mound of regolith with a road leading up to it”, explains Montes. A site is selected suitable for building the mound shape, and robotic printers would heat the inorganic polymers within the regolith locally to form a hard surface.

The Brute



Design Considerations

Feature poor/in-situ

3D printed ejecta shield

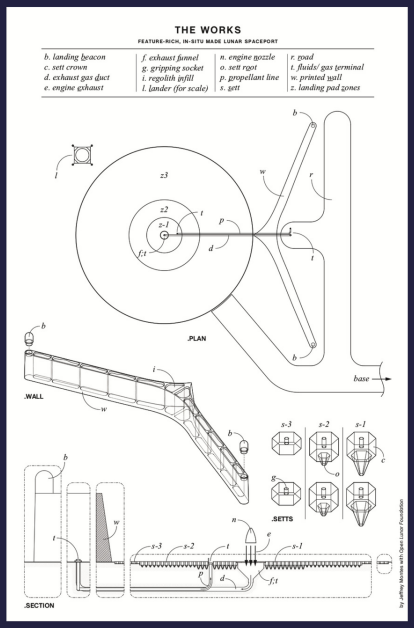
Policy Considerations

If made using in-situ resources, would it be accessible by other actors capable of reaching the lunar surface?

THE WORKS

The Works is aptly named. It is a design that represents imagining the most sophisticated combination of in situ resource utilization as well as imported robotics and industrial scale capacity to install such a system on the lunar surface. In sum, it combines tooth-like paving stones, with exhaust pipes, fuel lines, and a printed wall.

The Works



Design Considerations

Feature rich/in-situ

3D printed ejecta shield

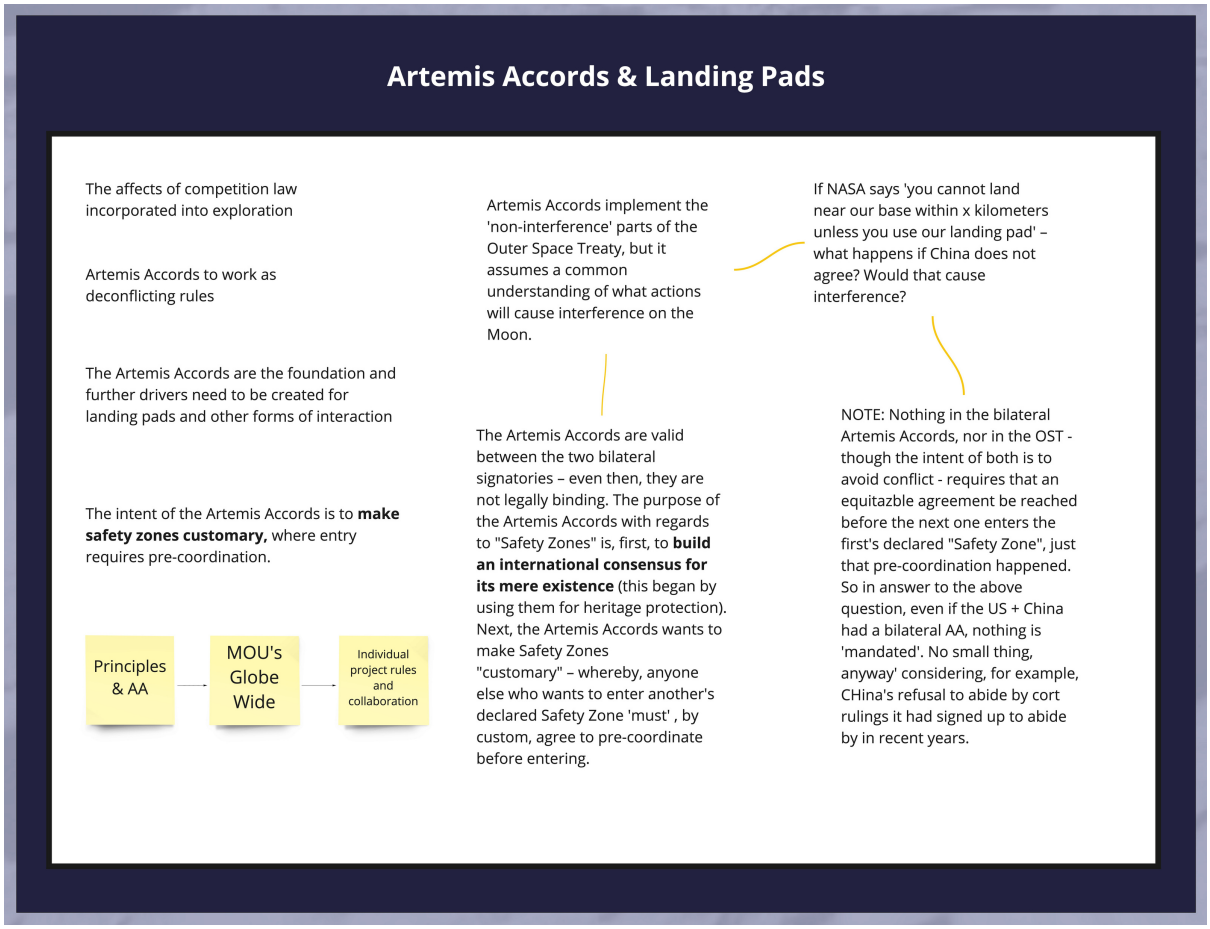
Would capture exhaust

Ejecta shield wouldn't be needed if the landing were perfect - but need to plan for accidents as precaution

Potential utilization of exhaust gasses to perform operations needing high termperatures

Discussion Themes and Prominent Points

LEGAL CONSIDERATIONS



Discussion Themes and Prominent Points

LEGAL CONSIDERATIONS

"We tie this strongly to an expression of the freedoms of Article One of access and use and freedom of exploration. Creating a landing pad, especially if you're using in situ lunar regolith to do that pad, it's difficult to argue that that's appropriation, when you're merely say, reordering those materials that you find and not removing them. So long as that landing pad is open to many people, and you're transparent about it, it doesn't fall into exclusive use or excluding others. No matter what you do, people will object and say that it is a violation of international law, we should confront that. We need to lay out a path to say to the people who want to do these landing pads, 'here's the requirements of our international law, please make sure you conform to these', and give them recommended best practices about transparency and confidence building measures so that they don't fall into rivalry situations or people contesting it. "
- Christopher Johnson

The Outer Space Treaty Article II and Applications to Landing Pads

OST provides for "right to inspect" what other nations are doing. To get near another country's lunar assets without damaging them you may need landing pads

Building landing pads might be seen as making a territorial claim because you are establishing a permanent facility, but if you make it a shared asset then you could avoid that

Discussion Themes and Prominent Points

SQUATTING

" I was in the appropriation and squatting group, which may or may want to be renamed, maybe to something related to the graveyard syndrome effect, right, where you have lots of lots of expendable landers that get left behind and may or may not have a path to refurbishment. This is closely coupled with how many pads you do have, and whether you have other infrastructure on the Moon that can tow away a lander that can never fly again. So if landing pads are already going to be a difficult thing to implement, we can't have them occupied indefinitely by derelict spacecraft. This is another one of those things that connects reusability and landing pads and, for lack of better word tow trucks!" - Jeffrey Montes

Appropriation and Squatting

How is this different from a derelict craft out at sea?

Is there a "spacejunk law" for the Moon? No.

Standards might prevent some of this - is there a pad design that could deter this?

Appropriating regolith for a pad – difficult to argue that this is appropriating, it's more like rearranging.

What is the 'bad faiths' aspect of this topic?

India, China, and Russia are significant missing signatories although they have signed onto the Outer Space Treaty

Can you turn a graveyard into a scrapyard?

Maybe a spaceport needs equipment to chew up and sell the metal from lander descent stages?

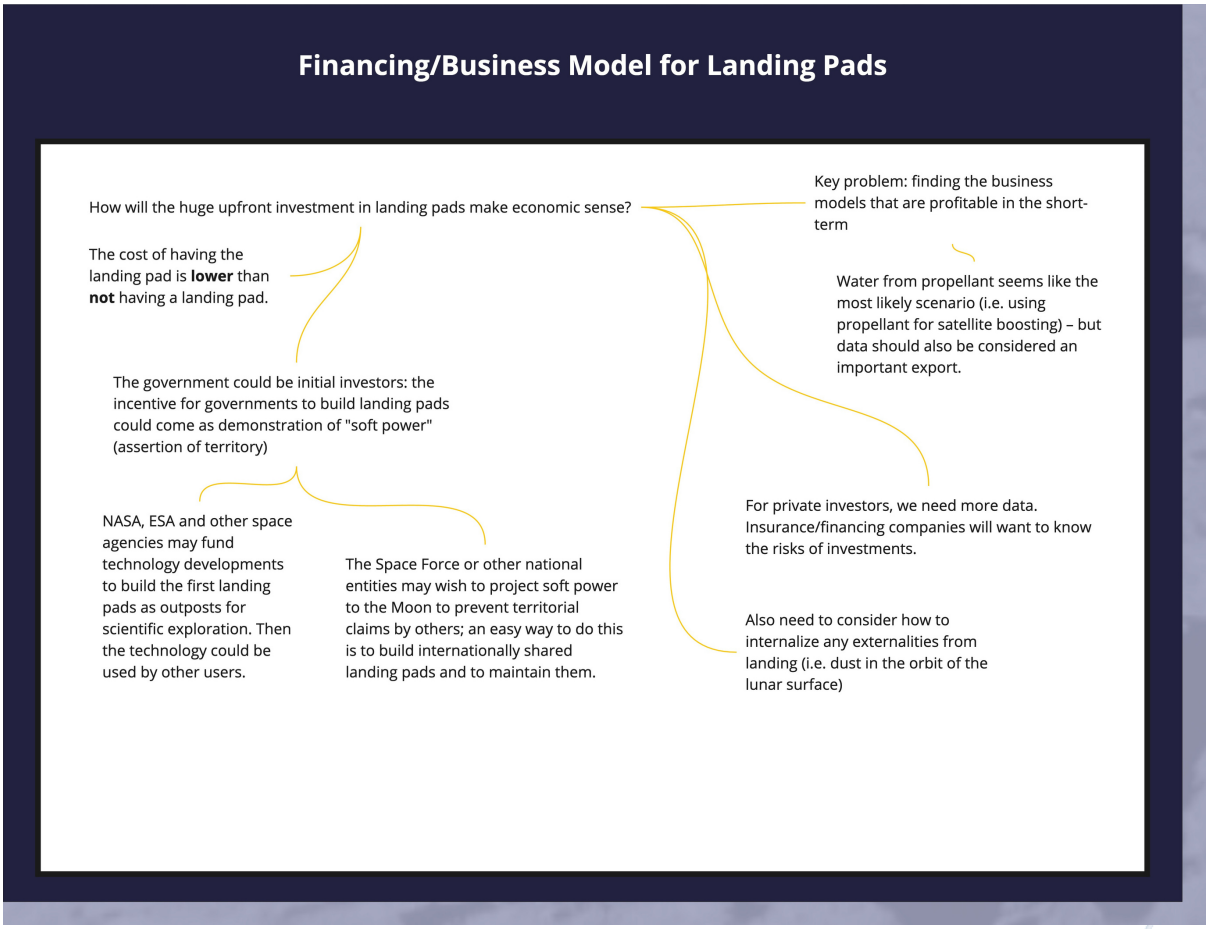
What's the right model? Charging per landing or is it just a sunk cost that each organization needs to absorb?

Without full reusability, you'll need a tow truck.

Discussion Themes and Prominent Points

ECONOMIC CONSIDERATIONS

"There's going to be a huge capital expenditure to build one of these. So the first question we addressed is, at what point does spending a bunch of money to build a landing pad actually outweigh the cost of the alternative, which would be to land somewhere new every time. How we got to actually making it make economic sense is you have to price in the negative externalities: the pollution involved and the destruction of the environment. That's actually a place for policy to step in first. After that, you need to have some sort of, ideally, business case or science case to need lots of repeat launches, we looked at that as more of a long term issue. More short term the economics is actually more of a geopolitical rationale, for example the ability of nations to leverage soft power within area of the Moon by putting an international landing site."
- One of the participants of the dialog.



Discussion Themes and Prominent Points

STAKEHOLDER CONSIDERATIONS

First Actors: Who should build the first landing pads?

Early customers will most likely be space agencies (ESA, NASA, China) and early landing pads will most likely be constructed by commercial providers - similar to CLPS

Only need pads when returning often – i.e. for a base or a resource capturing feature

How will the initial flattening or leveling be done?

The cost of "the skinny" is crucial to the use model and create a business plan.

Starship and Landing Pads/Dust Effects

Starship will use upper thrusters for the last part of the descent - the main problem will be at lift-off.

A Starship lander would be ~85 tons of dry mass, 200 tons if returning to Earth in contrast to the 8 ton Apollo Lunar Module (meaning dust plume effects would be considerably greater)

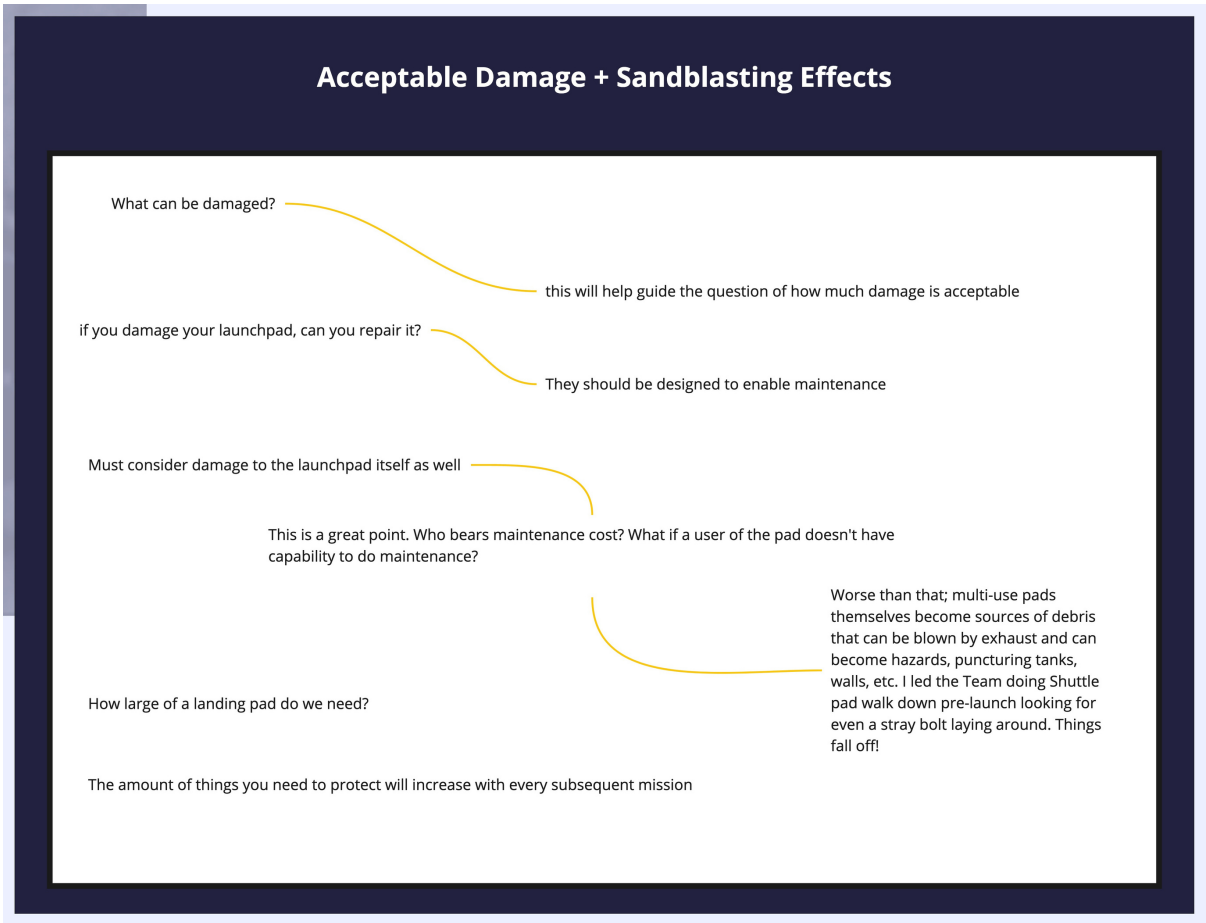
Sample designs indicate rocket exhaust will be controlled, but it is likely not to be as straightforward

Possible mitigation techniques:

- Make use of natural features such as craters to help avoid debris impact
- Are there sites where the regolith layer is thin enough to "broom" away to expose solid rock that would not produce dust effects?

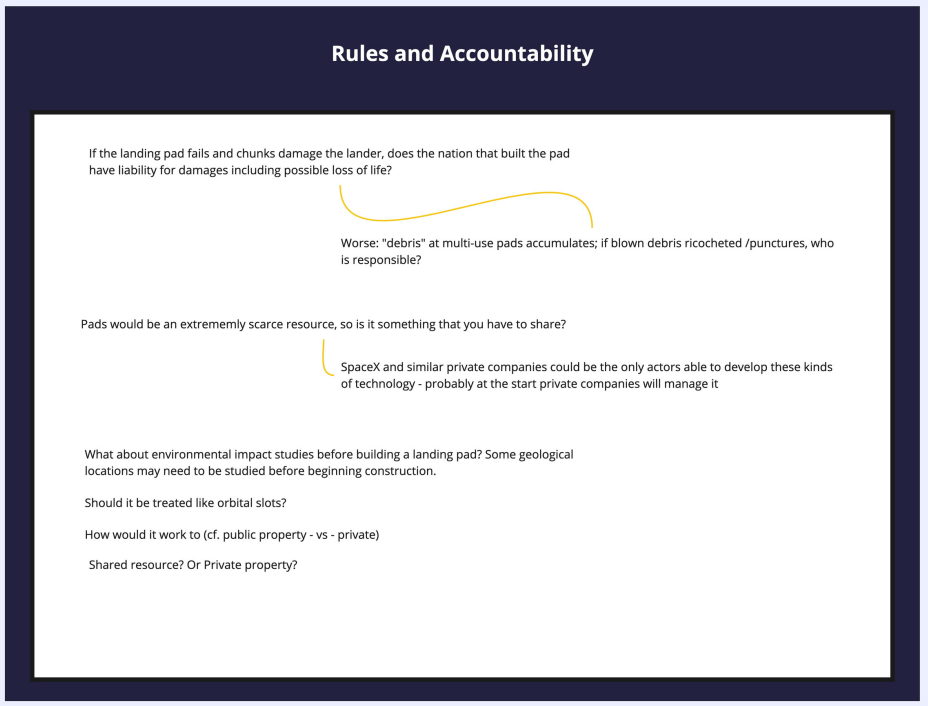
Discussion Themes and Prominent Points

STANDARDS CONSIDERATIONS

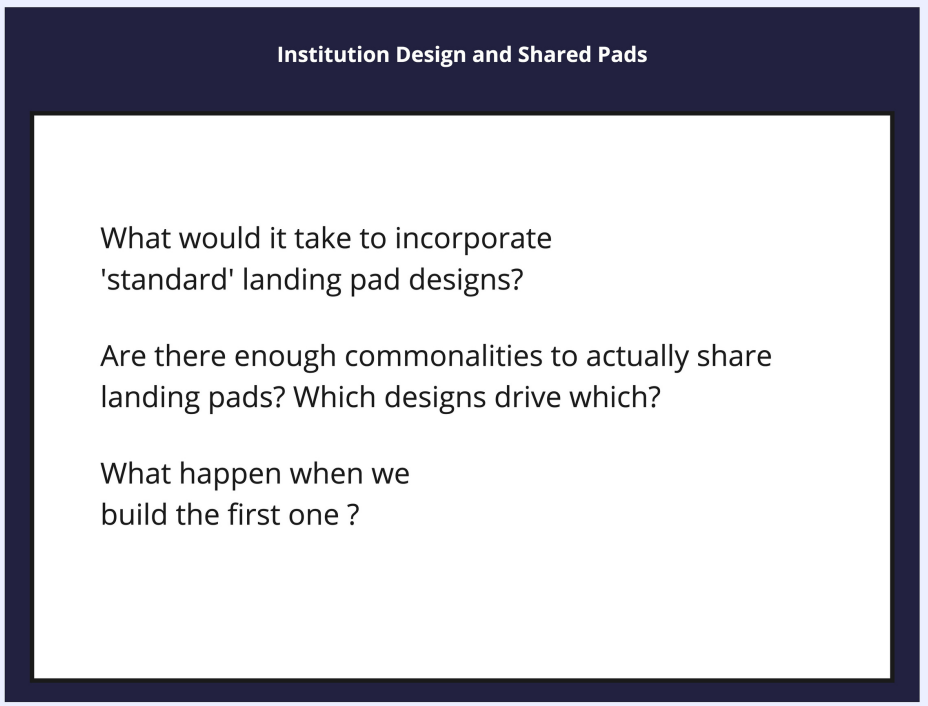


Discussion Themes and Prominent Points

RULES & ACCOUNTABILITY CONSIDERATIONS



MANAGING SHARED PADS



Conclusions & Moving Forward

MULTIFACETED ASSESSMENTS NEEDED

"This raises a really interesting perspective on on landing pads that at least I haven't thought through. It's not just a scientific or an engineering problem. It's policy, its financial, it's business. It's international collaboration. It's governments and commercial. It's just all of these pieces. For something that maybe once, at least in my head, sounded simple and straightforward, I realize now it really isn't!" - Dr Ryan Watkins

"We know that we need them, who's gonna pay for them? An economist would look at it and say that they are public goods meaning we have a community has to contribute to make them, there will be people who can pay more, and some people less. We know that they will need to be maintained, we know that there are going to be free riders who don't contribute to the system, but we still need them. Perhaps an analogy is ports. If a city wants to be a trading city, and exists on the ocean and waterways, it needs to have a port and a port authority to maintain it. Commercial users steam in and unload their goods and then steam off again. We don't know how many we will need, but we know that if you want to have infrastructure and development, there is going to kind of be some type of necessary outlay, like an anchor tenant. I'm sure that those who are more economically minded than myself could weigh in" - Christopher Johnson

DUST ISSUES CAN PROMPT COMMERCIAL SERVICES & PRODUCT INNOVATION

"Every problem is really the opportunity for solutions and for progress. Problems caused us to feel the need to change something, and to become innovative. Some of the things that this problem will do is it'll motivate us to create construction technologies that we can use on the Moon, it will motivate cooperation, because we're going to need to not damage each other's hardware. It's going to start to incentivize cooperation and building landing pads, and then it creates a commercial opportunity for companies to provide those services. So I think that this is going to motivate progress and that's going to be useful." - Phil Metzger

LANDING PADS AS A RALLYING POINT FOR INSTITUTIONAL COOPERATION AND SETTLEMENT PLANNING

"The landing pads, if they're found to be successful and feasible, may then dictate the design of the landers themselves. Then you have towing vehicles, landing pads, usage, remote sensing. This piece of infrastructure might be at the center of that Venn diagram, right of all of the lunar community's interest. I think everyone could have something to contribute to this one thing, which is really could be a great start to to that lunar future itself."
- Jeffrey Montes