

The New Age of Lunar Science

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Masten

Masten Space Systems
www.mastenmoon.com

Take aways:

- Moon Science is Happening Now
Same Moon, Different Path
- Access & Core Capabilities Available
NASA Commercial Lunar Payload Service
- Early Adopters are in the Past
Stories to Help Illuminate the Way



Moon Science is Happening Now

Same Moon, Different Path



The accessibility of the Moon
has changed.

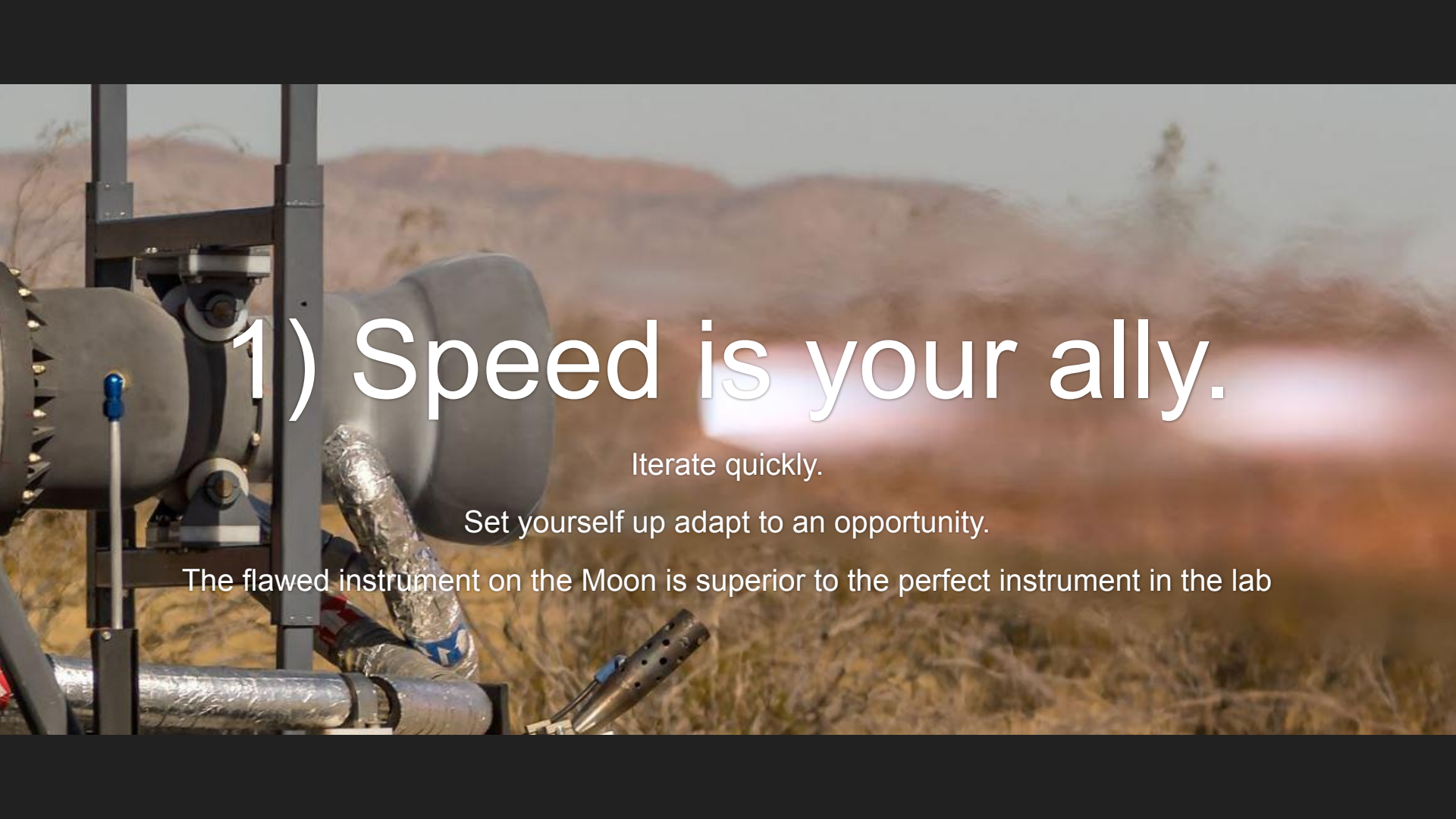
You need to change as well to
be part of this opportunity.

Cubesat paradigm shift
changed the art of the
possible for LEO.

A new paradigm is emerging
for the Moon.

Ridiculously oversimplified guidance:

- 1) Speed is your ally.
- 2) Risk is your friend.
- 3) Testing is truth.

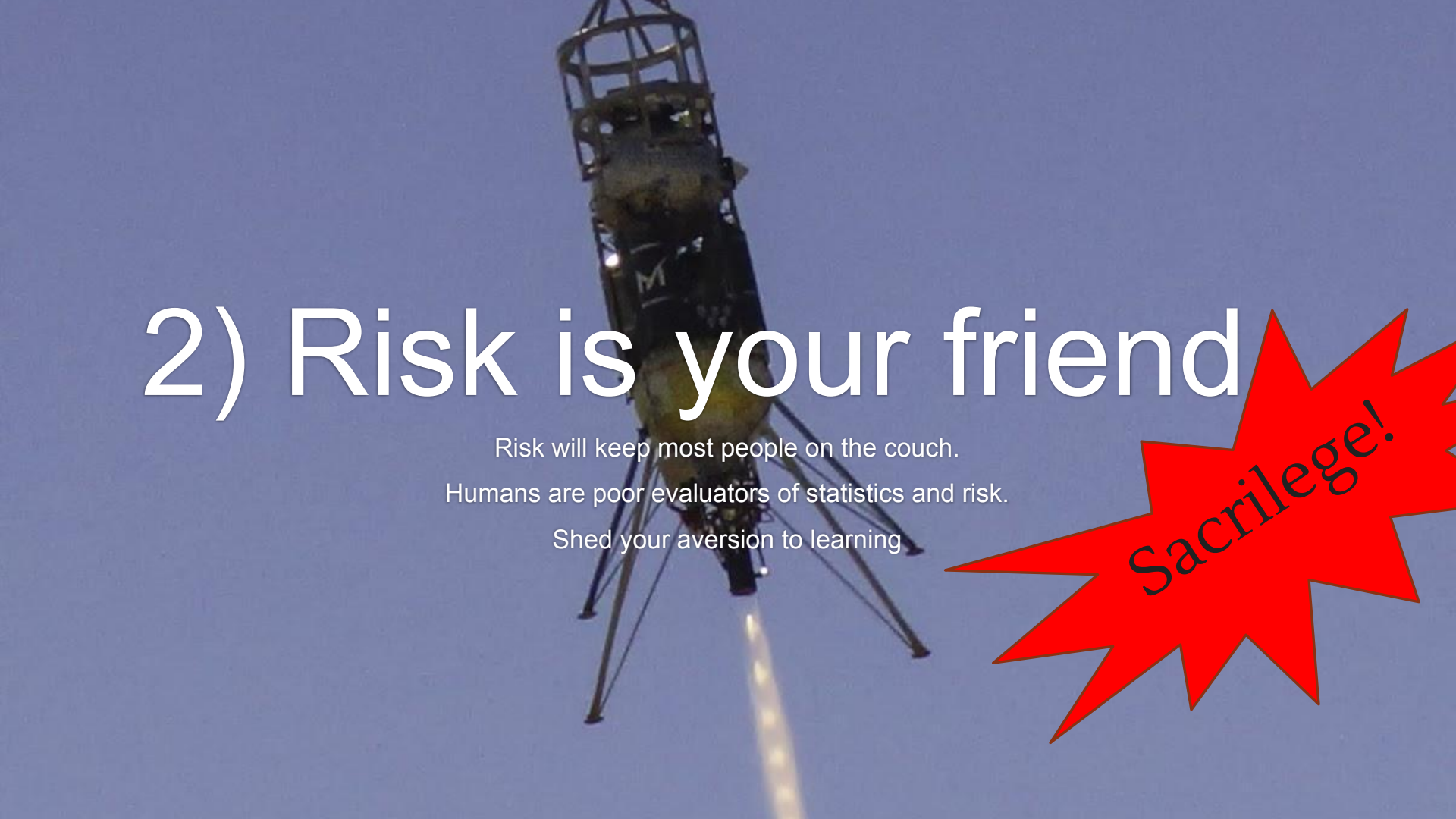
The background is a blurred photograph of a desert landscape with reddish-brown hills and sparse vegetation. In the foreground on the left, there is a scientific instrument, possibly a spectrometer or telescope, with a large cylindrical lens or mirror and various mechanical components. The text is overlaid on the right side of the image.

1) Speed is your ally.

Iterate quickly.

Set yourself up adapt to an opportunity.

The flawed instrument on the Moon is superior to the perfect instrument in the lab

A rocket is shown ascending vertically against a clear blue sky. At the top of the rocket is a capsule with a metal cage structure. A white plume of smoke or exhaust is visible at the base of the rocket.

2) Risk is your friend

Risk will keep most people on the couch.

Humans are poor evaluators of statistics and risk.

Shed your aversion to learning

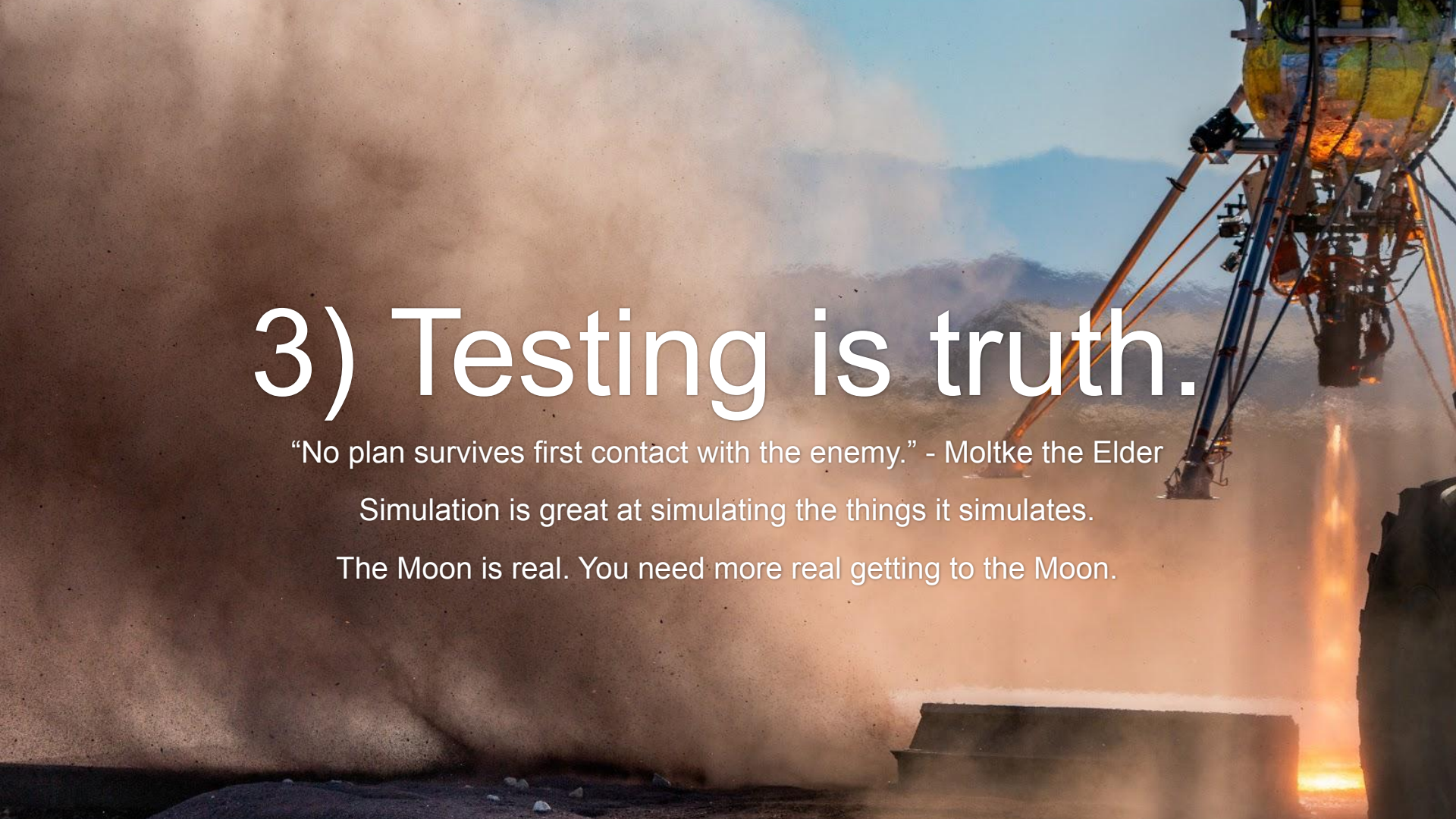
Sacrilege!

3) Testing is truth.

“No plan survives first contact with the enemy.” - Moltke the Elder

Simulation is great at simulating the things it simulates.

The Moon is real. You need more real getting to the Moon.



Headed
to
Moon





Landed
on Mars



Headed
to Moon
& Mars



Oh... Yeah.

When you are ready to get the Moon,
Masten is ready make it happen.



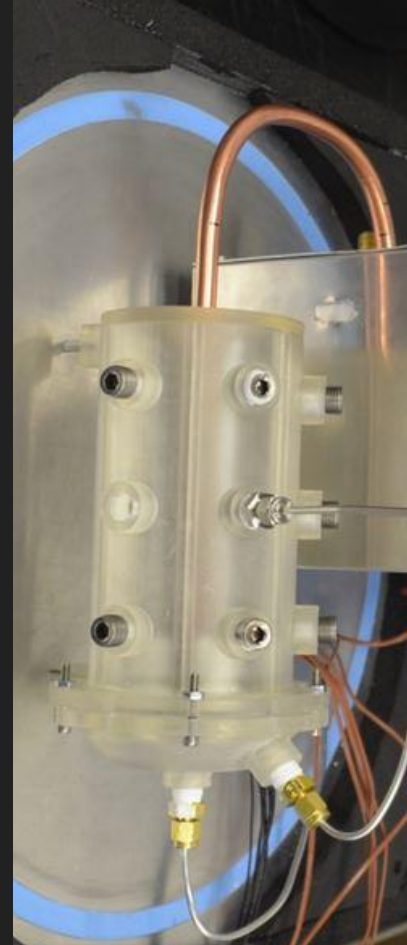
Tech Dev



Terrestrial Test



Lunar Delivery



Product Labs

Access & Core Capabilities Available

NASA Commercial Lunar Payload Service



Masten Mission One - NASA CLPS 19C Instruments

Heimdall

- flexible camera system for conducting lunar science on commercial vehicles

Laser RetroReflector

- small optical instrument designed to provide a target for precision laser ranging on the lunar surface

Lunar Compact InfraRed Imaging System (L-CIRiS)

- infrared radiometer to explore the Moon's surface composition and temperature distribution

Linear Energy Transfer Spectrometer (LETS)

- monitor the lunar surface radiation

MoonRanger

- small, fast-moving rover that has the capability to drive beyond communications range with a lander and return to it

Mass Spectrometer Observing Lunar Operations (MSolo)

- device to measure potentially accessible resources on the Moon's surface

Near-Infrared Volatile Spectrometer System (NIRVSS)

- imaging spectrometer to analyze the composition of the lunar surface

Sample Acquisition, Morphology Filtering, and Probing of Lunar Regolith (SAMPLR)

- sample acquisition technology that will make use of a robotic arm

NASA Plan

NASA Lunar Missions	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Artemis	1		1	1	1	1	1	1	1	1
Human Landing System (HLS)				4	4	4	4	4	4	4
Lunar Gateway PPE and Halo			1							
Lunar Gateway iHab					1					
Lunar Gateway JAXA Logistics Habitat								1		
Lunar Gateway JAXA Pressurized Rover										1
Gateway Logistics Services (GLS)				1	1	1	1	1	1	1
Artemis Base Camp Foundation Habitat								1		
Artemis Base Camp Mobility Habitat									1	
Artemis Base Camp Logistics Mission										1
Commercial Lunar Payload Services	2	2	2	2	2	2	2	2	2	2

Source: Bryce Space & Technology

Early Adopters are in the Past

Stories to Help Illuminate the Way



Flying: We Love It

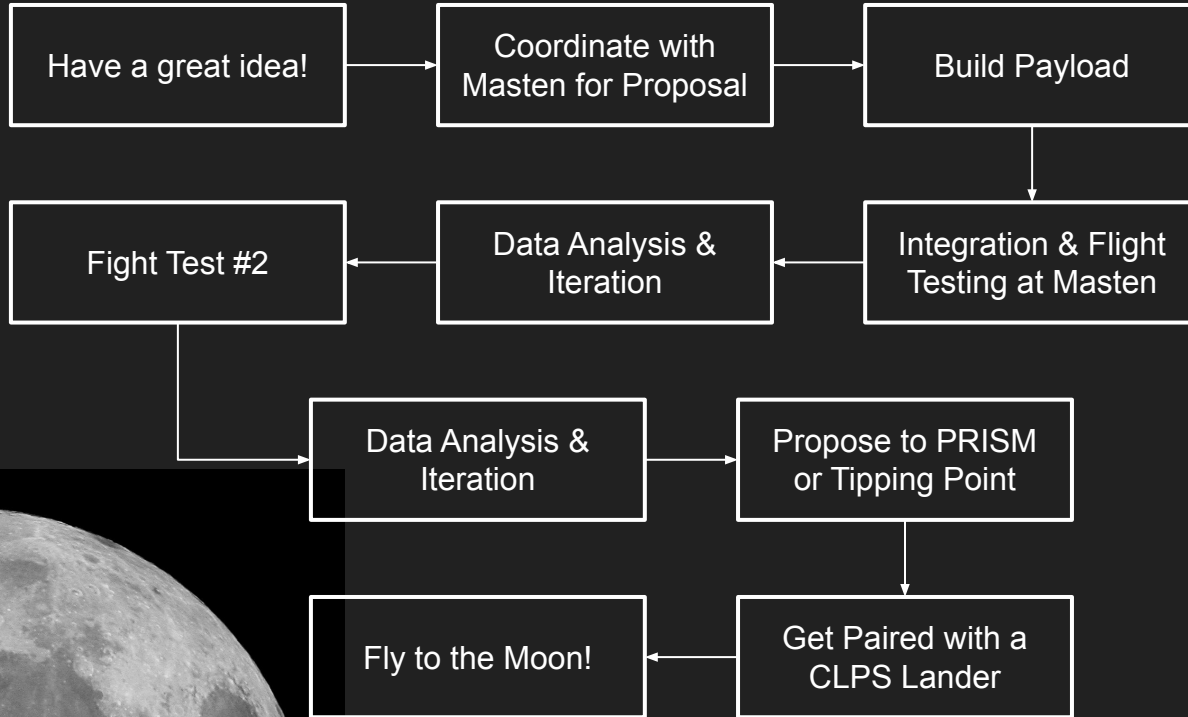
- We understand mission needs from FLYING them
- Every flight campaign is a progression - increasing our capabilities to meet your needs
- Work to add mission value and increase chances of payload success

“Technology isn’t a zero sum game...Leapfrog over the competition to the next thing” ~ P. Metzger

Masten enables you to literally leap



Masten Works with Scientists



Earth Based Risk Reduction

- For commercial customers and with NASA Flight Opportunities program Masten flies VTVL rockets in Mojave CA
- Test flight and landing technology critical to mission success
- Including landing vision systems that are going to the Moon and Mars

There is high value in tests as it clearly showed the paths to pursue (on rocket landing pads) ~ P. Metzger

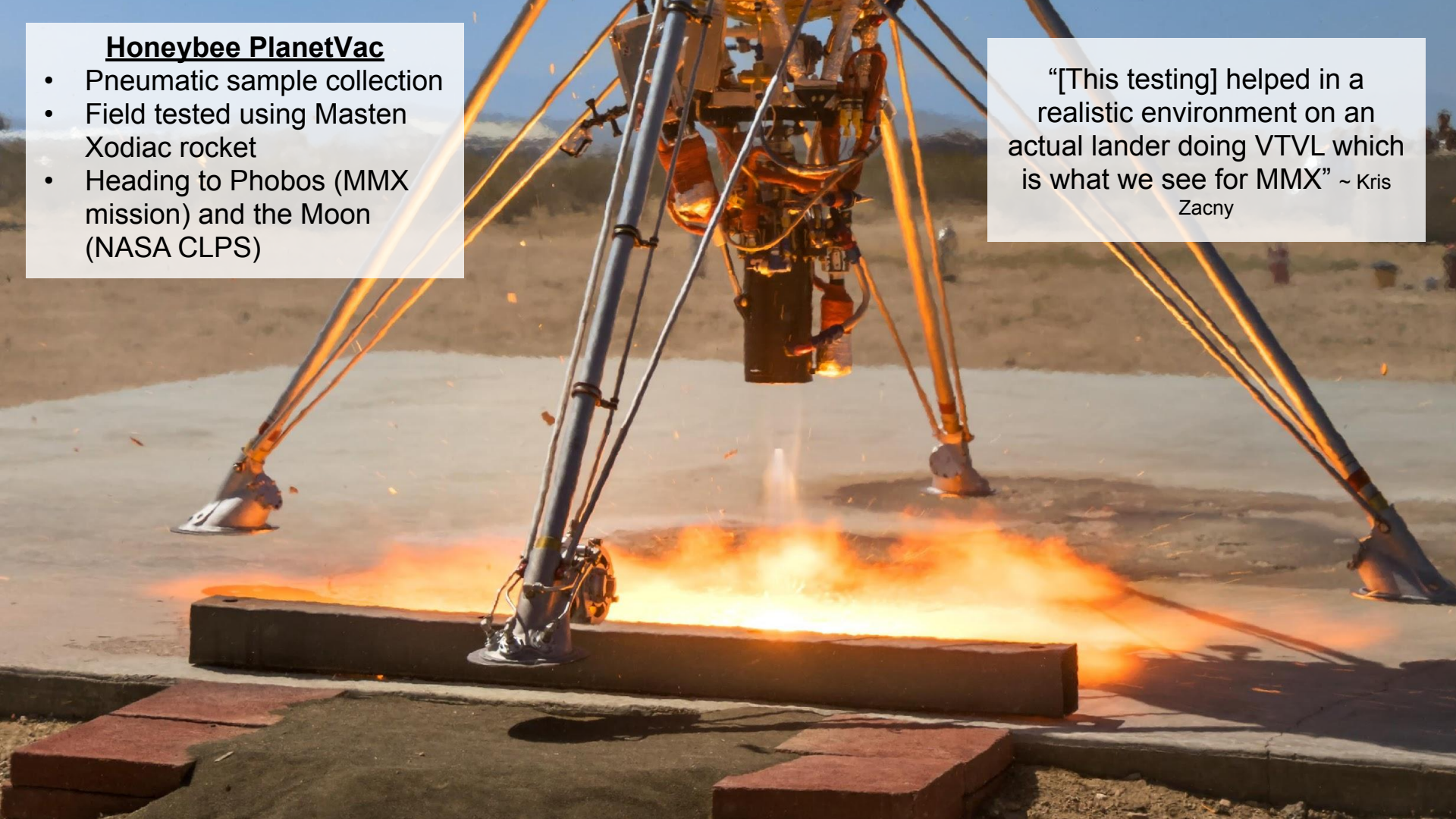
Check them out! NASA Flight Opportunities for rapid demonstration of promising technologies for space exploration via suborbital testing
<https://www.nasa.gov/directorates/spacetech/flightopportunities/index.html>



Honeybee PlanetVac

- Pneumatic sample collection
- Field tested using Masten Xodiac rocket
- Heading to Phobos (MMX mission) and the Moon (NASA CLPS)

“[This testing] helped in a realistic environment on an actual lander doing VTVL which is what we see for MMX” ~ Kris Zacny



A Team Effort

- Development took several years with support from the Planetary Society, NASA, and Masten. All lead by Honeybee Robotics and their excellent team.
- It demonstrated the power of team based development and risk reduction testing, with some support even coming from the public via Kickstarter.
- Collaboration and support of the science lifts up the entire community and paves the way for a CisLunar economy. The Masten testing helped get PlanetVac a mission on CLPS 19D with Firefly going to the Moon and JAXA MMX.

**Honeybee Robotics
PlanetVAC
2018 NASA Flight
Opportunities**



Two flight test campaigns were flown in 2020 to look at an iterated technical design, and also the effects of plume scouring on the sample collection. Honeybee developed one campaign and Masten the other. Both were successful and helped mature the system for flight!



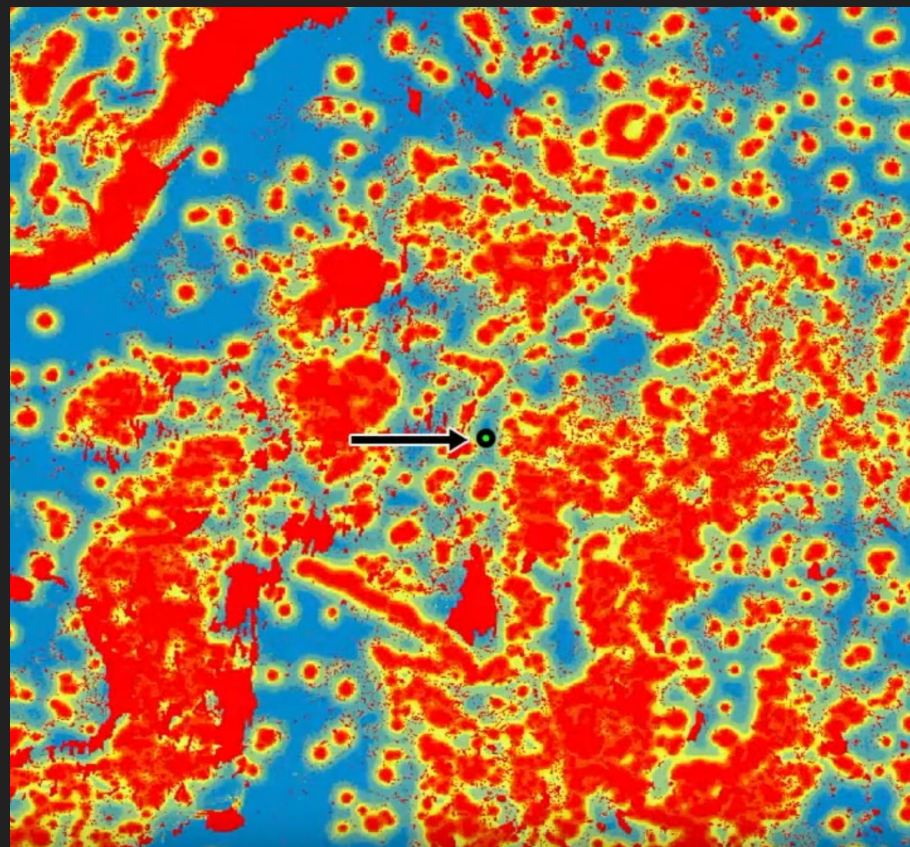
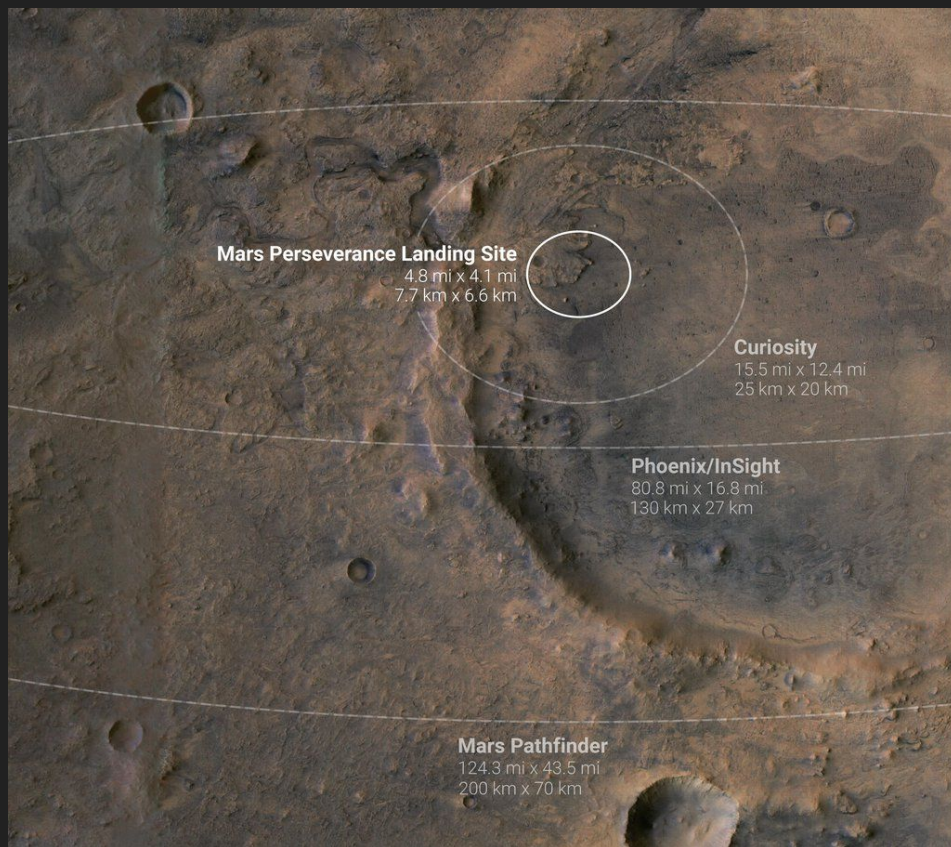
ADAPT: LVS & G-FOLD



"This represents a huge step forward in our future capabilities for safe and precise Mars landing, and demonstrates a highly effective approach for rapid, low-cost validation of new technologies for the entry, descent and landing of spacecraft"

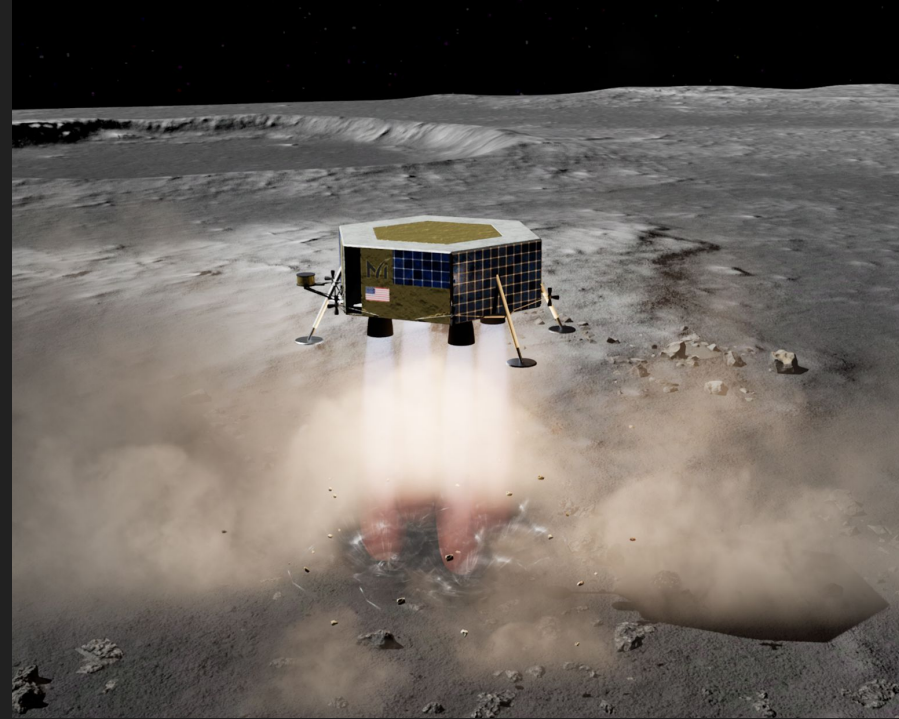
- Chad Edwards, chief technologist of the Mars Exploration Directorate at JPL.

Perseverance landing



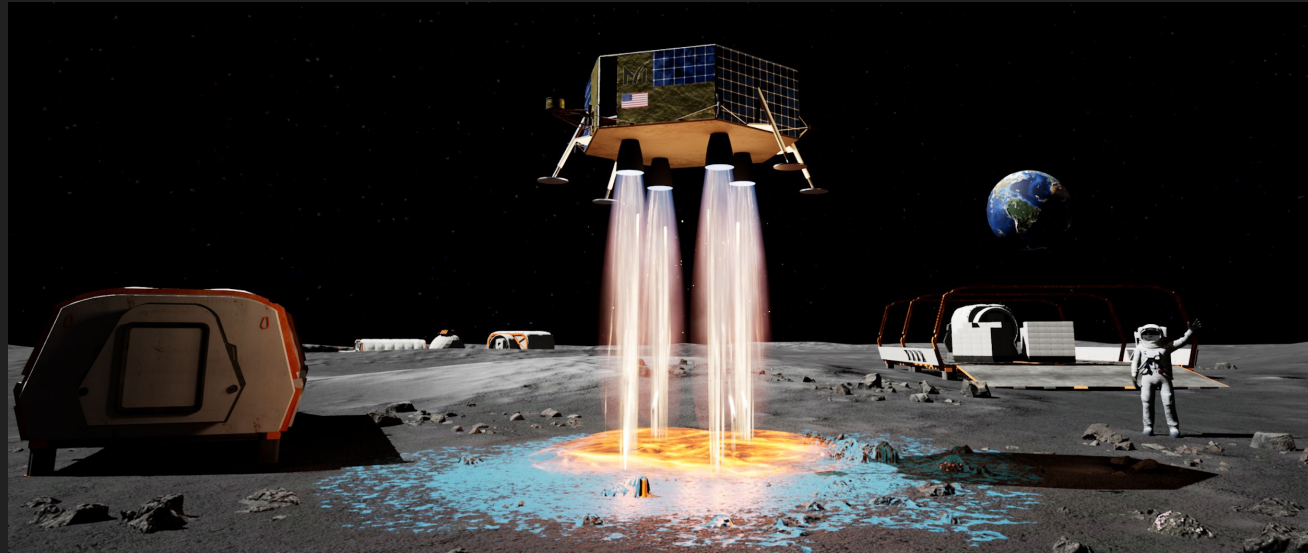
We Are Working On This Now

- Scouting science missions: investigating several potential landing sites ahead of time will lead to improved science return from human lander missions
- Developing technical capabilities for improved mission performance
- Increasing mission safety



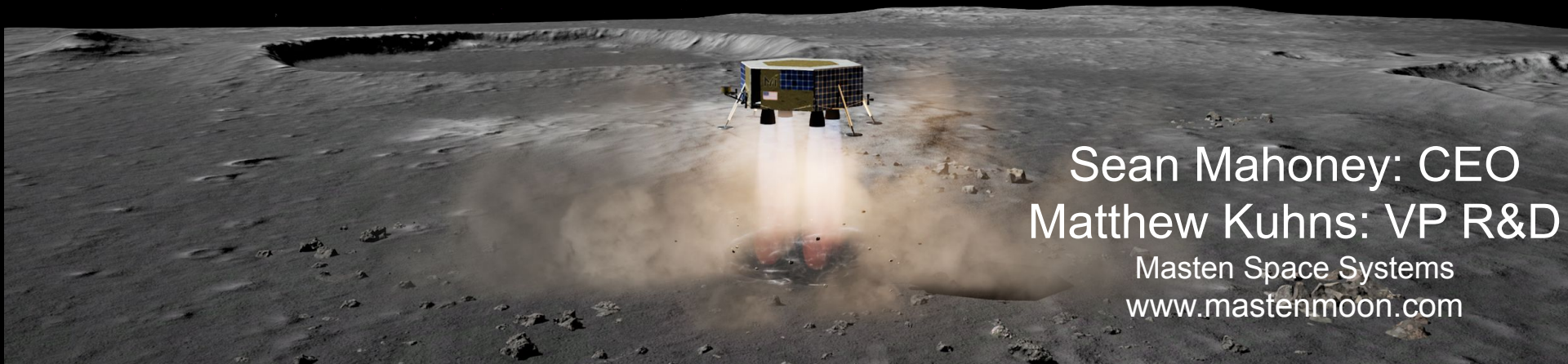
The Coming Decade

- Reusable vehicles
- Base Resupply
- Pre-placed equipment and infrastructure
- Sample Return
- Landing Pads



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