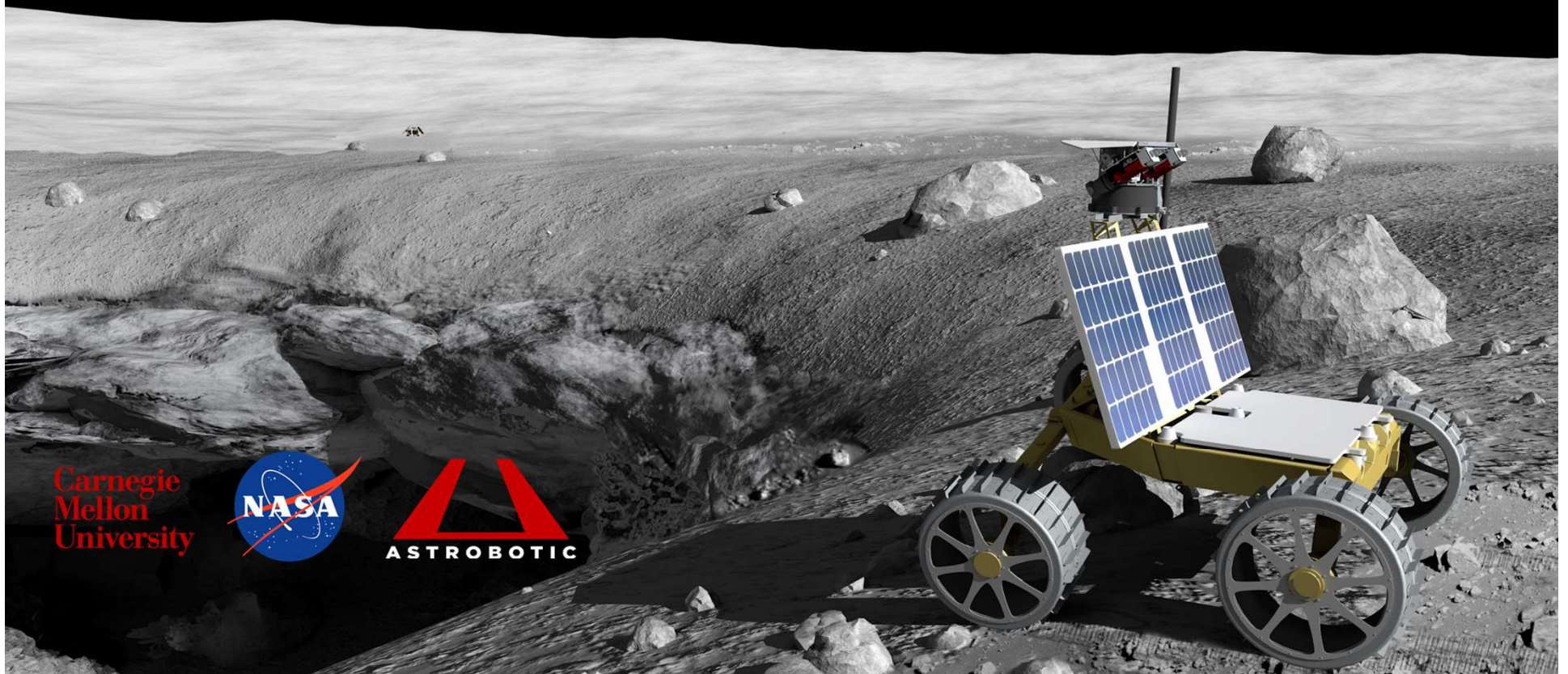


Lunar Pit Exploration and Mapping via Autonomous Micro-Rover



Carnegie
Mellon
University





Jordan Ford



Khaled Sharif

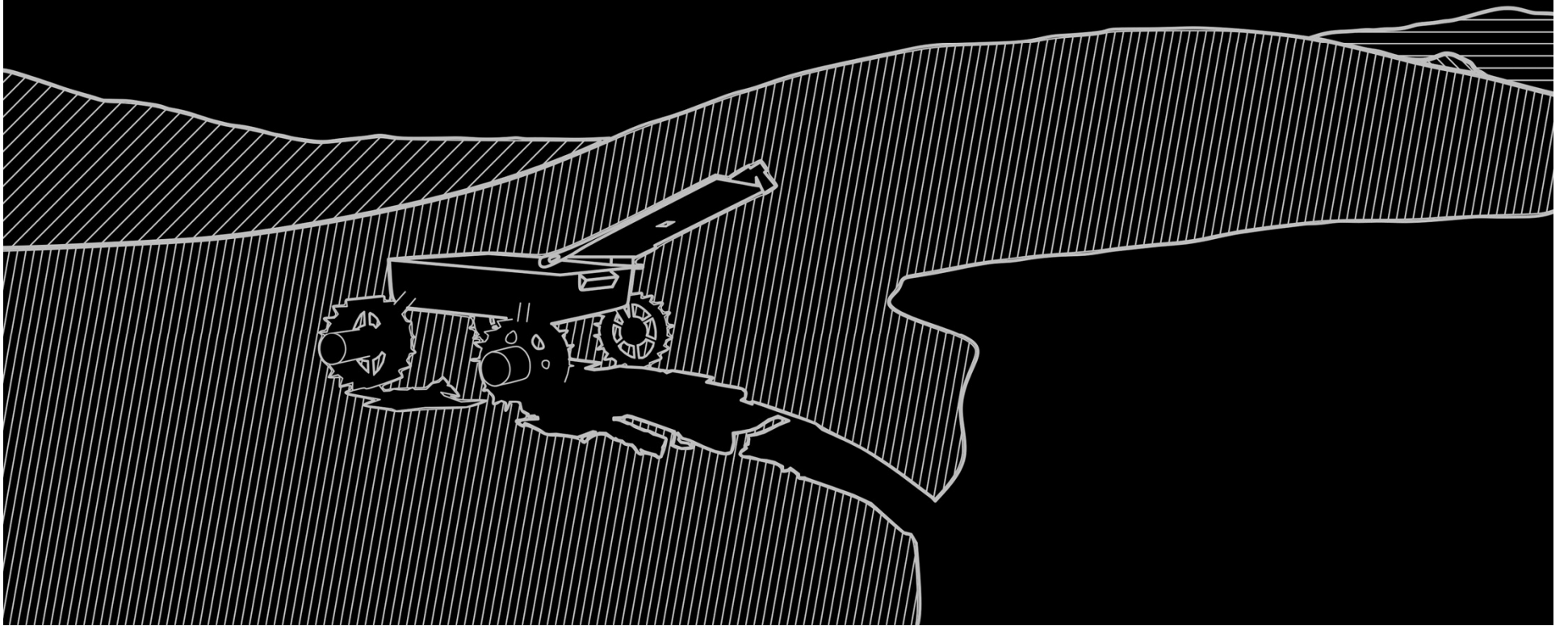


Heather Jones

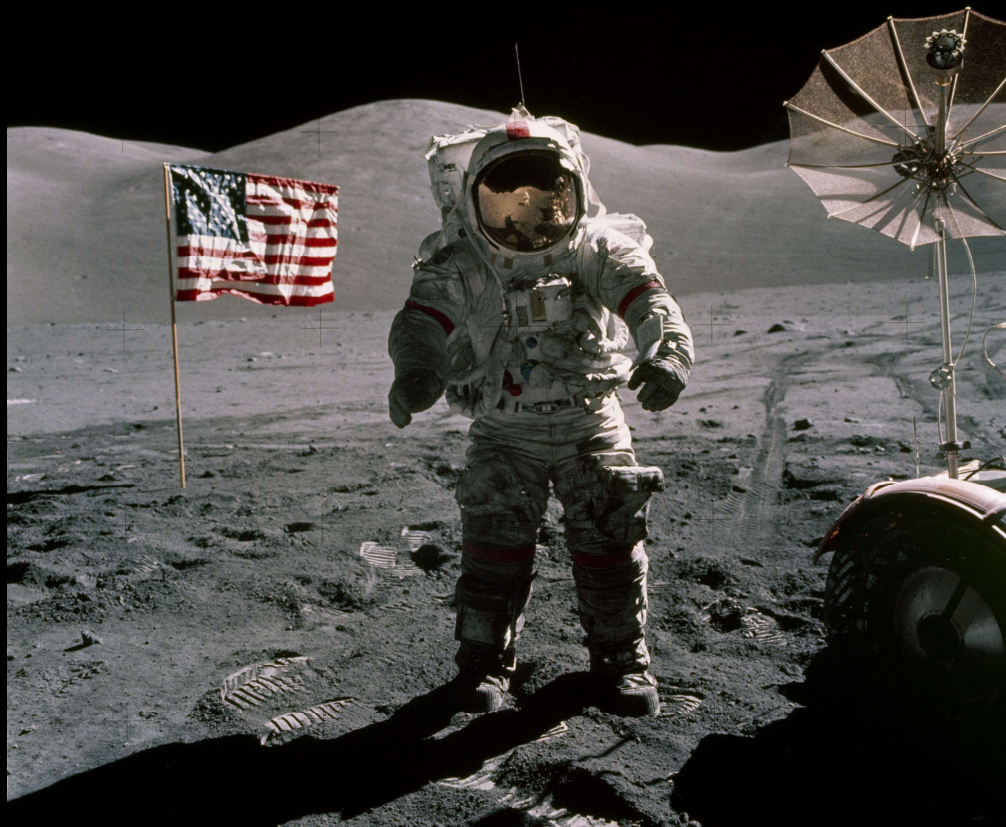


Red Whittaker

Introduction



Apollo 11 landed the first humans on the Moon in 1969;
in 2024 we will return, this time to stay



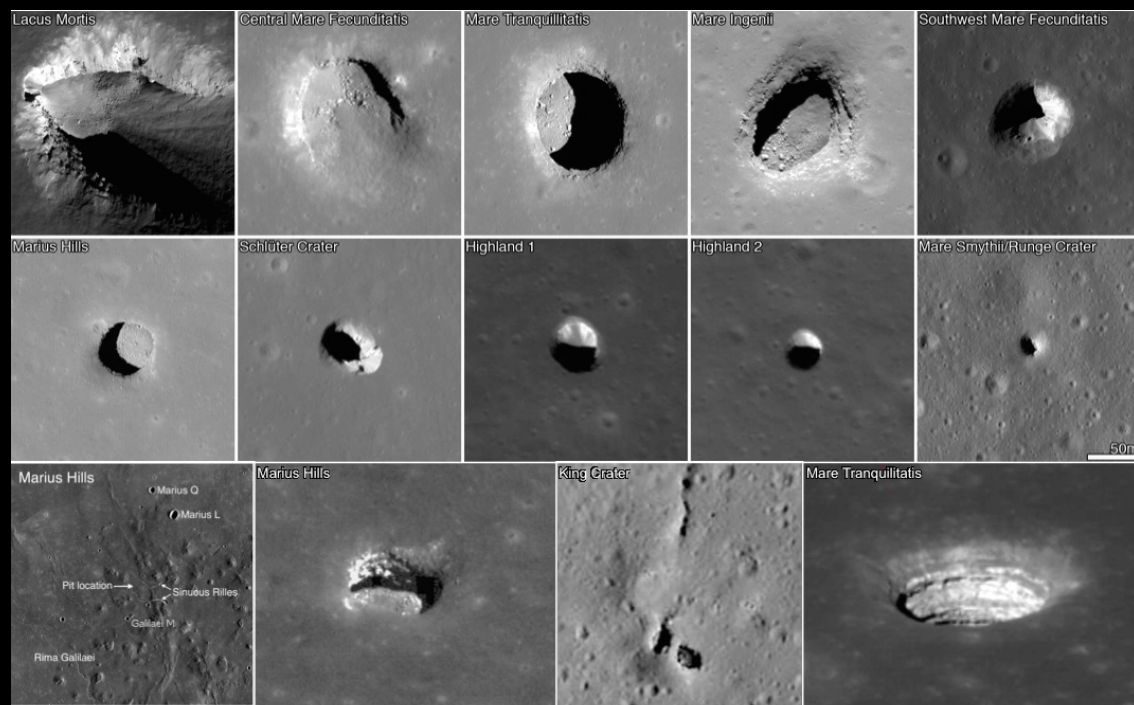
Astronauts on the Moon face harsh conditions, such as
radiation, extreme temperatures, and micrometeorites



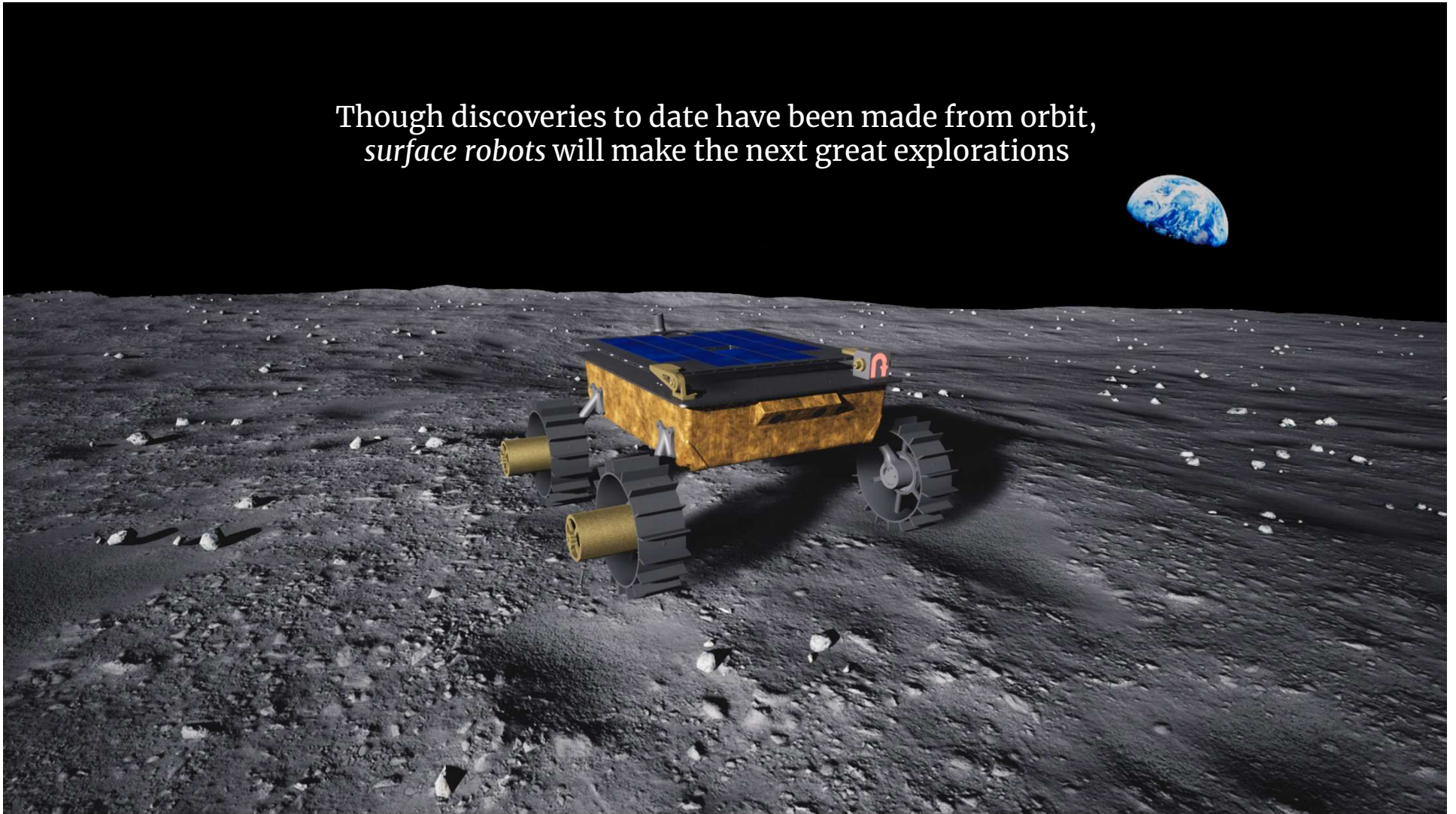
Temperatures on the Moon range from
-173°C to 127°C within a *single* lunar day



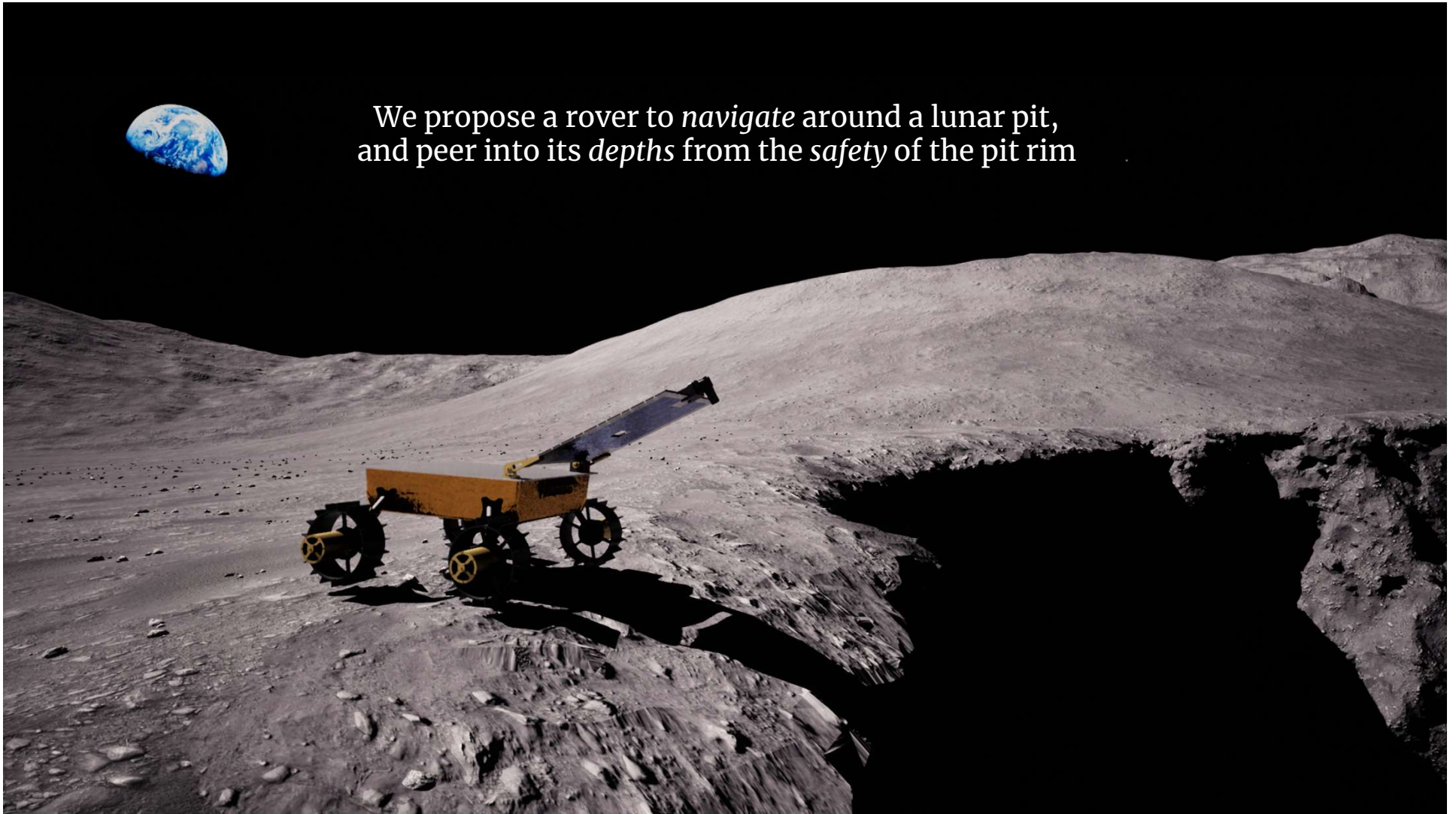
Hundreds of caves on the Moon could provide shelter,
but *none* are yet known to be *accessible*



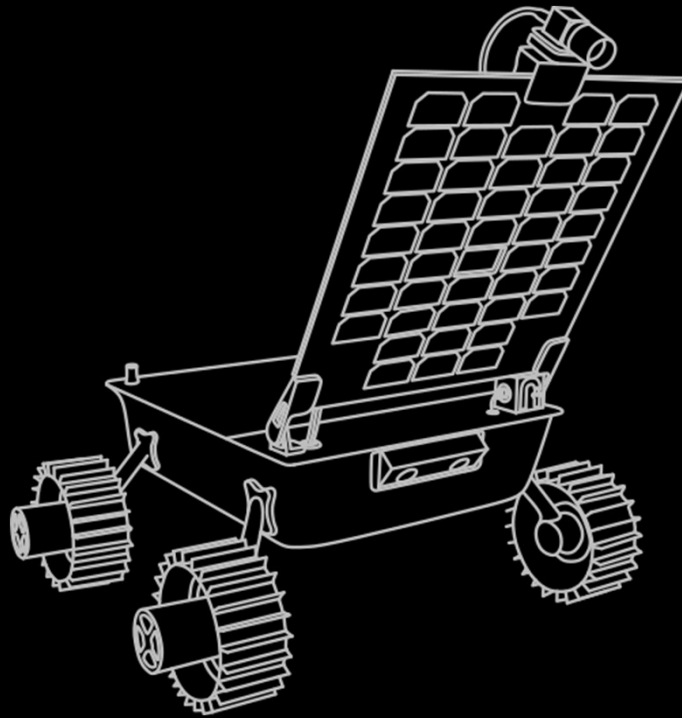
Though discoveries to date have been made from orbit,
surface robots will make the next great explorations

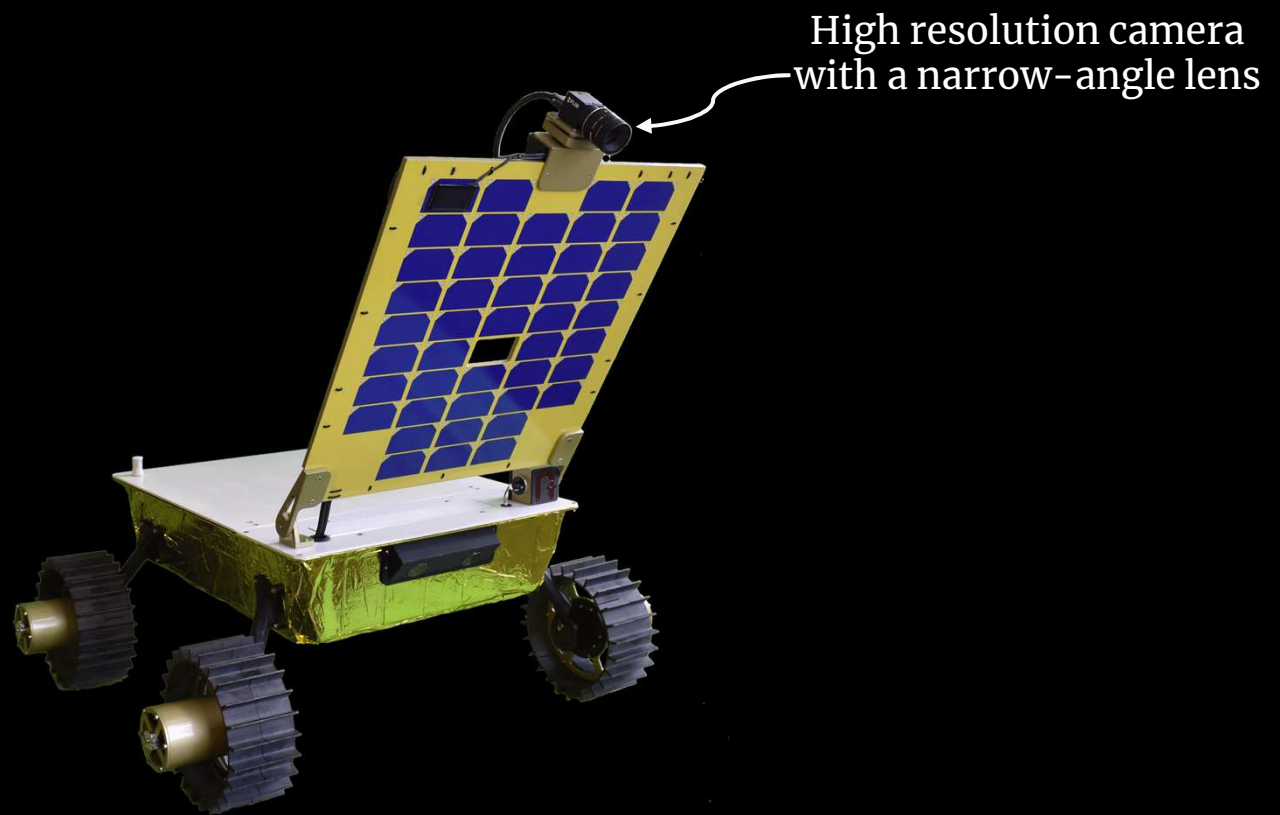


We propose a rover to *navigate* around a lunar pit,
and peer into its *depths* from the *safety* of the pit rim

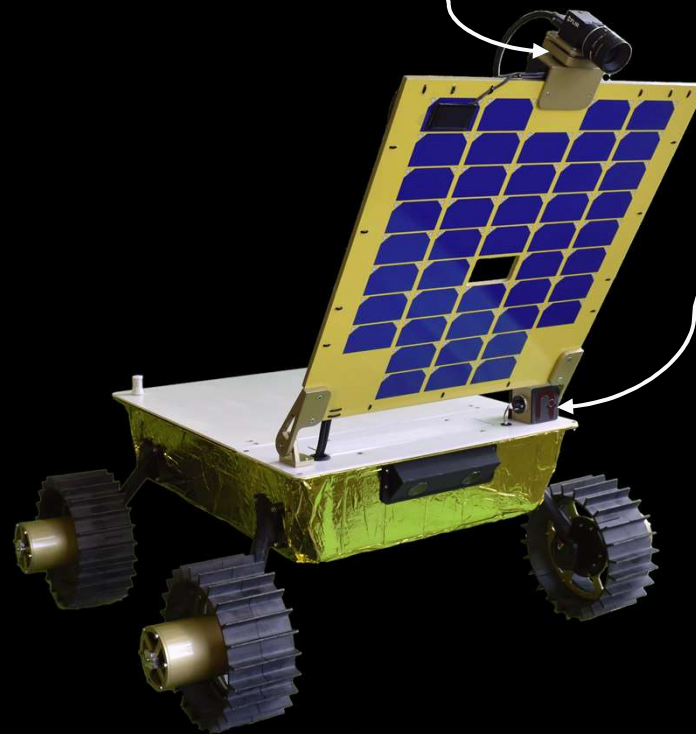


Engineering



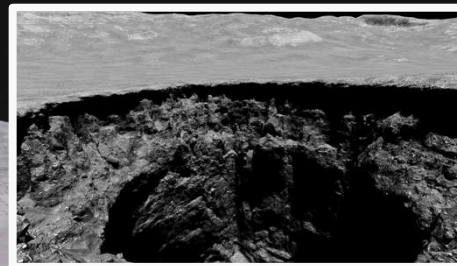


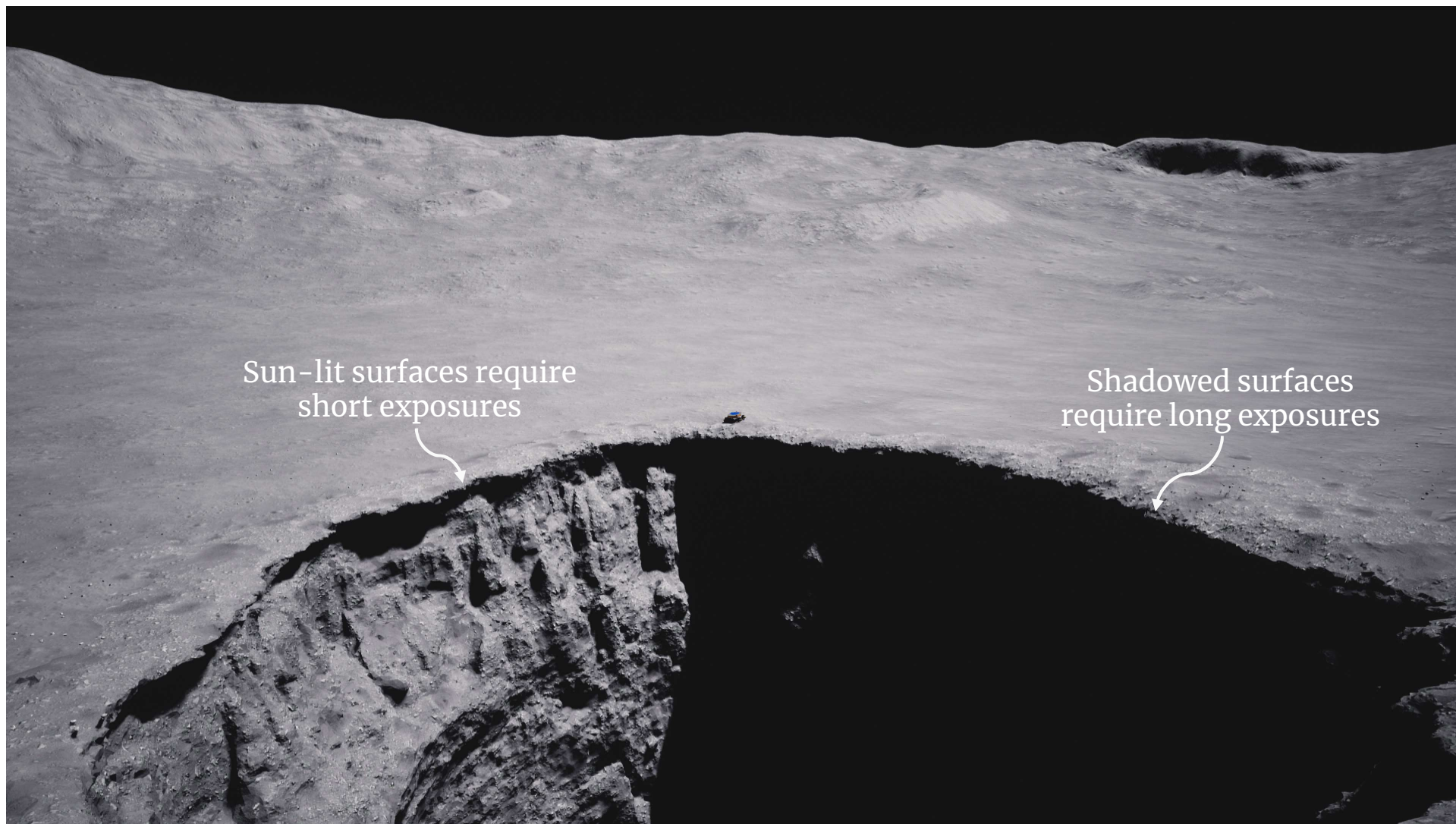
The camera pans 90 degrees
to the left and right



The solar panel tilts up
to 180 degrees to view
the pit floor

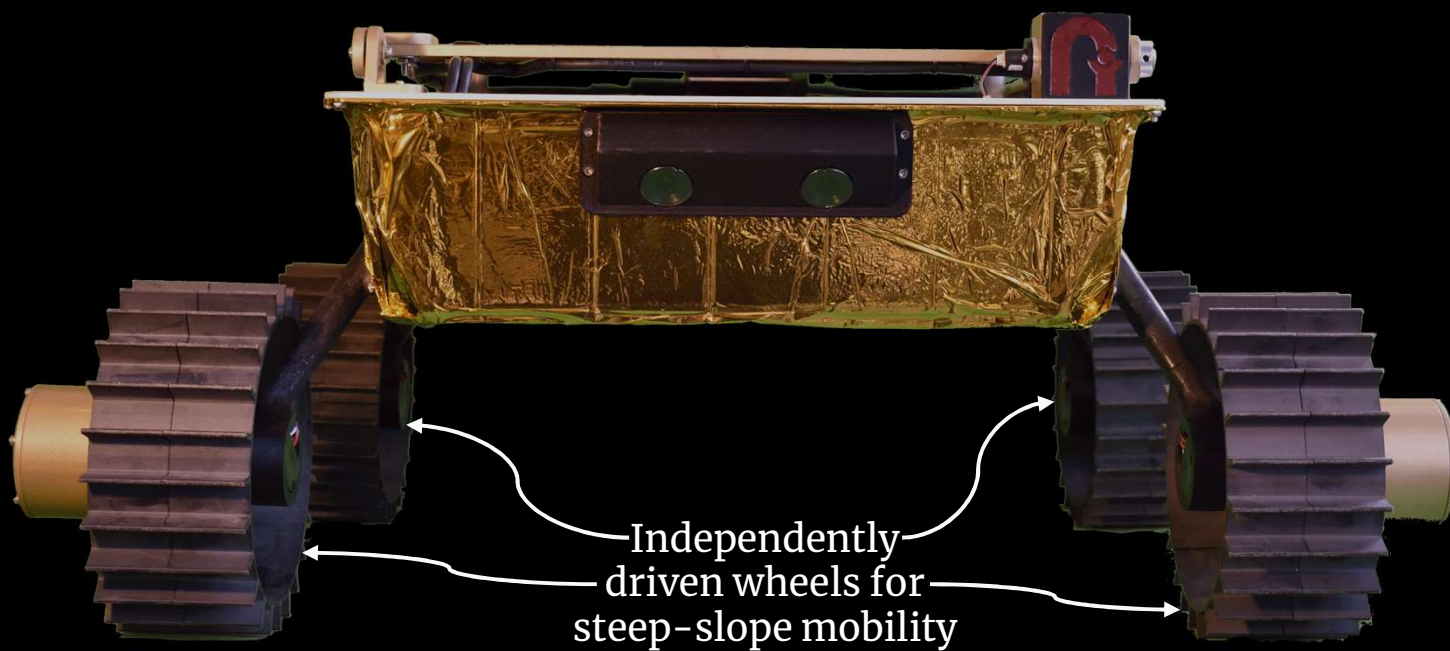
Images of pit walls,
floors, and caverns





Sun-lit surfaces require
short exposures

Shadowed surfaces
require long exposures

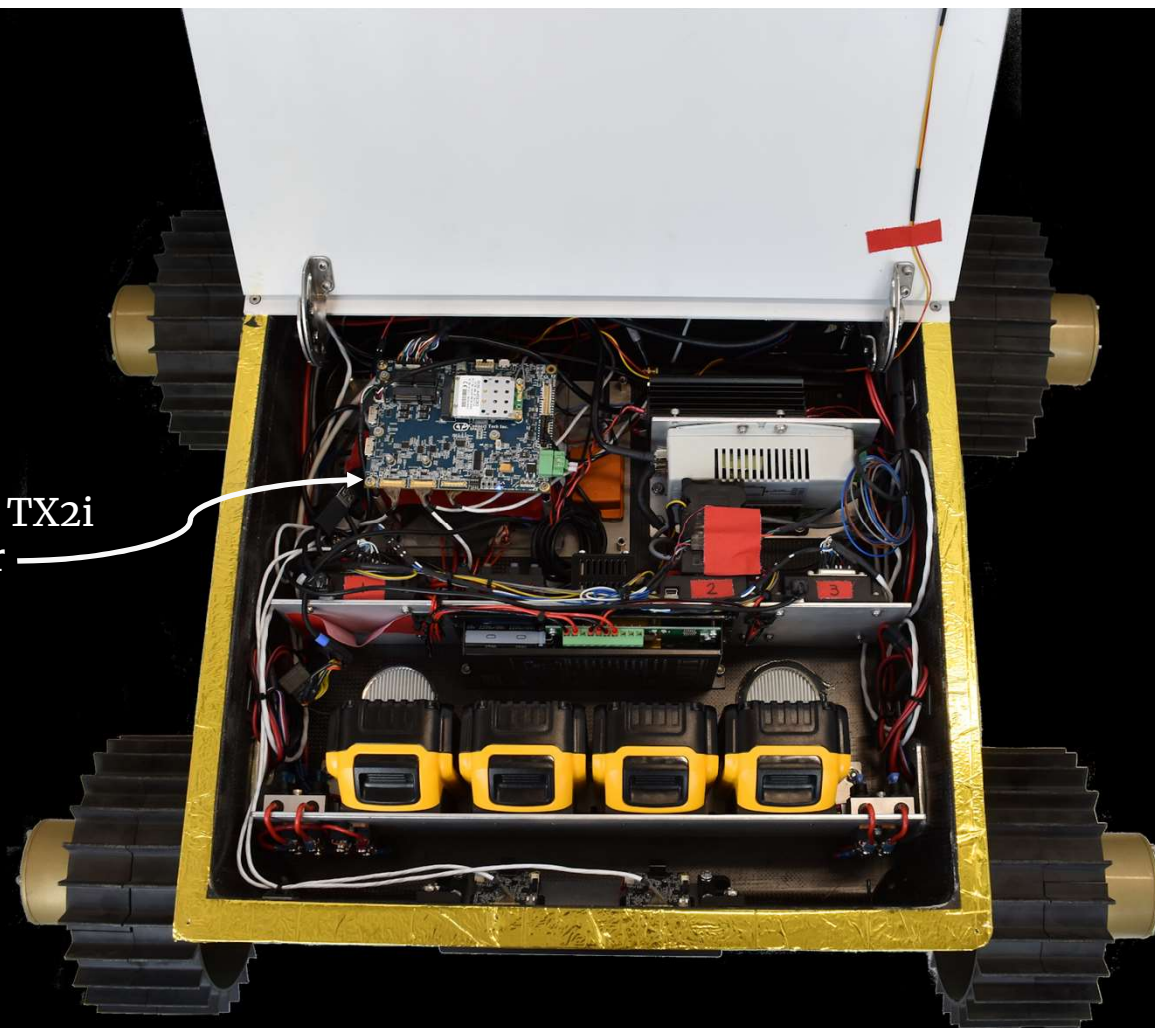


Independently
driven wheels for
steep-slope mobility



Stereo cameras on
the front and back

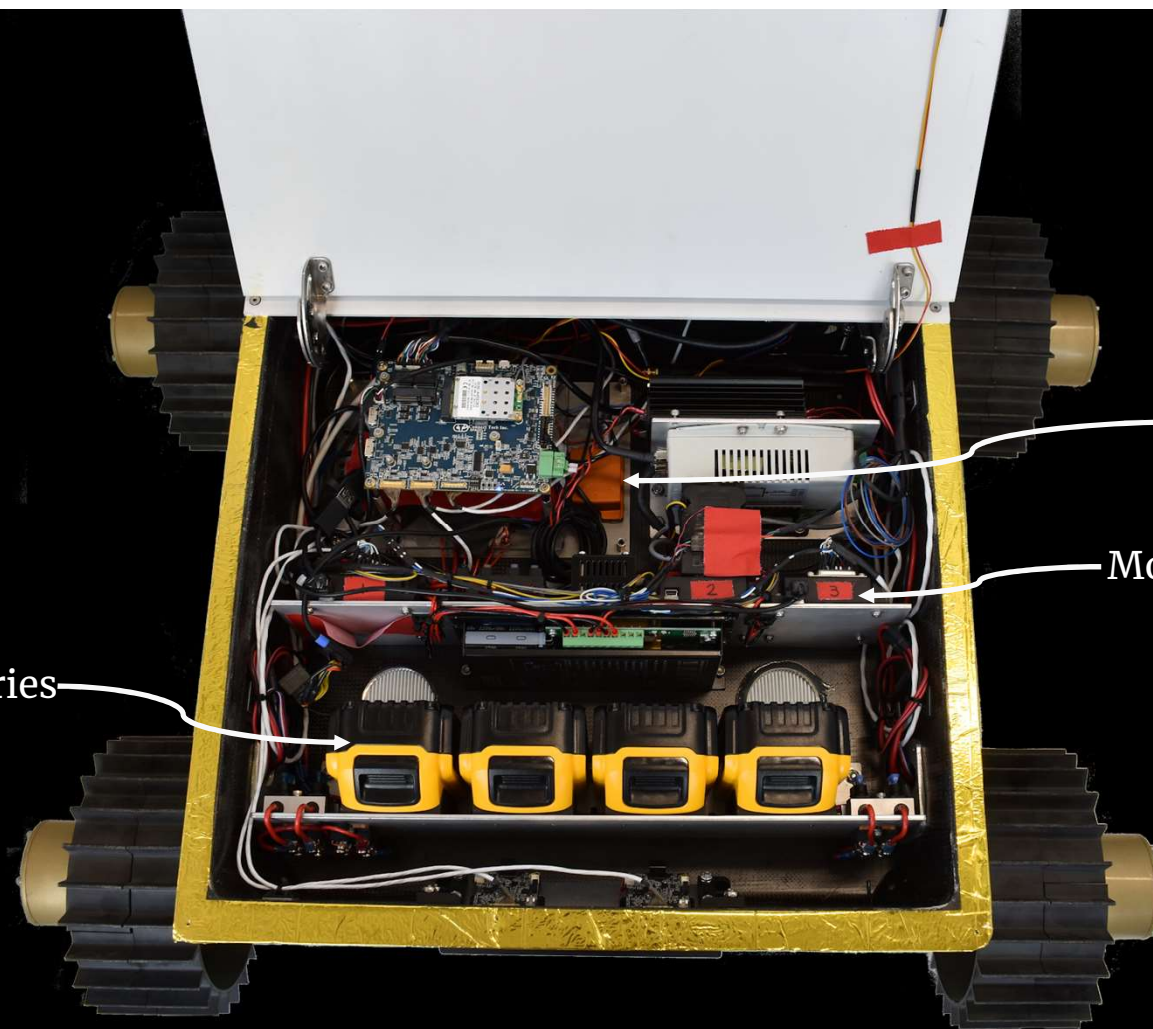
NVIDIA Jetson TX2i
Computer



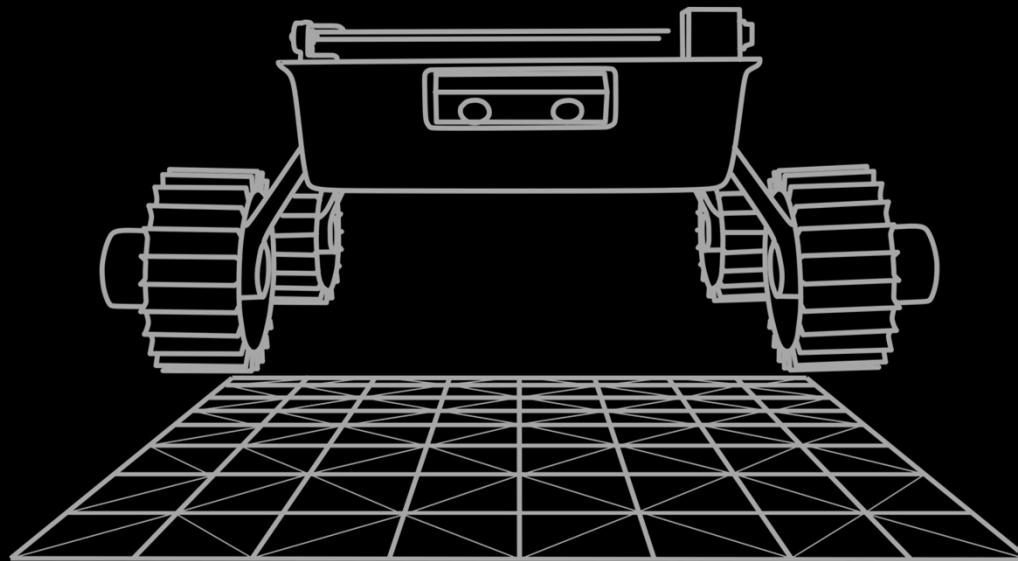
Batteries

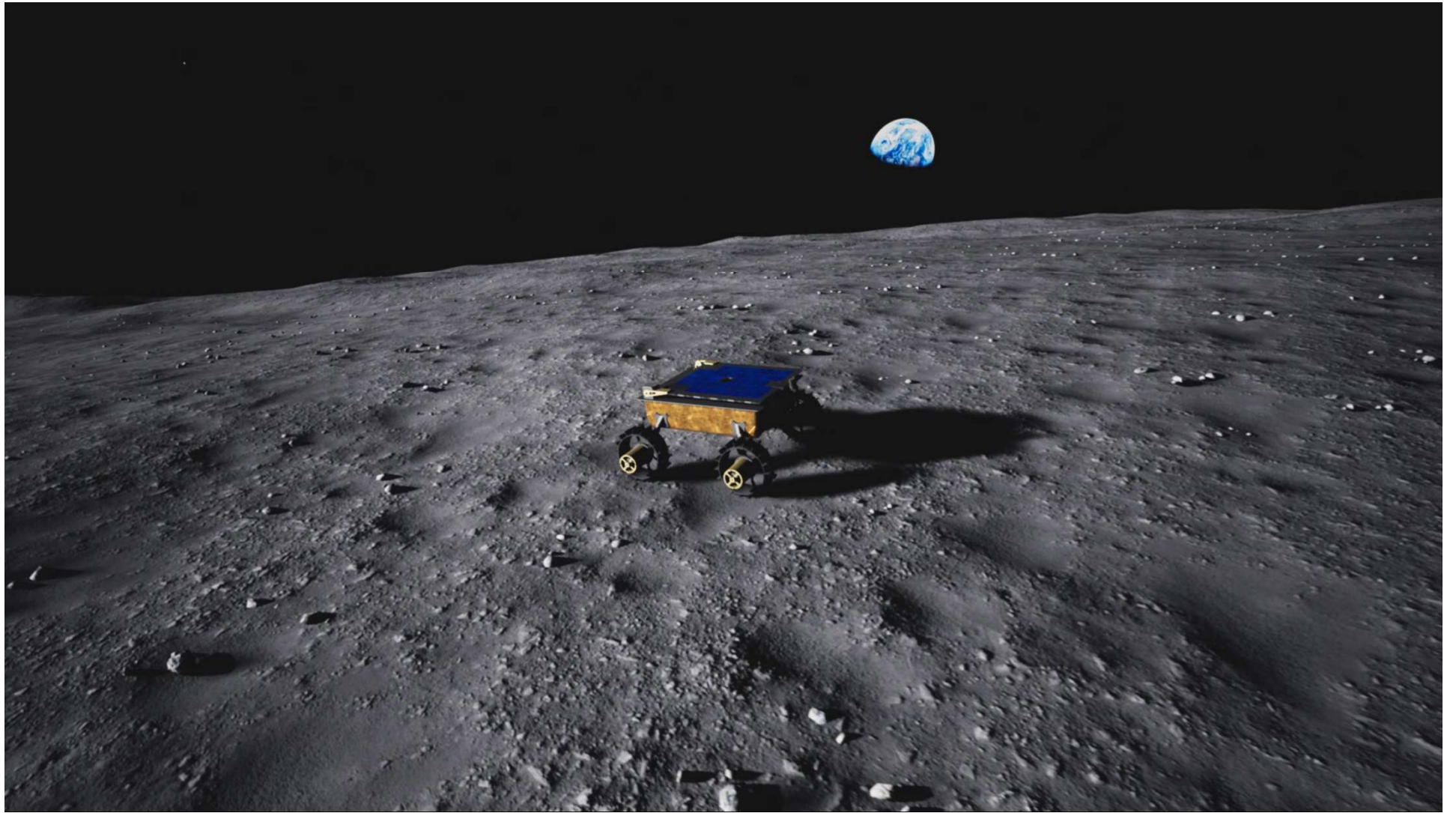
Inertial
Measurement
Unit

Motor controllers

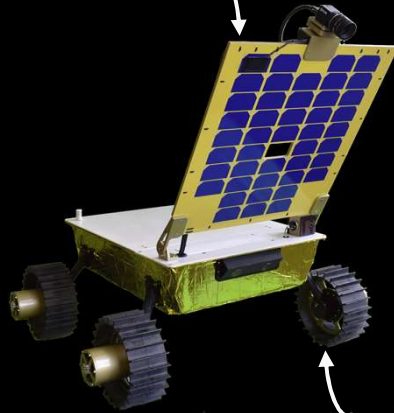


Autonomy



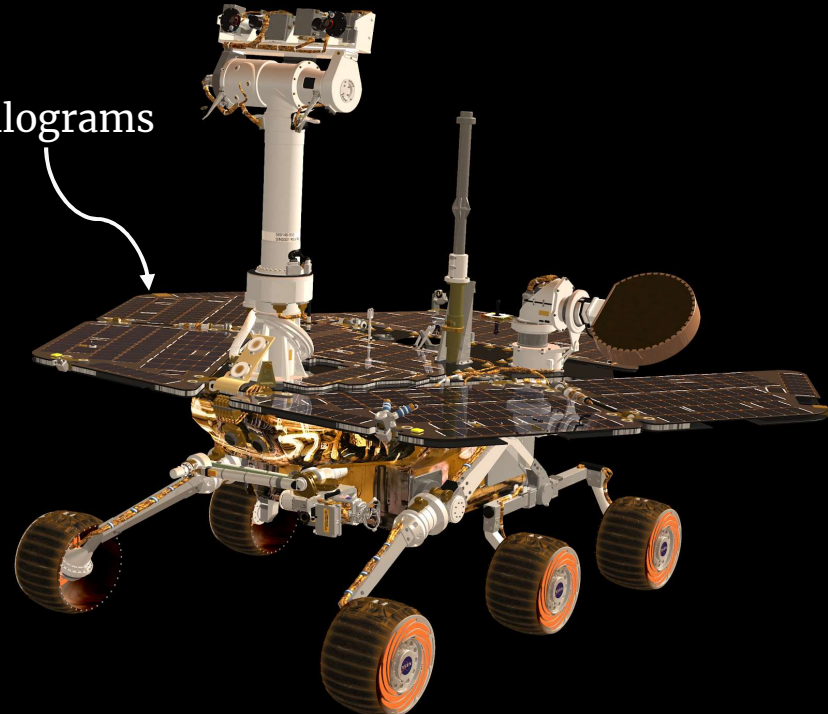


~20 kilograms



~2 cm/second average

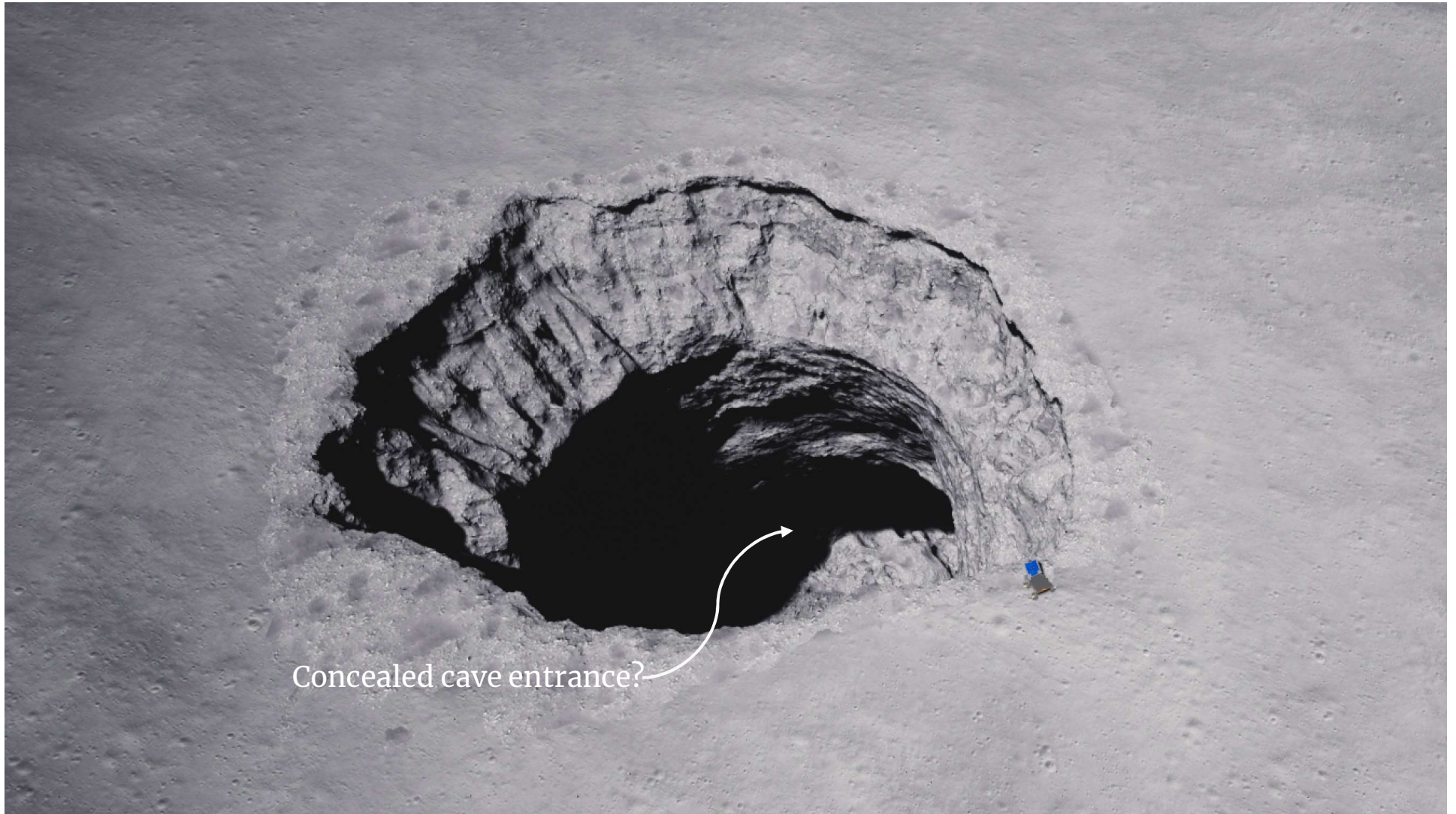
~180 kilograms



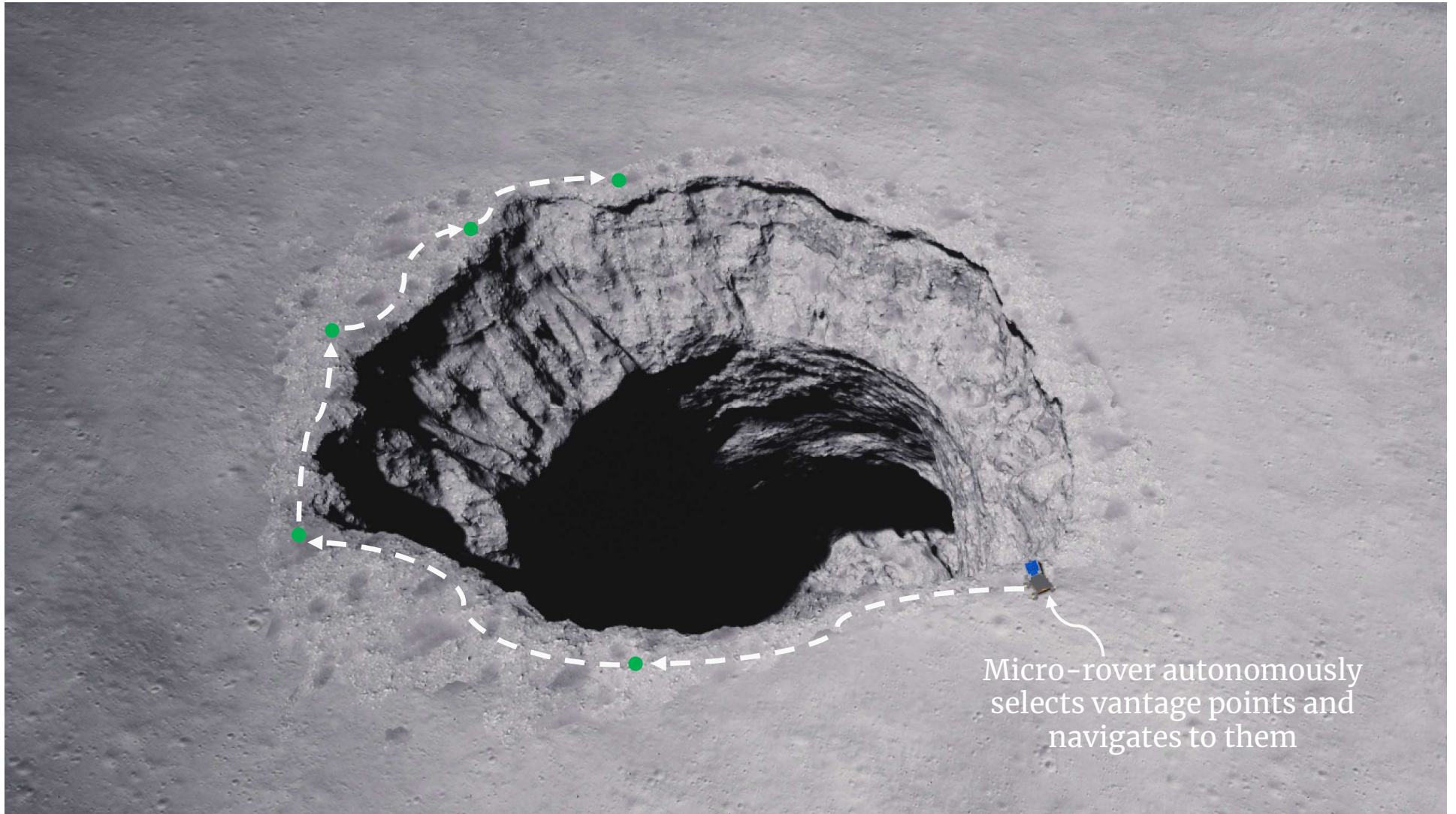
~0.02 cm/second average







Concealed cave entrance?

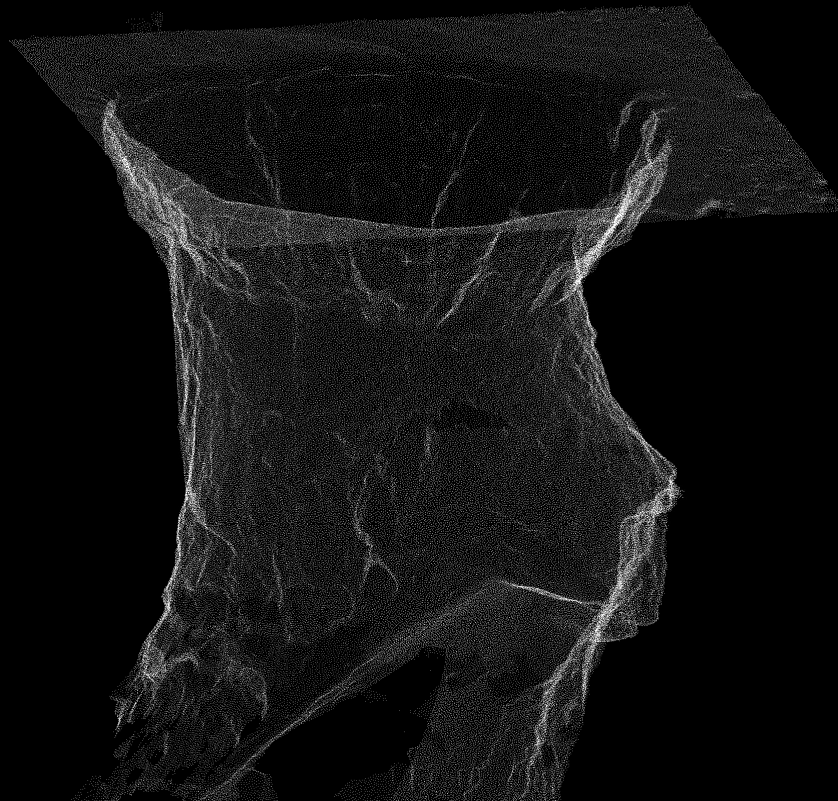


Micro-rover autonomously
selects vantage points and
navigates to them

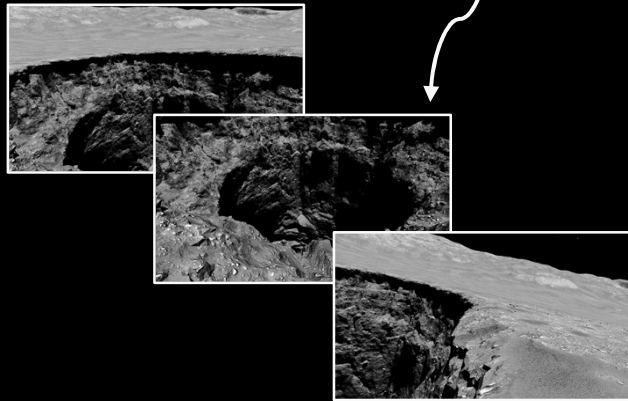
Rover returns to the lander to offload
data acquired, which is then
downlinked to Earth



Modeling

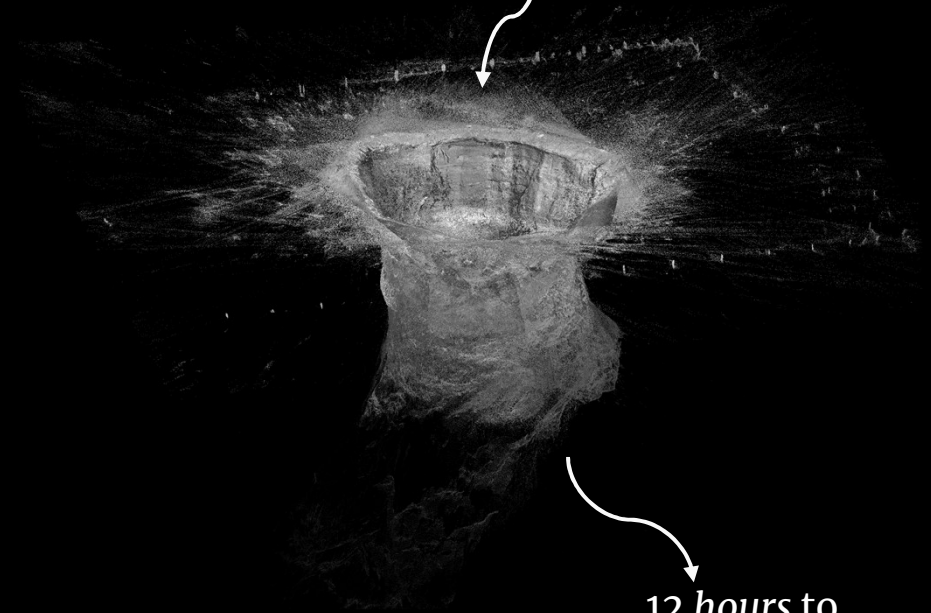


~10,000 *images* take up
~200 GB of space



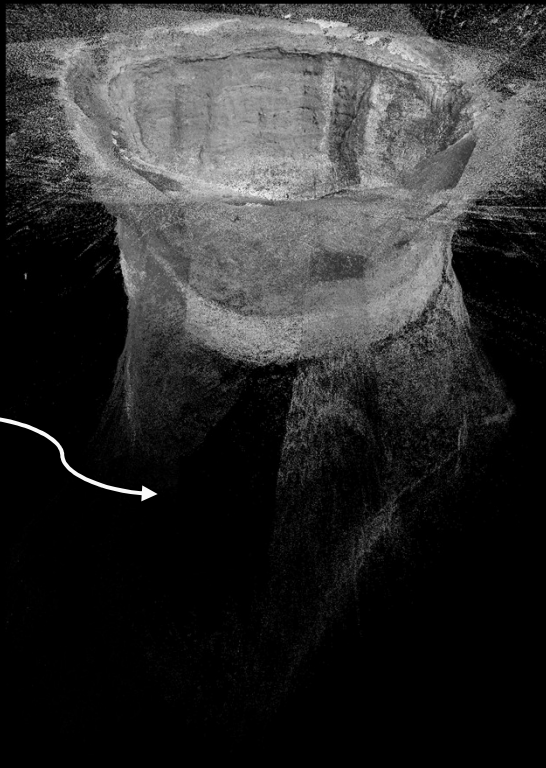
4000 *hours* to
transmit to Earth

1 *model* takes up
~600 MB of space



12 *hours* to
transmit to Earth

Model created using
images taken at 6 *vantages*



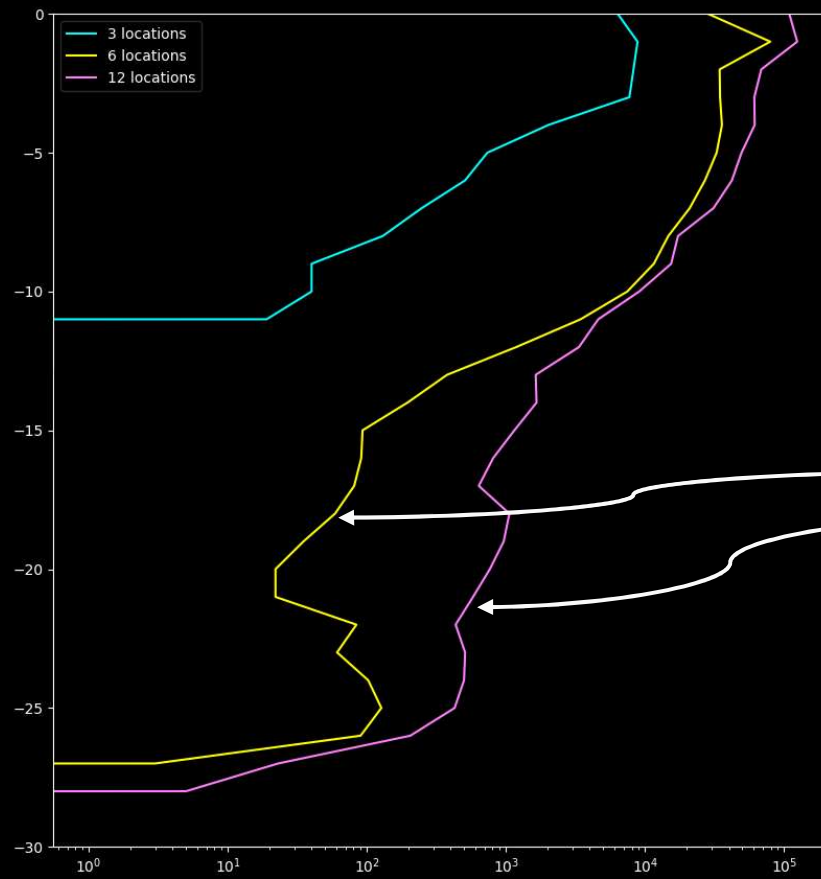
*Insufficient
coverage*

Model created using images
taken at 12 *vantages*



*Increased
coverage*

Elevation of the
model in meters



Model coverage in cubic centimeters

Using more overlooks
improves coverage
significantly



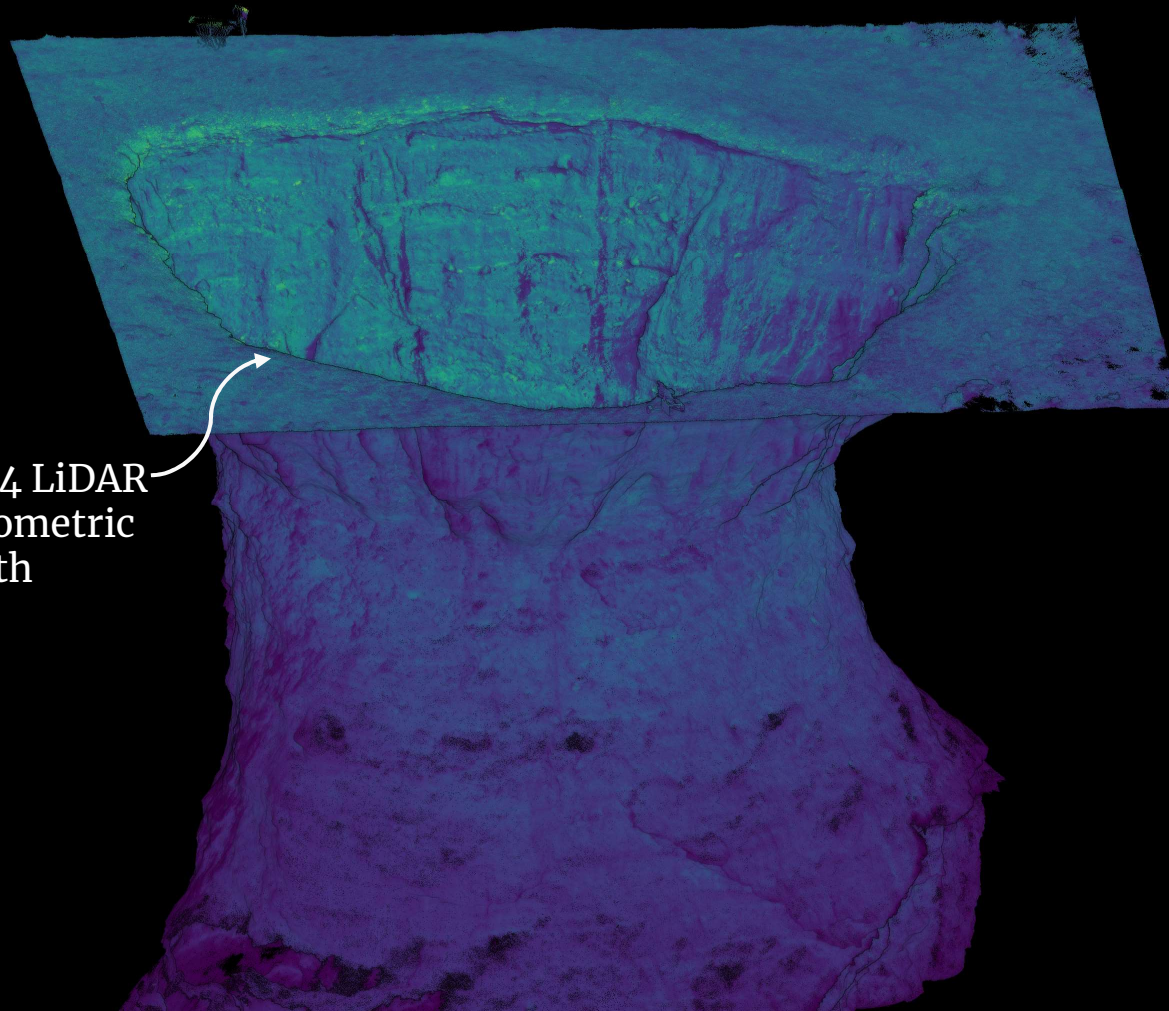


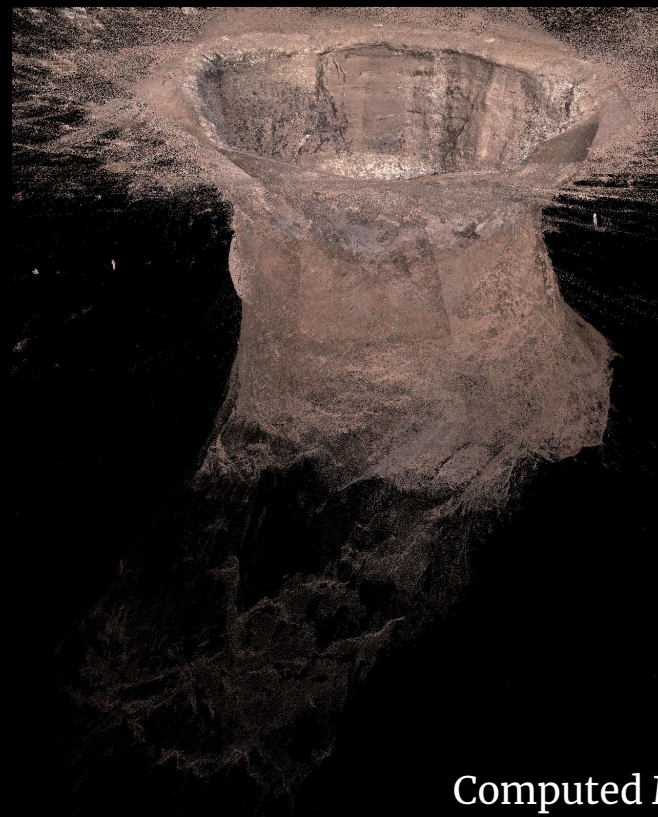
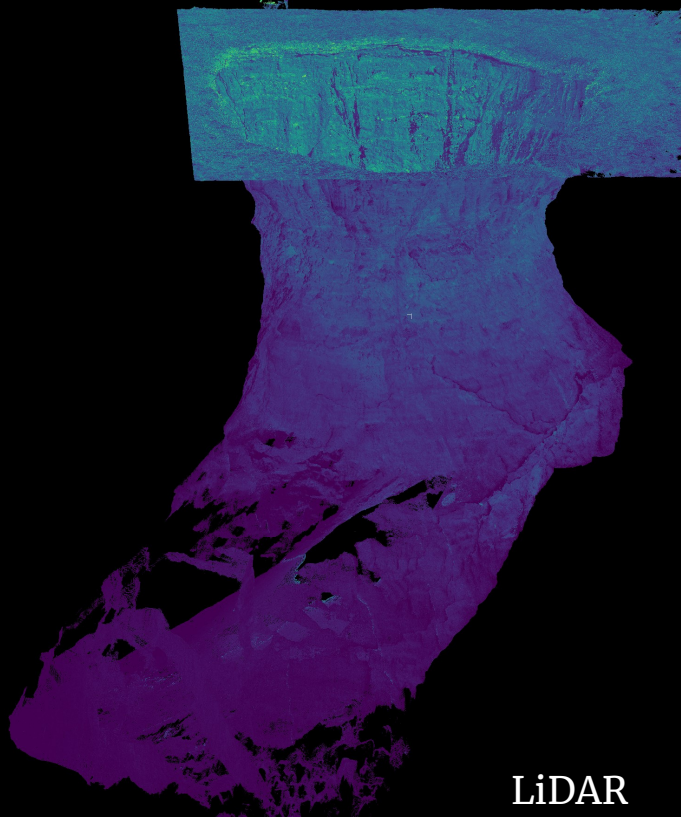


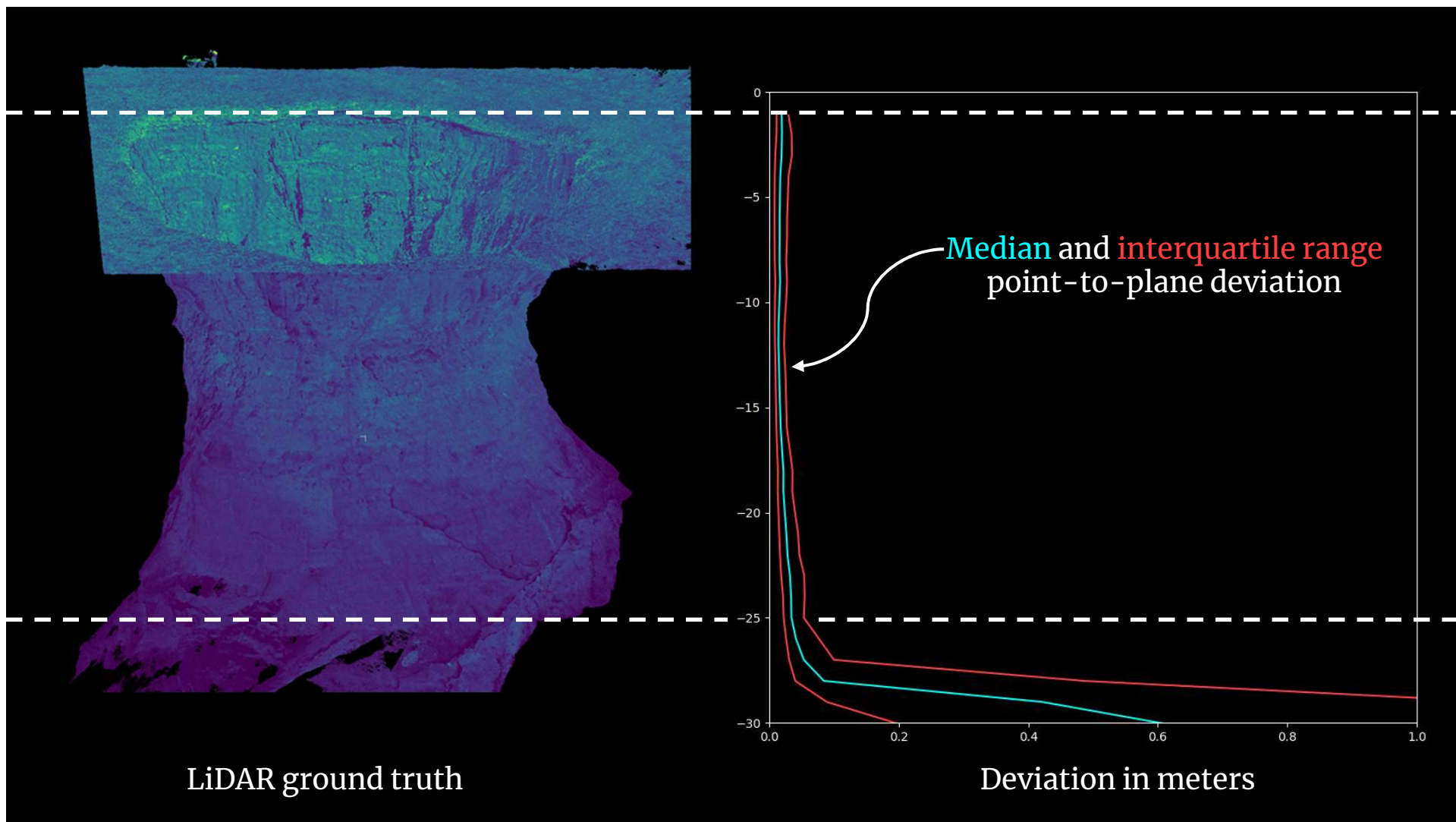


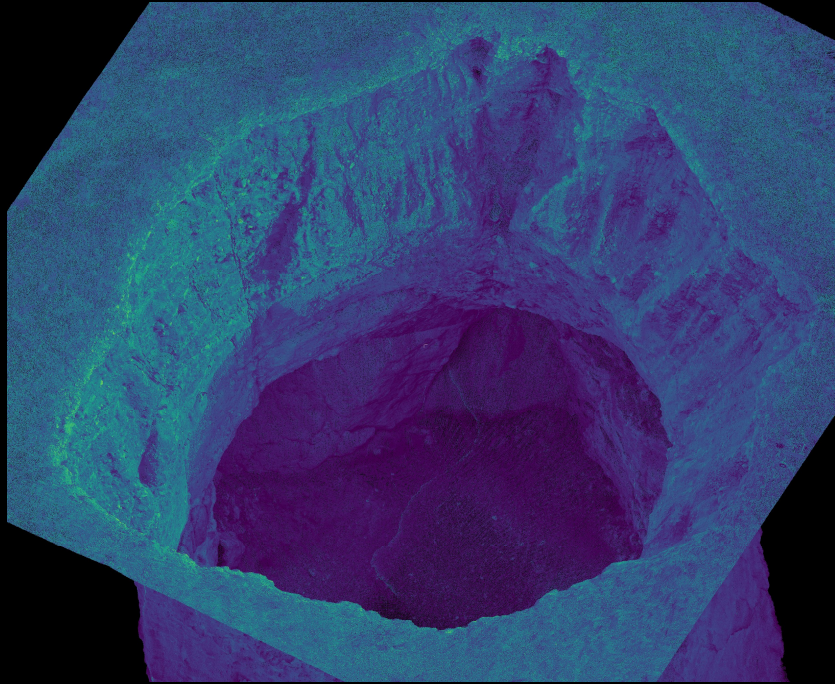
LiDAR scanner capable of
3.5 millimeter precision

Combination of 44 LiDAR
scans formed geometric
ground truth







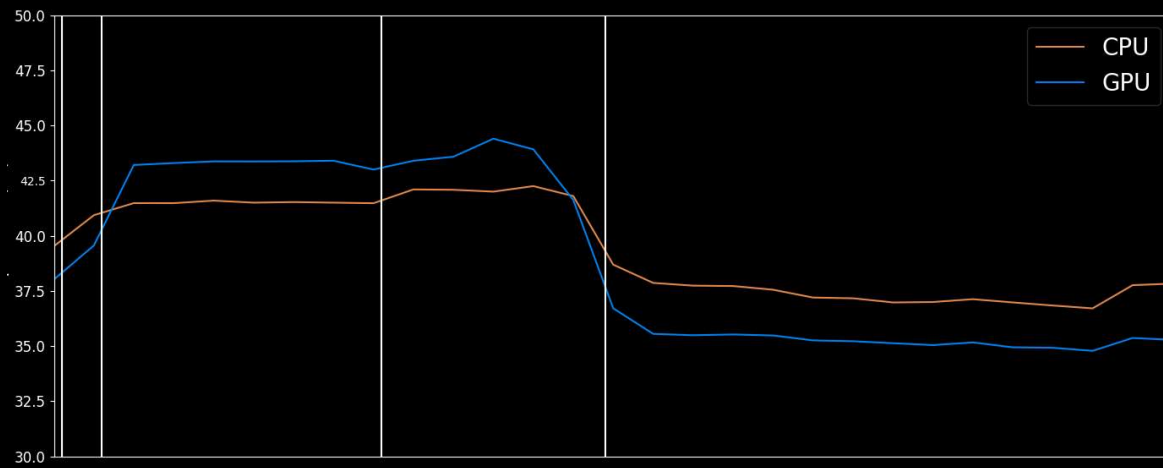


LiDAR

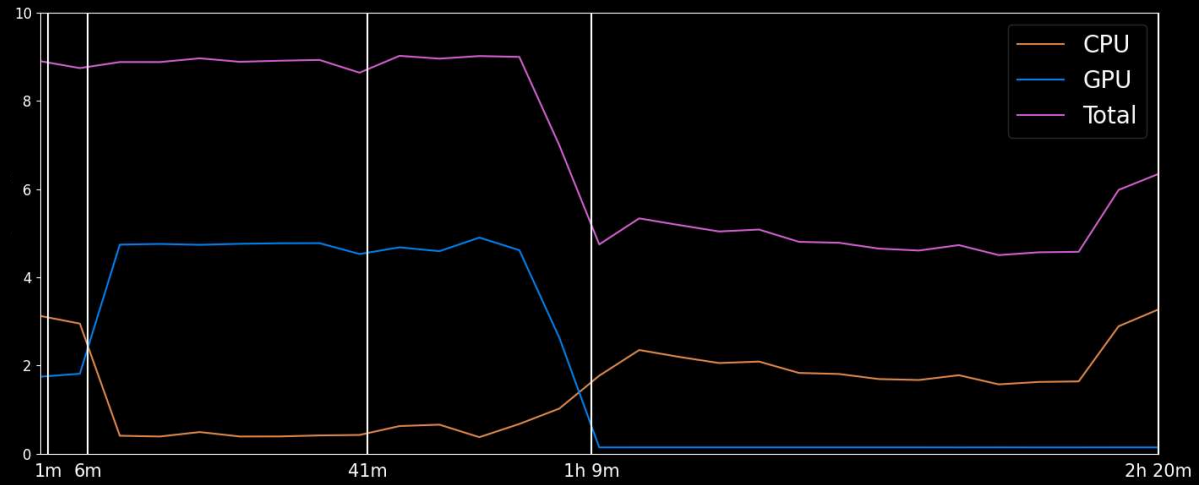


Computed Model

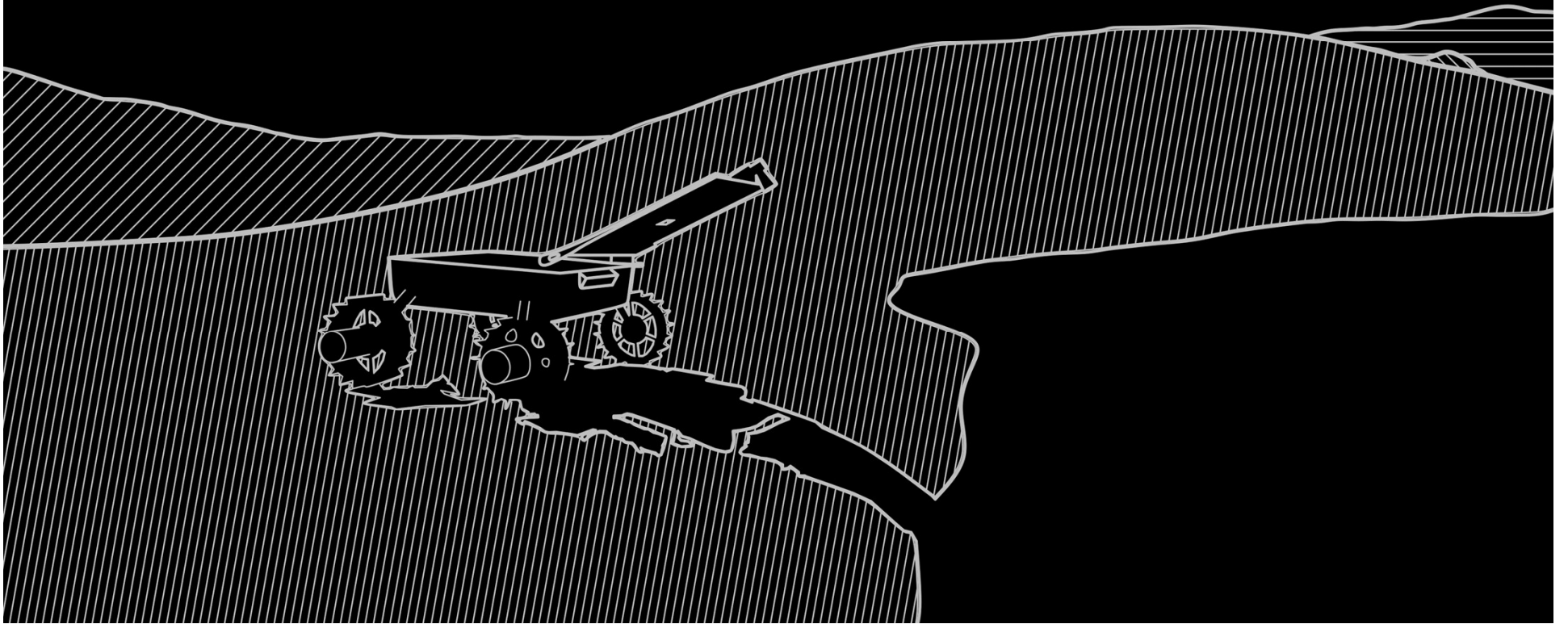
Temperature
(Celsius)



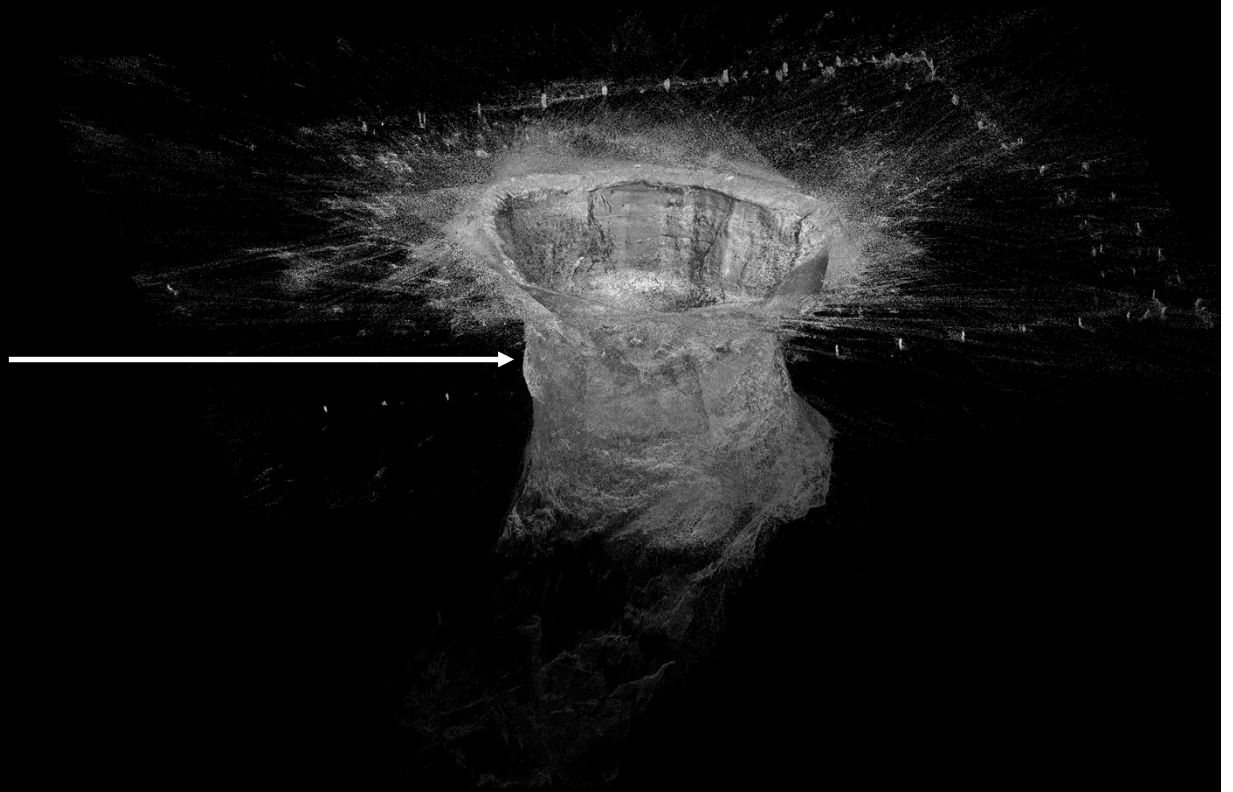
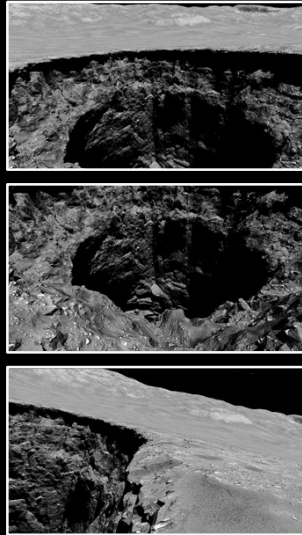
Power
(Watts)



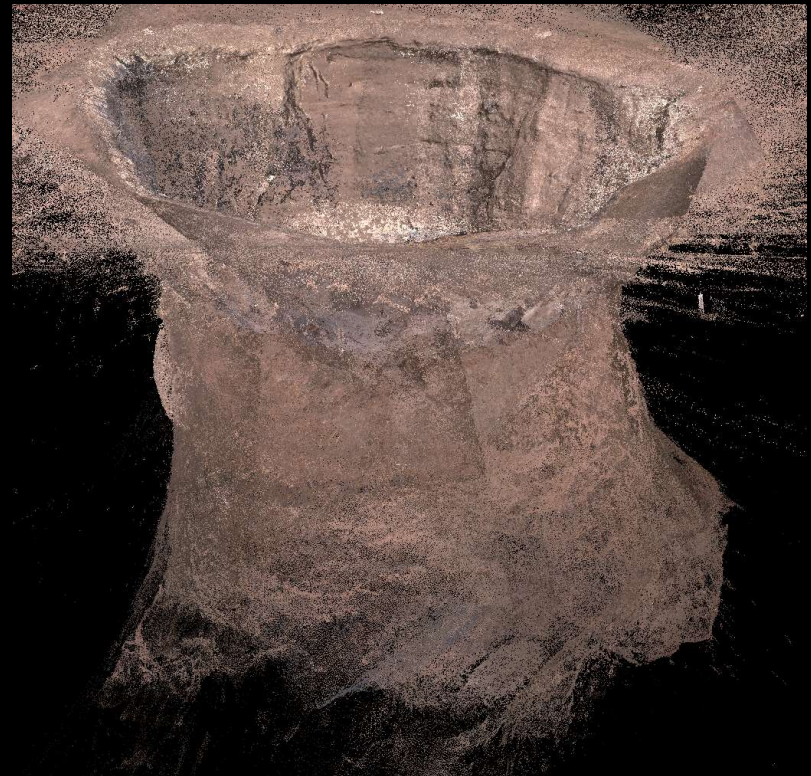
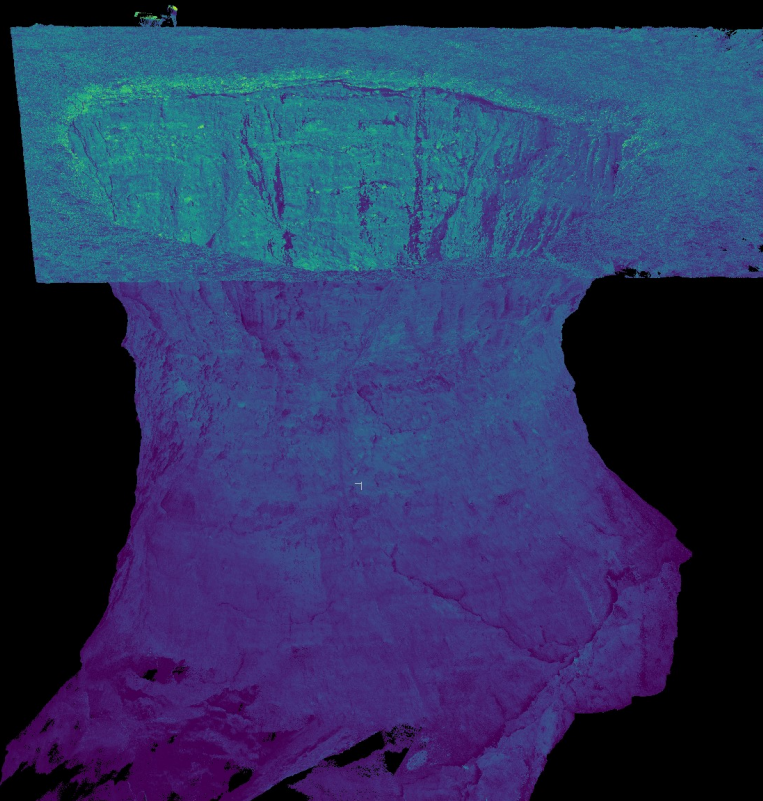
Conclusion



The *robotics*, *autonomy*, and *algorithms* necessary
for lunar pit modeling have been developed



The *viability* of our proposed mission has been
demonstrated using a terrestrial analog



We have proven that a *high-value, low-cost, near-term*
mission to explore a lunar pit is *realistic*

