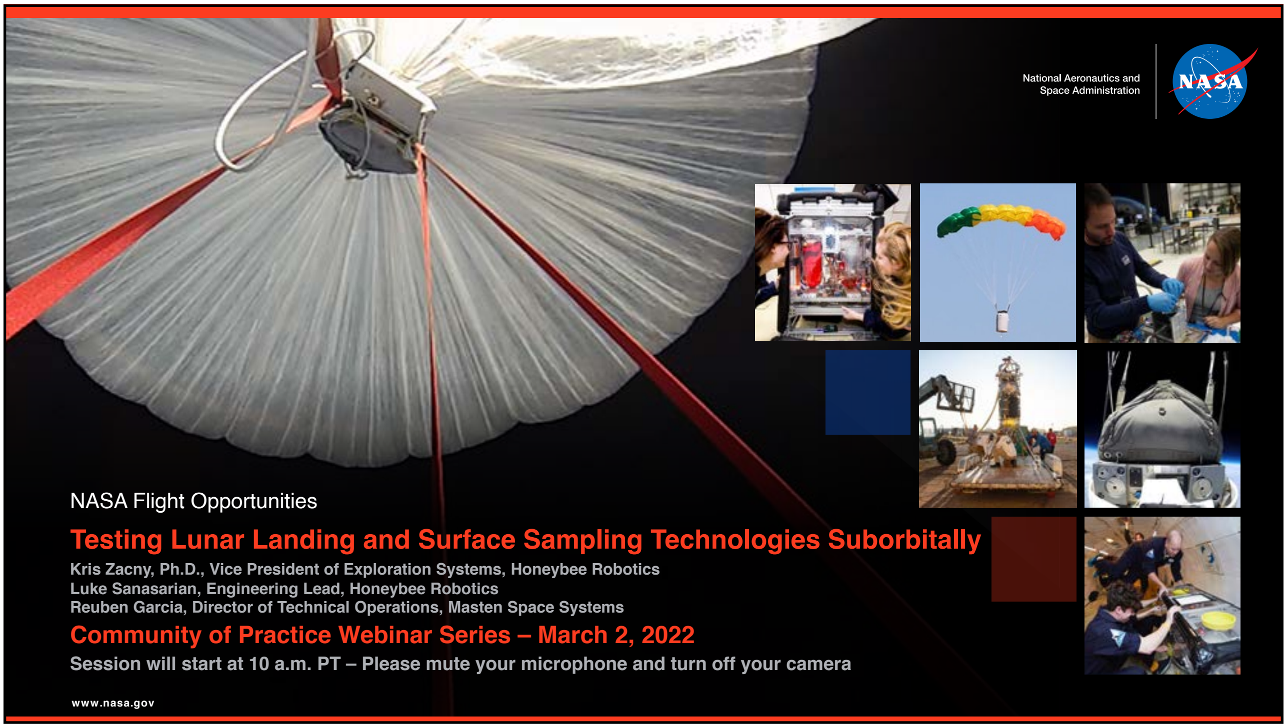

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NASA FLIGHT OPPORTUNITIES

National Aeronautics and Space Administration

Welcome to the Community of Practice Webinar Series!

First, a bit of housekeeping…

- Please mute your microphone and turn off your camera
- Today's session will be recorded
- Recordings for all future sessions are on the Flight Opportunities website
- Please engage!
  - Use the chat throughout the session to ask questions

2

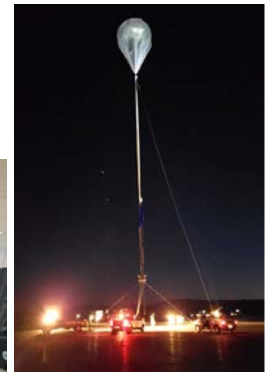
2

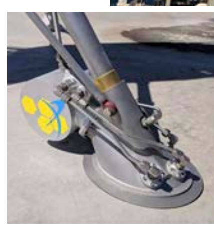
NASA FLIGHT OPPORTUNITIES

National Aeronautics and Space Administration

Flight Opportunities Mission

The Flight Opportunities program facilitates **rapid demonstration** of promising technologies for space exploration, discovery, and the expansion of space commerce through **suborbital testing with industry flight providers**.





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NASA FLIGHT OPPORTUNITIES

National Aeronautics and Space Administration

Join us for future Community of Practice webinars!

From Suborbital Flight to the International Space Station

Wednesday, April 6th at 10 am PT

Future webinars

- Webinars are held 1st Wednesday of each month at 10 a.m. PT
- Topics will be announced in the Flight Opportunities newsletter and website
- Session recordings will be posted on the Flight Opportunities website
- Let us know session topics you would like to see covered

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4

NASA FLIGHT OPPORTUNITIES

National Aeronautics and Space Administration

NASA TechLeap Prize

NASA TechLeap PRIZE

Nighttime Precision Landing Challenge No.1

Seeking proposals for sensing systems that can detect hazards from an altitude of 250 meters or higher and process the data in real time to help spacecraft land safely in the dark

- Open to researchers from qualified commercial businesses and academic institutions, as well as individual entrepreneurs and other innovators
- Up to three winners may receive awards of up to $650,000 and access to a suborbital flight test
- Key Dates
  - Q&A on April 12, 2022
  - Register by May 5, 2022
  - Applications due May 19, 2022
- https://www.nasa.gov/centers/armstrong/features/techleap-lunar-landings.html
- https://www.precisionlanding1.nasatechleap.org/

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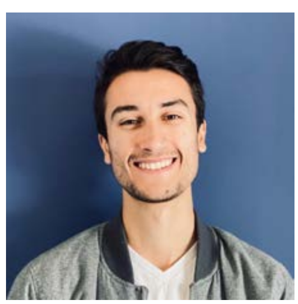
NASA FLIGHT OPPORTUNITIES

National Aeronautics and Space Administration

Today's Speakers

Kris Zacny, Ph.D.
Vice President of Exploration Systems
Honeybee Robotics



Luke Sanasarian
Engineering Lead
Honeybee Robotics

Reuben Garcia
Director of Technical Operations
Masten Space Systems

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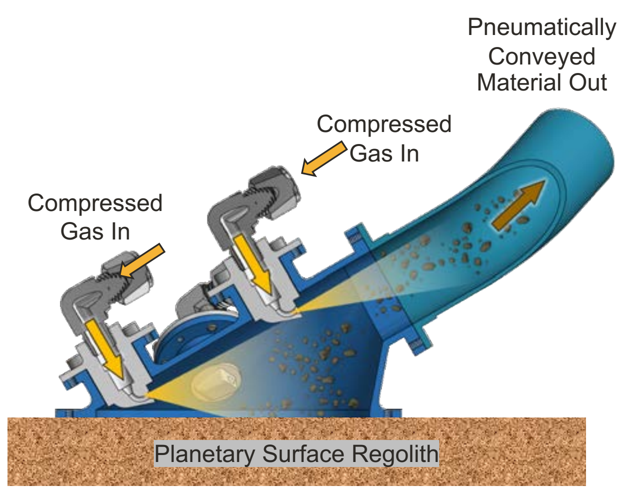
What is PlanetVac?

HONEYBEE ROBOTICS

PlanetVac is a technology developed by Honeybee Robotics that uses stored gas to pneumatically collect surface regolith from a planetary body.



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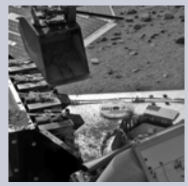
Why PlanetVac?

HONEYBEE ROBOTICS

PlanetVac adds another tool in the planetary sampling toolbox

Parameters	Robotic arm and scoop	PlanetVac
	 	
Mass, Volume, Power	High	Low
Cost, Complexity	High	Low
Sampling time	Hours – Days	Seconds
Relies on gravity	Yes	No
Can easily meter out?	No	Yes
Kinematic flexibility	No	Yes
Ability to sample >1 location	Yes	No
Sample size	High	Small

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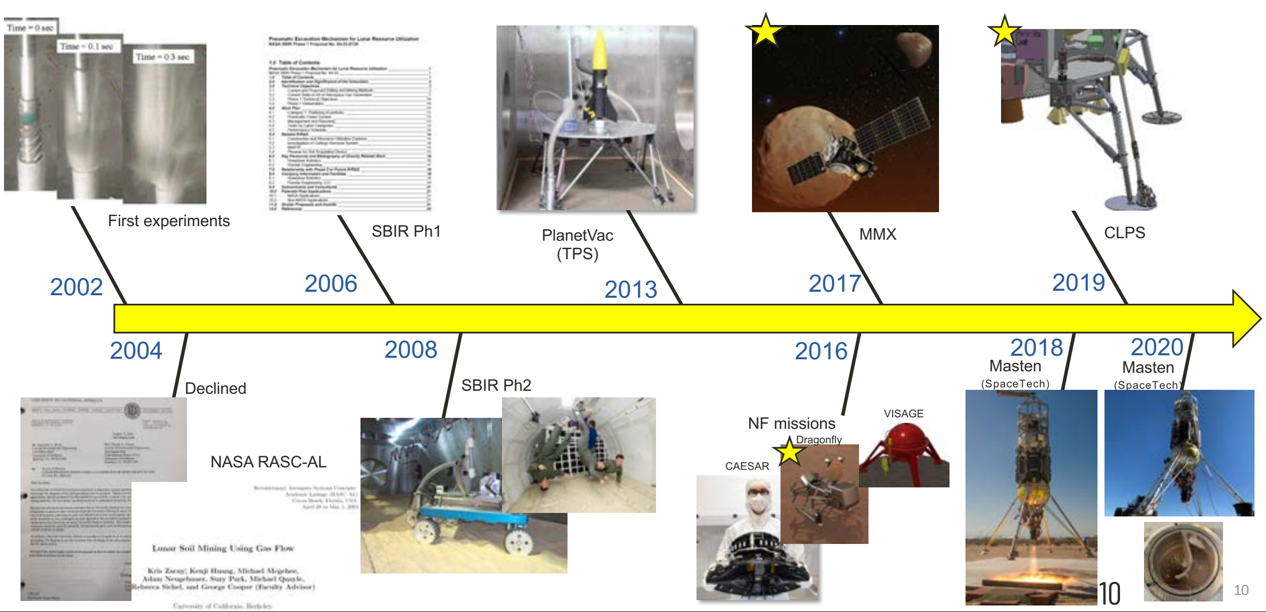
PlanetVac Heritage

Flight programs

HONEYBEE ROBOTICS



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Test Campaign Background

HONEYBEE ROBOTICS

Through NASA's Flight Opportunities and REDDI programs, Honeybee Robotics was able to fly an iteration of PlanetVac mounted as the foot of the Masten Space Systems Xodiac Suborbital Vehicle

This was PlanetVac's second test campaign on-board Xodiac

PlanetVac on Masten Xodiac Vehicle during flight and right before landing
Photo Credit: Masten Space Systems

11

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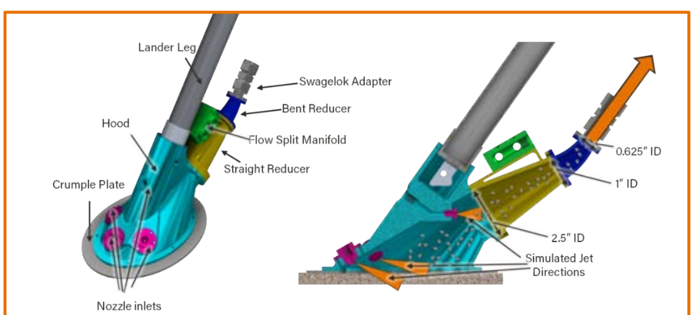
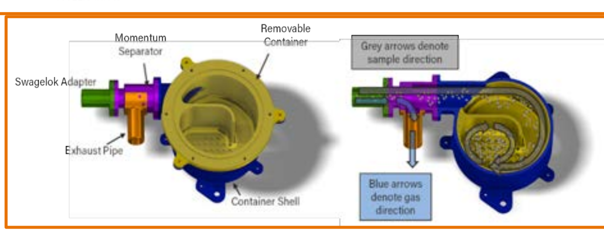
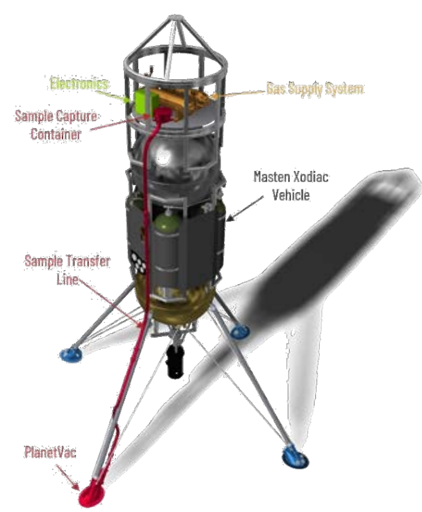
Test Configuration

HONEYBEE ROBOTICS







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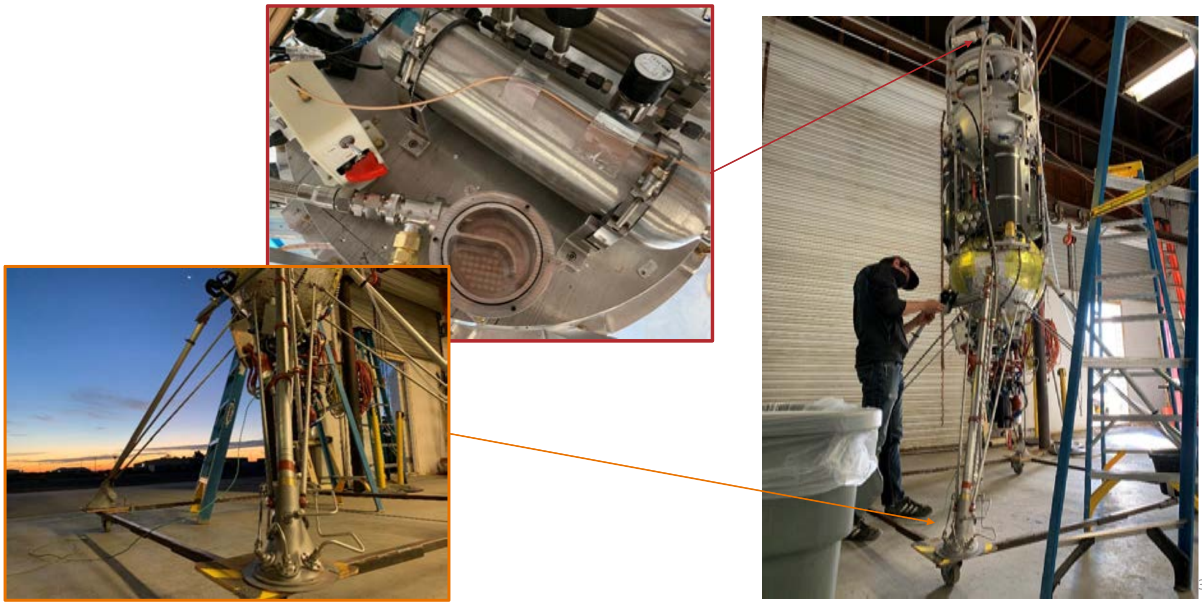
Integrating Onto PlanetVac

HONEYBEE ROBOTICS



13

Test Campaign Goals

HONEYBEE ROBOTICS

Goals: Increase TRL of PlanetVac system by performing tests in more representative and conservative environments relative to future flight deployments than previous Masten PlanetVac flights. Begin to understand the impact of testing on Earth vs a planetary body.

PlanetVac Was Tested In A Conservative Way:

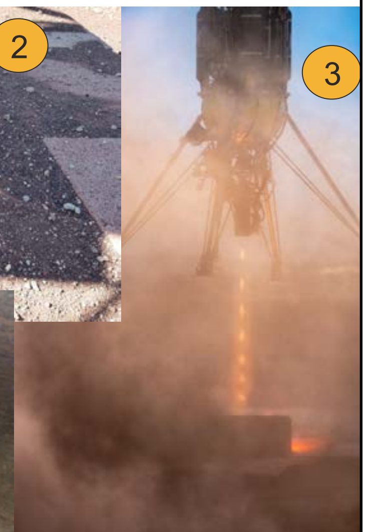
Atmospheric Pressure	Gravity	Elevation Gain	Compaction	Pneumatic Line Length	Supply Pressure
Earth Atmosphere	Earth Gravity	~3 meters	Varies	~5 meters	220 psig regulated line pressure
Conservative to Lunar Baseline	Conservative to Lunar Baseline	Conservative to Lunar Baseline	Comparable to Lunar Baseline	Conservative to Lunar Baseline	Conservative to Lunar Baseline

14

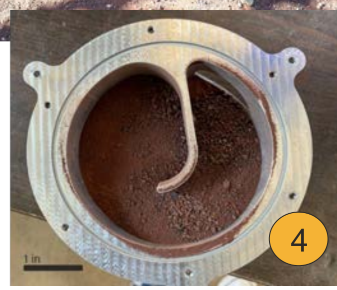
14

Test Images

HONEYBEE ROBOTICS



1. General Setup
2. Test 3 Pre-Pneumatic Pulse
3. Plume Scouring
4. 224 gram post-test fill



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Test Videos (2018 Deployment)

HONEYBEE ROBOTICS

16

16

Test Results

HONEYBEE ROBOTICS

Test #	Environment / Flight Pattern	Penetration Resistance @5cm depth Before / After Test	Pulse Parameters	Sample Collected	Notes
0	Ground demo on vehicle	Uncompacted*	220 psig; 5 seconds	90 grams	No Flight
1	High stands tether	Extreme compaction*	220 psig; 5 seconds	0.7 grams	Unmeasured High Compaction larger than lunar condition
2	High Stands Tether	Before Flight: 145 kPa Post Flight: 195 kPa	220 psig; 20 seconds	190.3 grams	Regolith pit scoured by incoming plume
3	High Stands Tether	Before Flight: 130 kPa Post Flight: 166 kPa	220 psig; 20 seconds	224.2 grams	Regolith pit blocked off from incoming plume
4	Ground to Ground	Before Flight: 290 kPa Post Flight: 625 kPa	220 psig; 20 seconds	65.0 grams	High compaction test
5	Ground Demo	160 kPa	220 psig; 20 seconds	11.1 grams	Placed onto uneven footing after scrubbed ground to ground attempt

17

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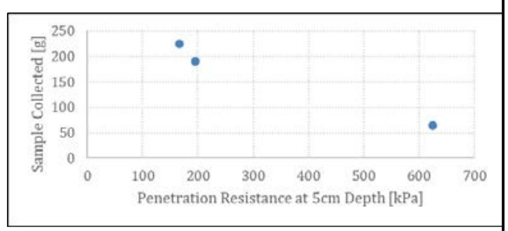
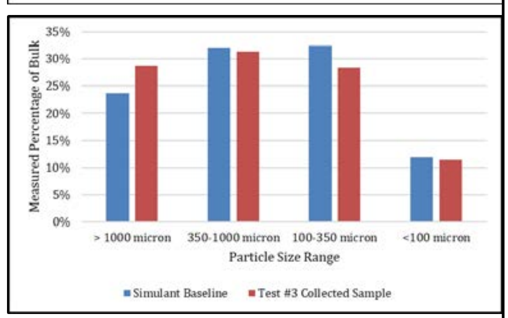
Test Results

HONEYBEE ROBOTICS

Increased Compaction = Decreased Sample Fill



Collected sample particle size distribution similar to random sample of simulant



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Acknowledgements

HONEYBEE ROBOTICS

This work was supported by NASA Flight Opportunities and REDDI Program.
This work was conducted by Honeybee Robotics in conjunction with Masten Space Systems (flight provider) and Texas A&M University (CFD Support).
Special thanks to Masten Space Systems for providing the flights and Texas A&M for CFD support.
Photos are credited to Honeybee Robotics and Masten Space Systems unless otherwise specified.

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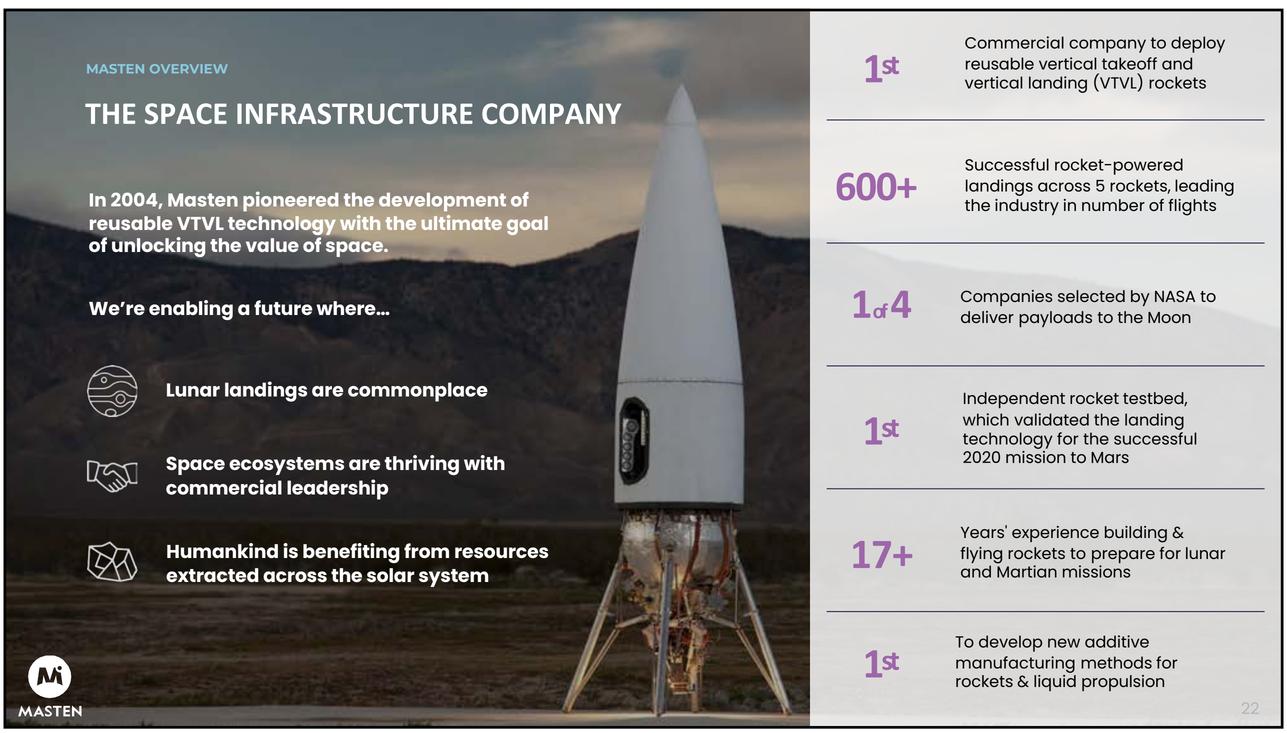
19

HONEYBEE ROBOTICS

20


MASTEN
Retiring Risk with Masten's Terrestrial Rocket Testbed
Reuben Garcia | Masten Space Systems

21


MASTEN OVERVIEW
THE SPACE INFRASTRUCTURE COMPANY
In 2004, Masten pioneered the development of reusable VTVL technology with the ultimate goal of unlocking the value of space.
We're enabling a future where...
Lunar landings are commonplace
Space ecosystems are thriving with commercial leadership
Humankind is benefiting from resources extracted across the solar system
MASTEN
1st
Commercial company to deploy reusable vertical takeoff and vertical landing (VTVL) rockets
600+
Successful rocket-powered landings across 5 rockets, leading the industry in number of flights
1 of 4
Companies selected by NASA to deliver payloads to the Moon
1st
Independent rocket testbed, which validated the landing technology for the successful 2020 mission to Mars
17+
Years' experience building & flying rockets to prepare for lunar and Martian missions
1st
To develop new additive manufacturing methods for rockets & liquid propulsion
22

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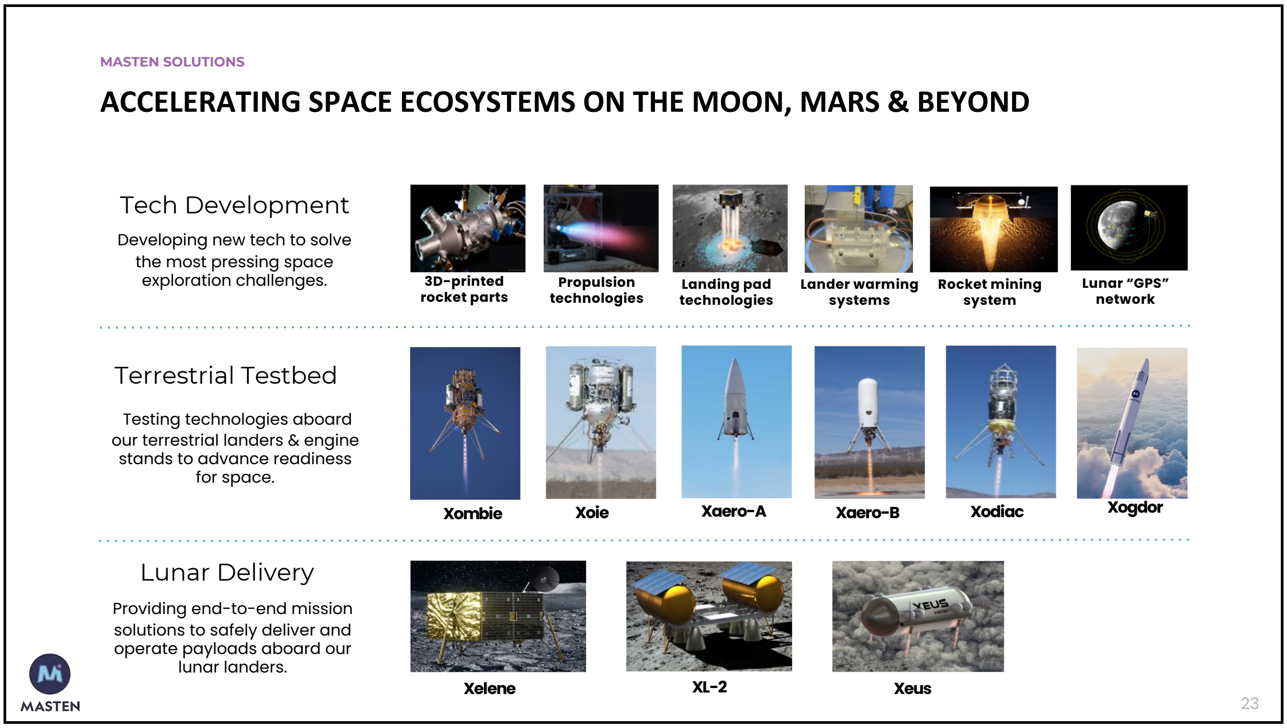
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Developing new tech to solve the most pressing space exploration challenges.
3D-printed rocket parts
Propulsion technologies
Landing pad technologies
Lander warming systems
Rocket mining system
Lunar "GPS" network
Terrestrial Testbed
Testing technologies aboard our terrestrial landers & engine stands to advance readiness for space.
Xombie
Xoie
Xaero-A
Xaero-B
Xodiac
Xogdor
Lunar Delivery
Providing end-to-end mission solutions to safely deliver and operate payloads aboard our lunar landers.
Xelene
XL-2
Xeus
MASTEN
23

23


TERRESTRIAL TESTBED
RETIRING RISK WITH EARTH-BASED TESTING
Entry, Descent, and Landing Tests
Suborbital Payload Testing
Plume Surface Interaction Testing
JPL Lander Vision System & G-FOLD algorithm on Xombie
Honeybee Robotics' PlanetVac on Xodiac
UCF Ejecta STORM instrument on Xodiac
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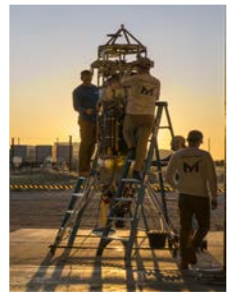
TERRESTRIAL TESTBED

WORKING WITH MASTEN TO ADVANCE TECH READINESS

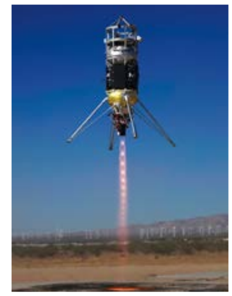
Technical specs & ConOps discussions

Technology integration

Closed-loop tether flights



Data analysis & iteration



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