Jet Propulsion Laboratory
California Institute of Technology

Exploring Mars in Augmented Reality

Lessons for Earth Science

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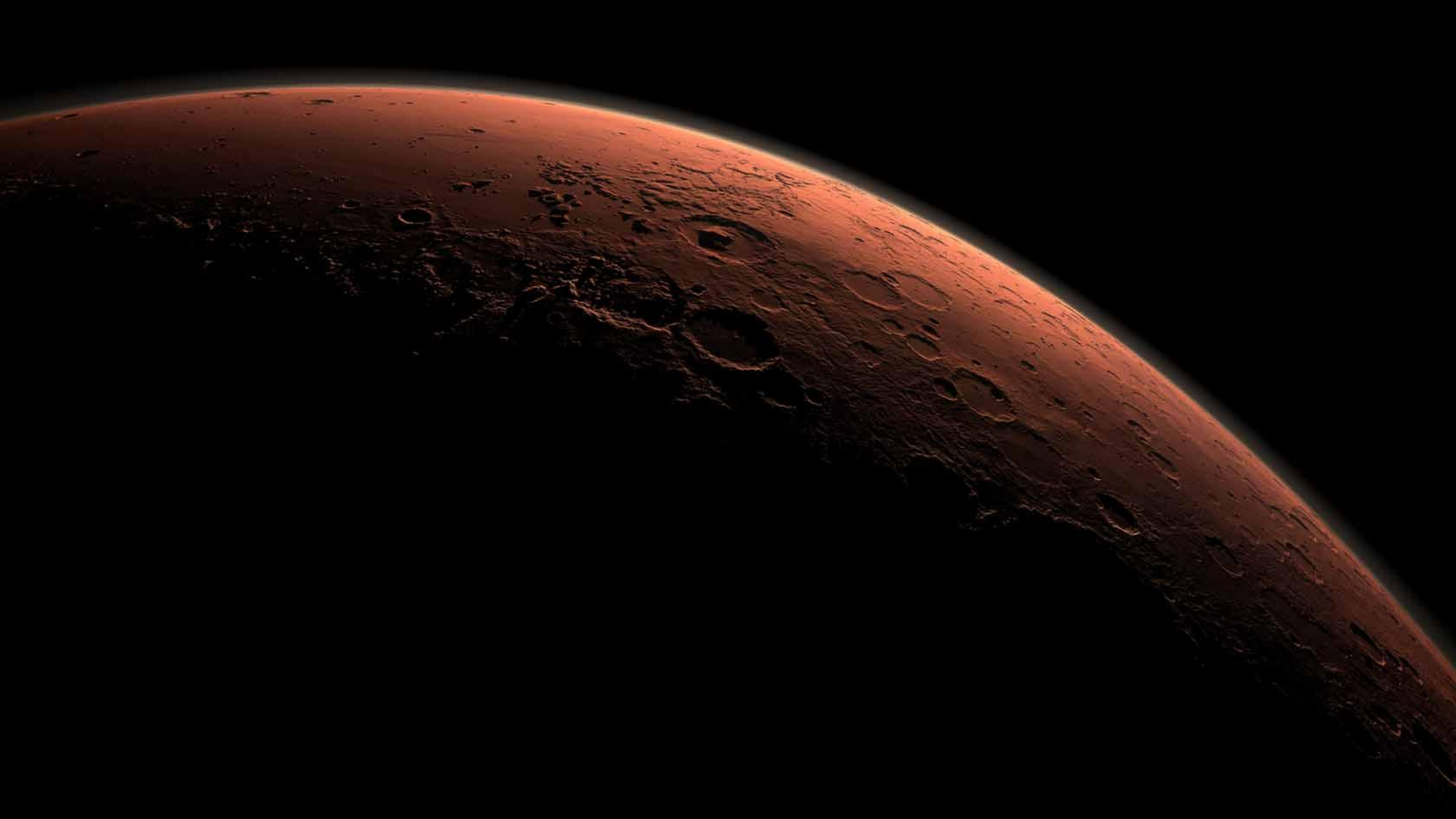
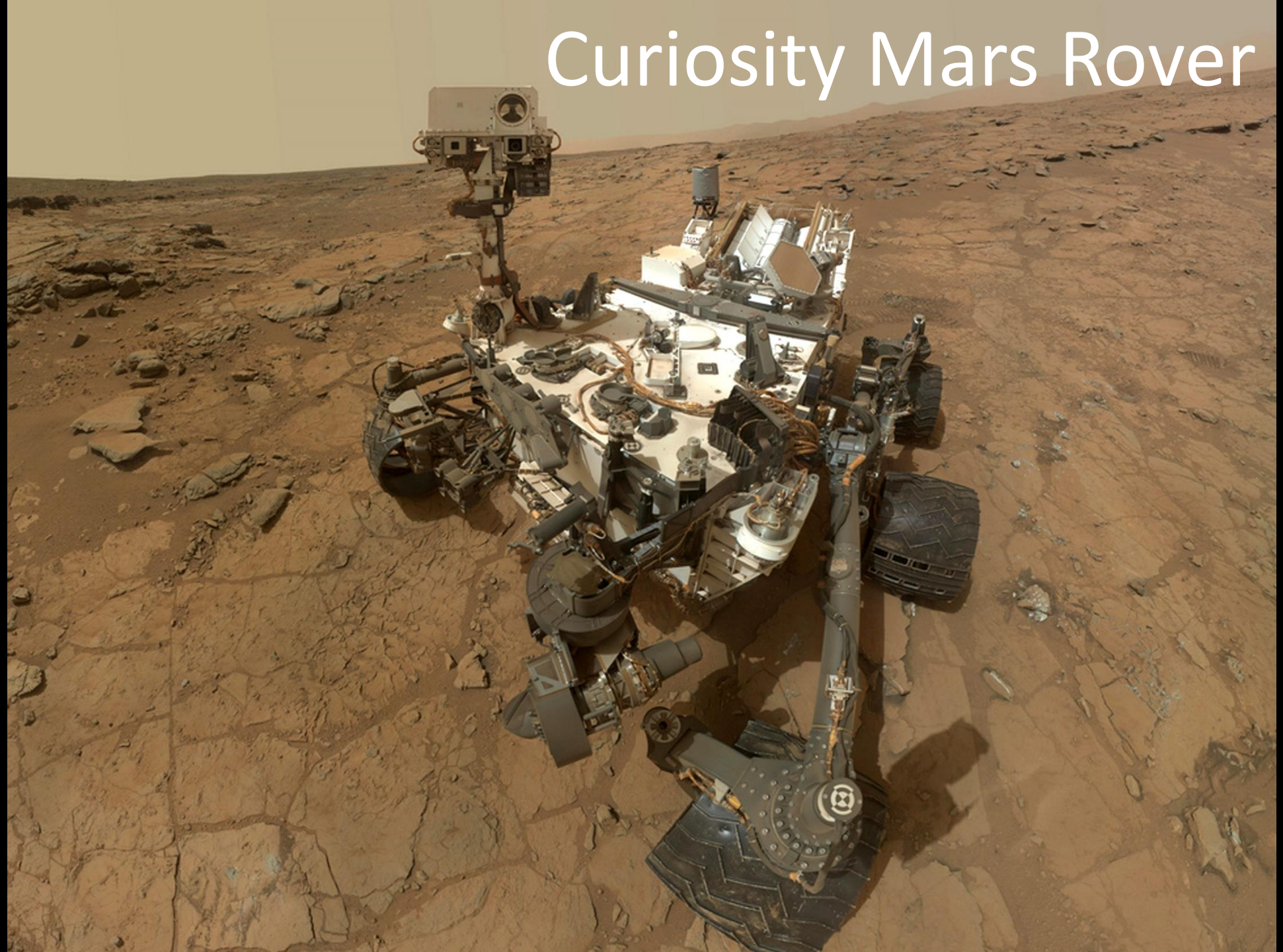
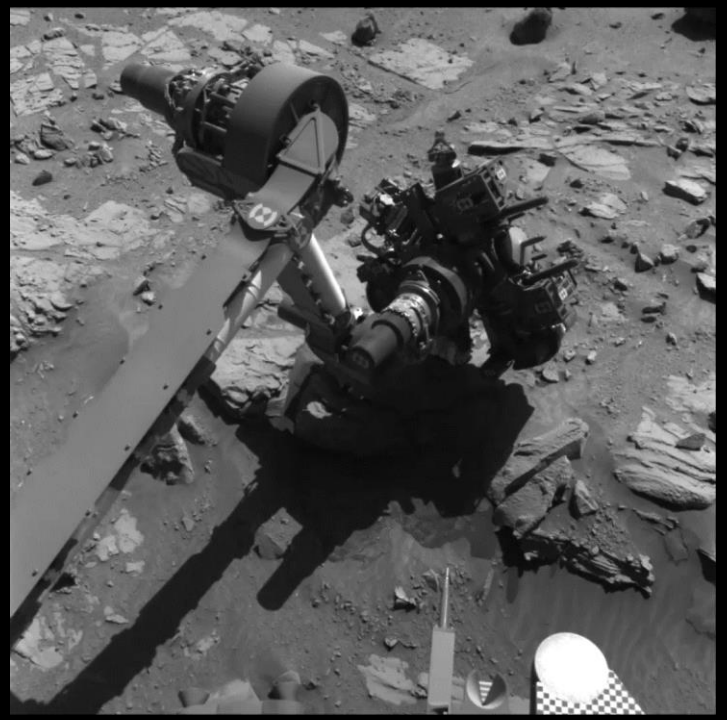
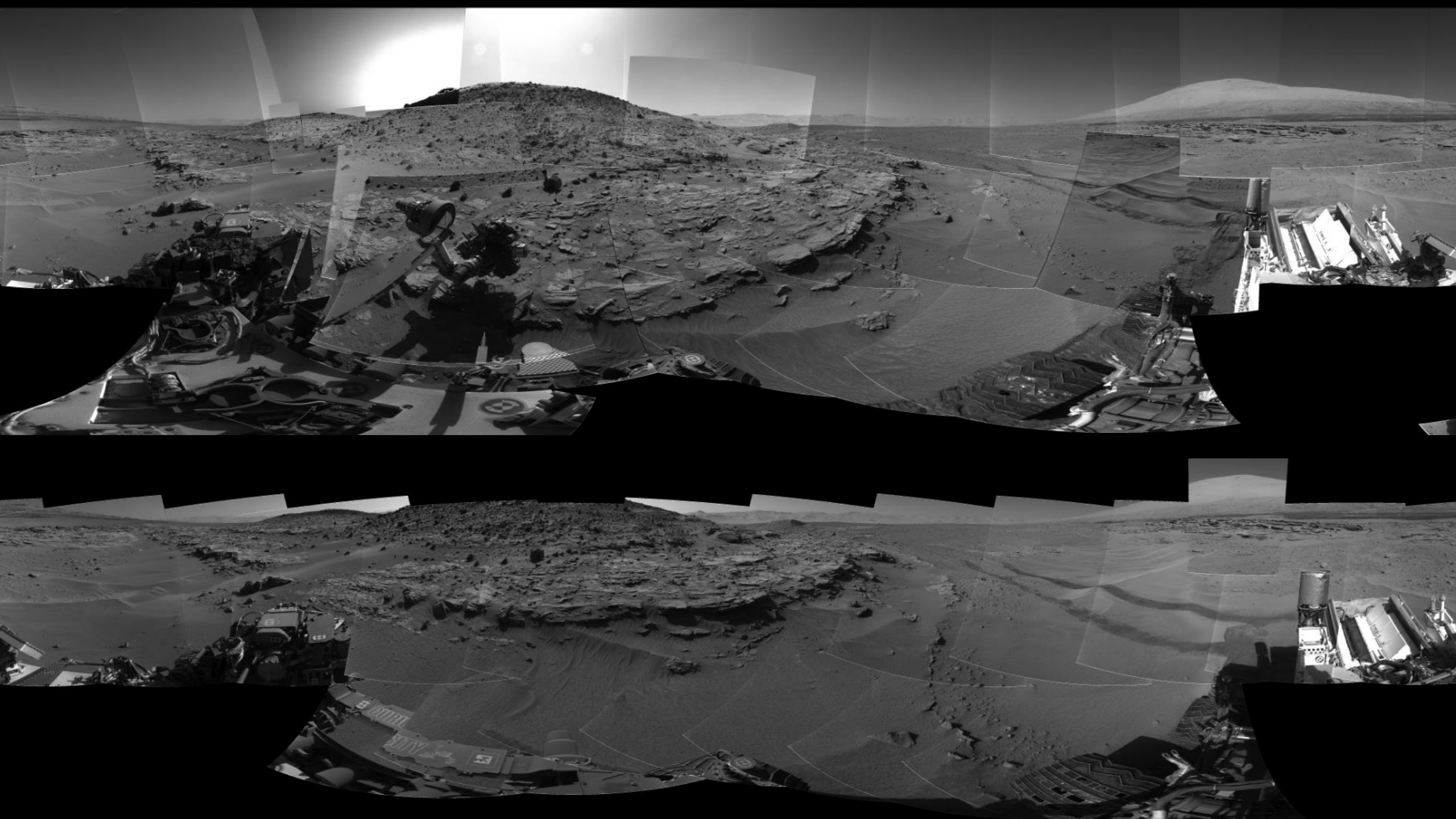


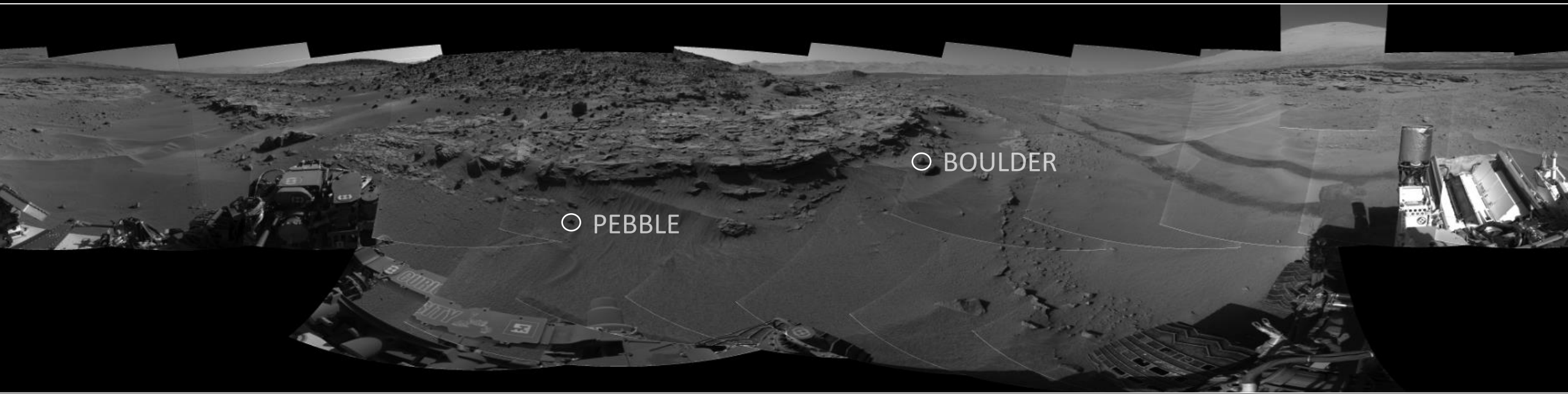
Curiosity Mars Rover

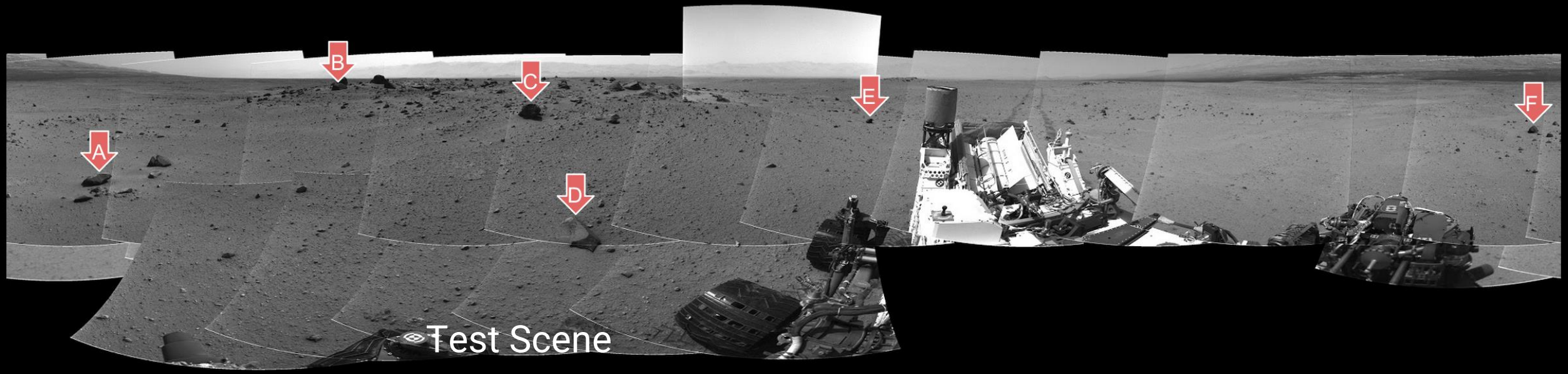


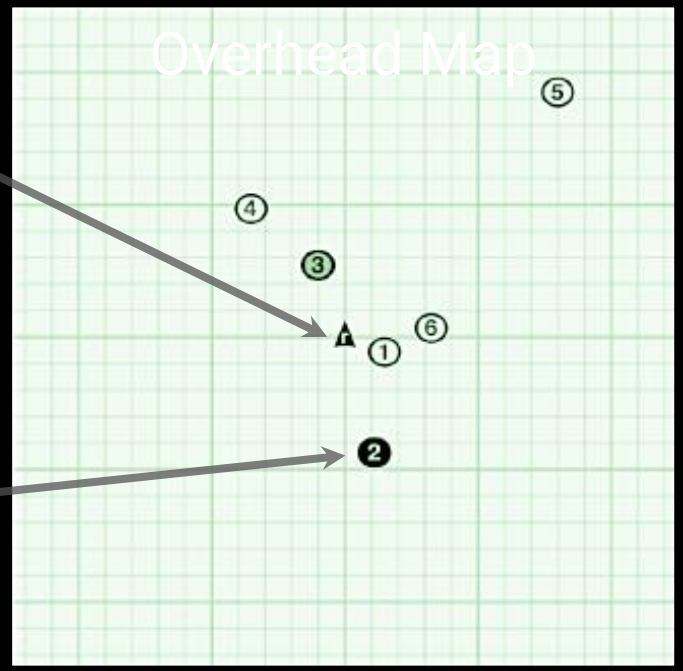




NORTH
SOUTH
STRAIGHT LINE


BOULDER
PEBBLE





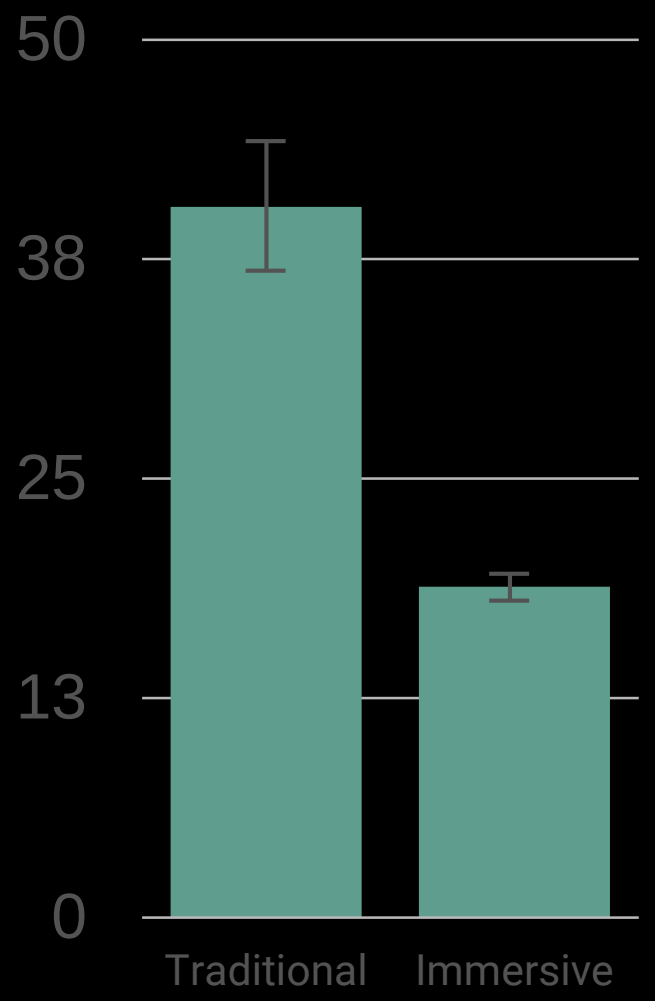
Rover Position

Fixed Point of Reference

The Task

While using the official mission tool or a prototype immersive system, produce an overhead map showing the locations of six objects in the vicinity of the Curiosity Mars rover.

Average accumulated distance error in meters



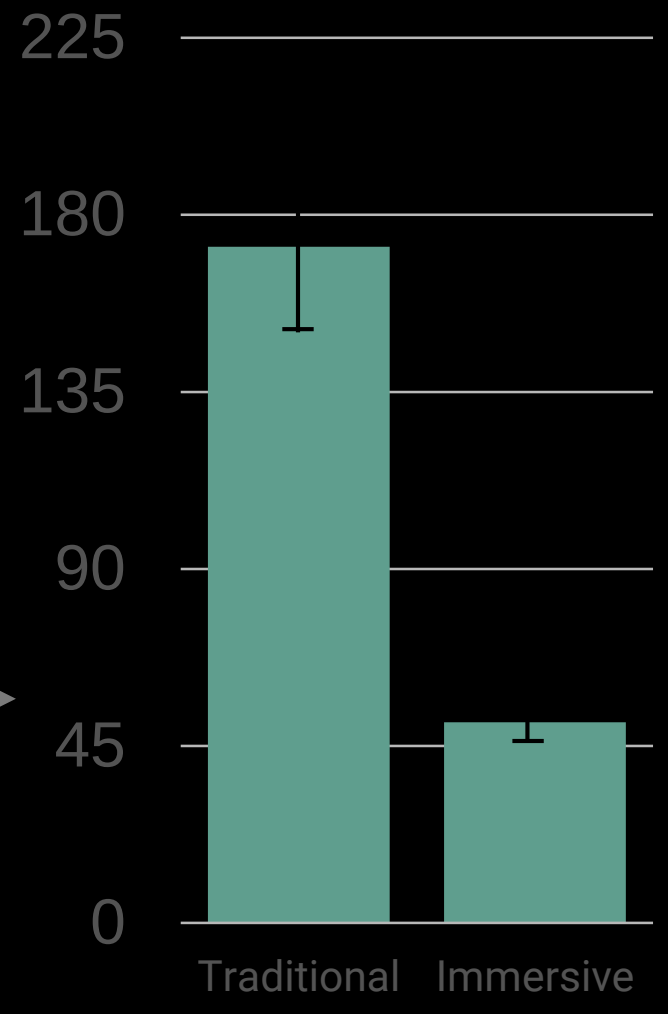
$t(17) = 2.91, p < 0.02$**

Using the immersive system...

scientists estimated distances more than twice as well

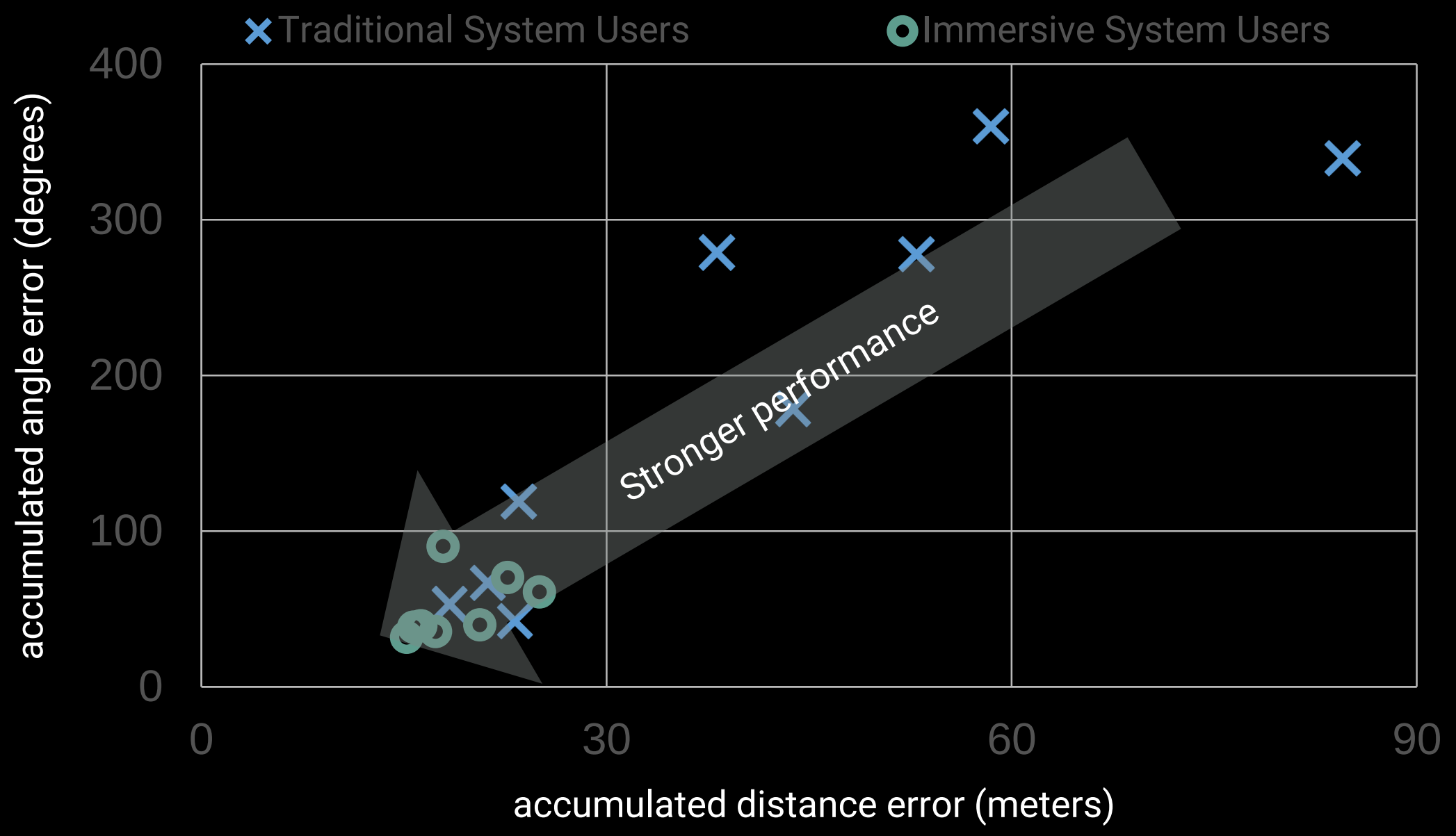
scientists estimated angles more than three times as well

Average accumulated angular error in degrees

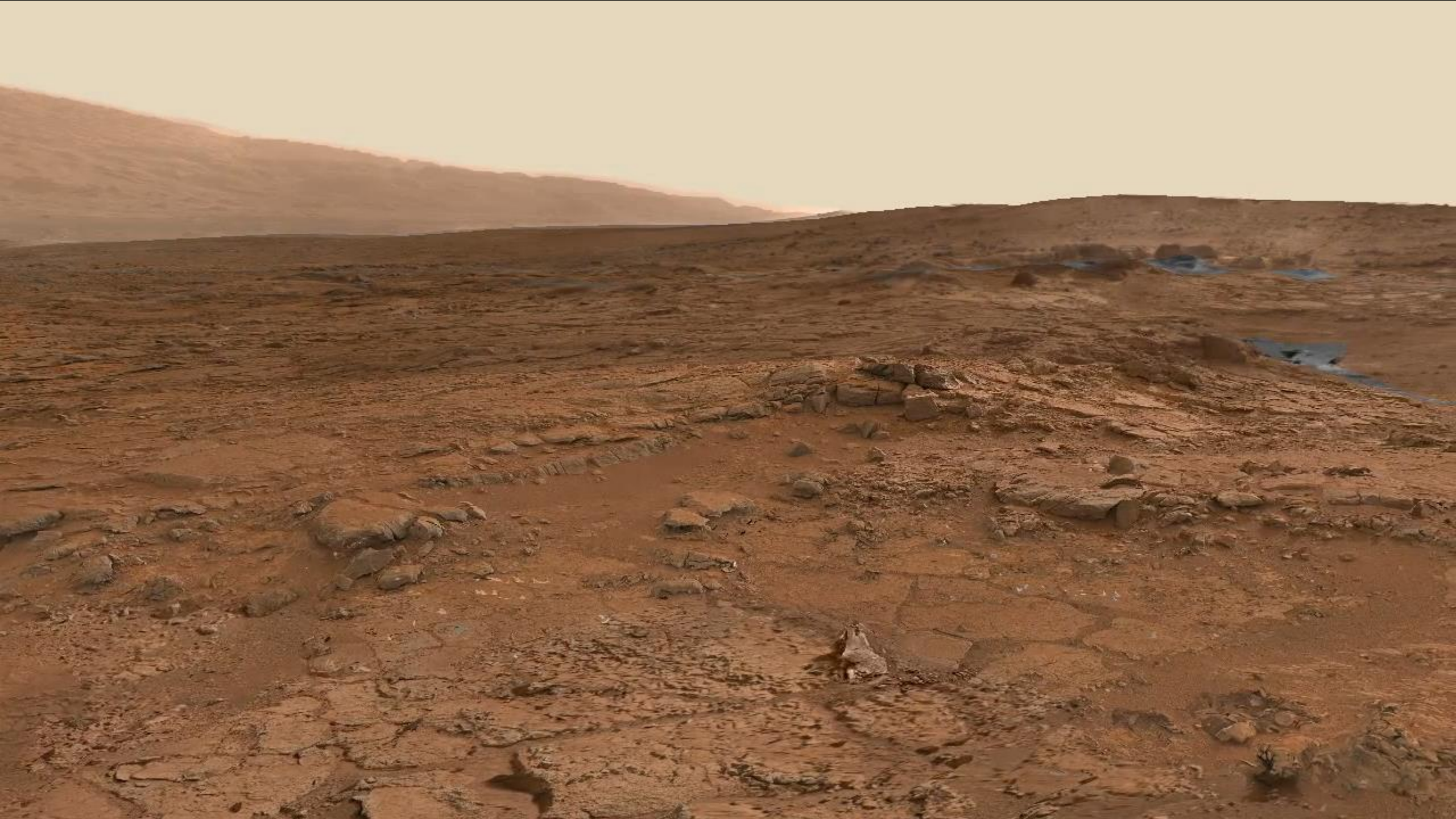


$t(17) = 3.27, p = 0.01$**

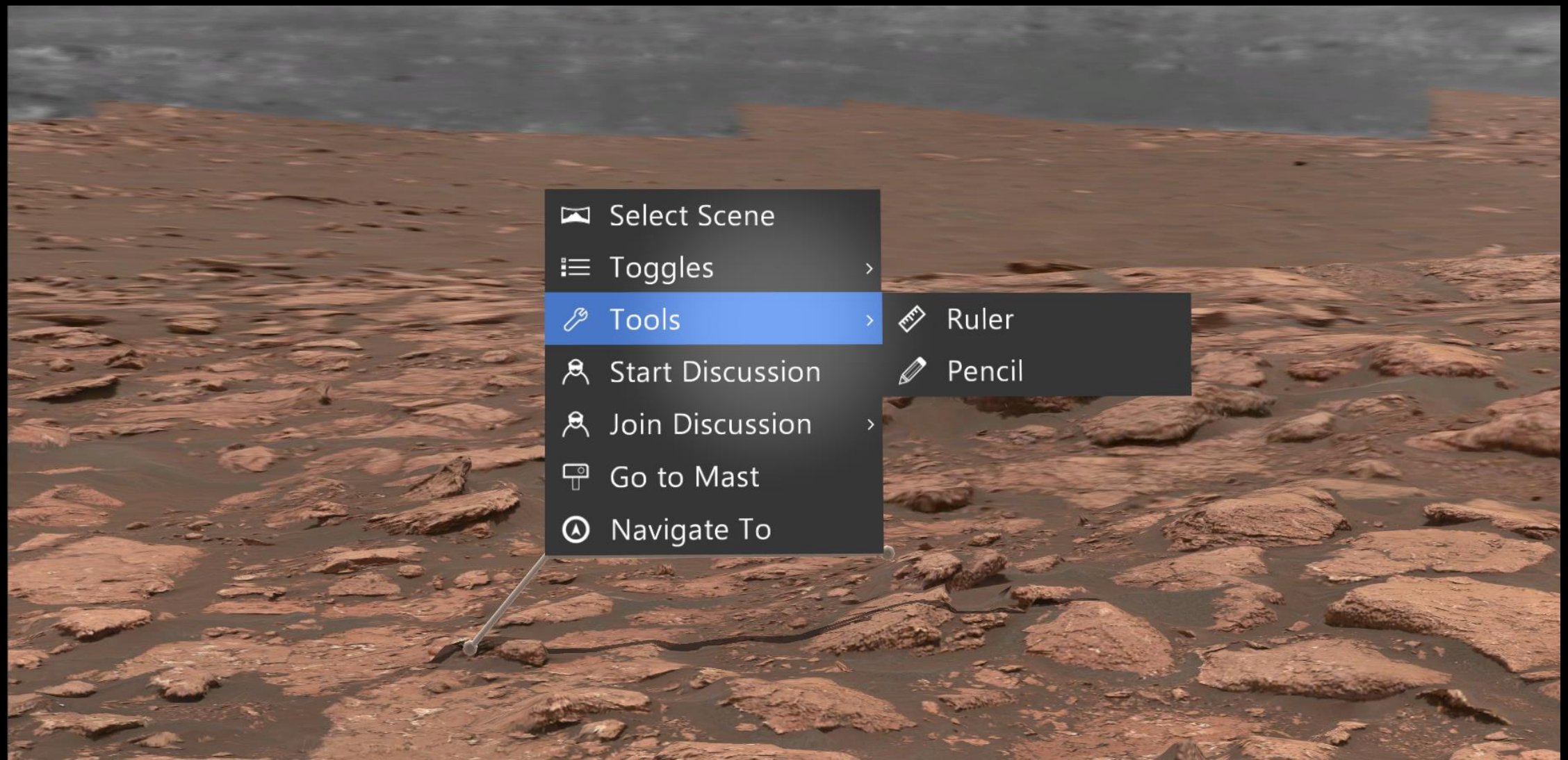
Accumulated Error Per User



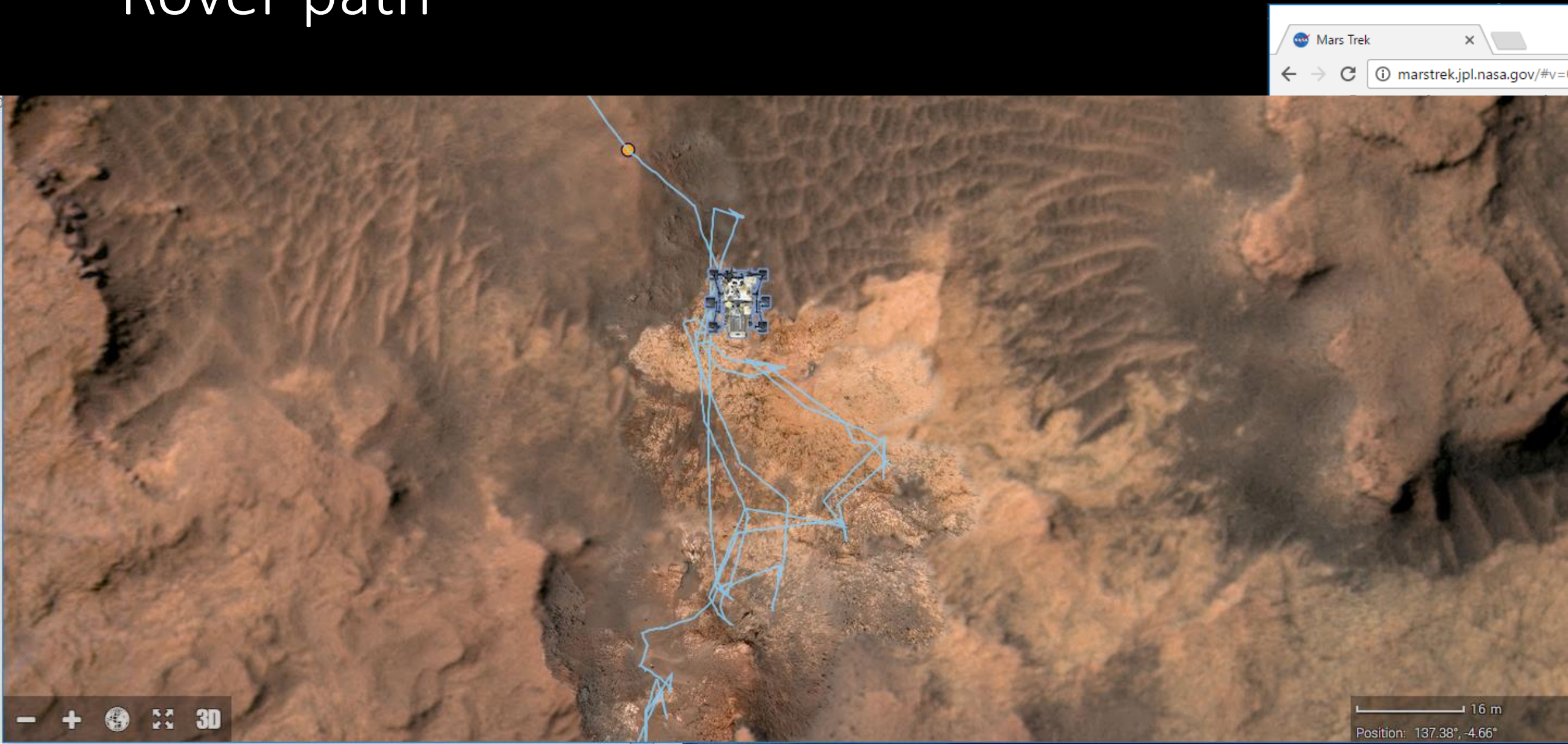
John
Enable scientists to work on Mars from their offices.
onsight



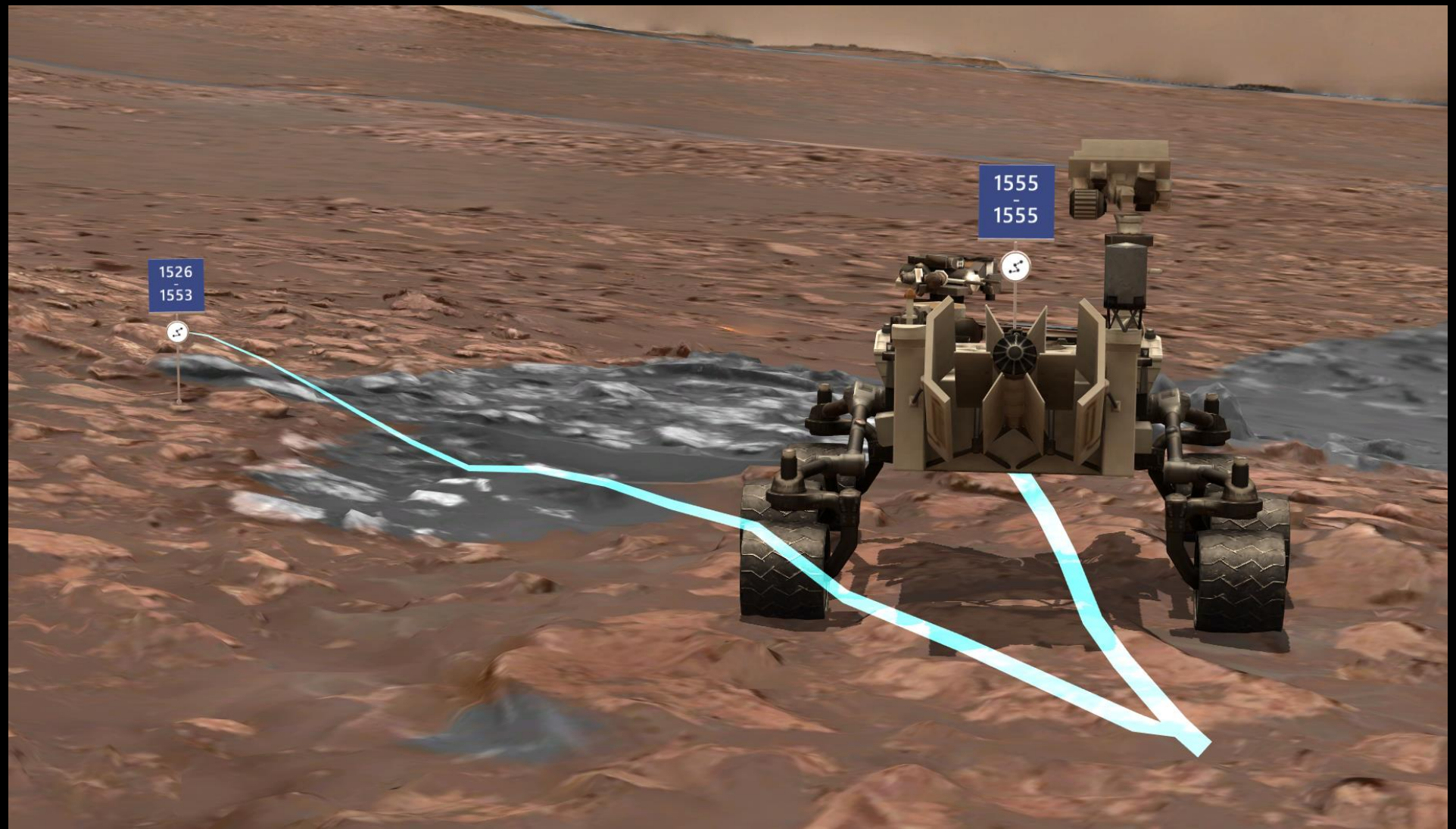
Menu system


Select Scene
Toggles
Tools
Start Discussion
Join Discussion
Go to Mast
Navigate To
Ruler
Pencil

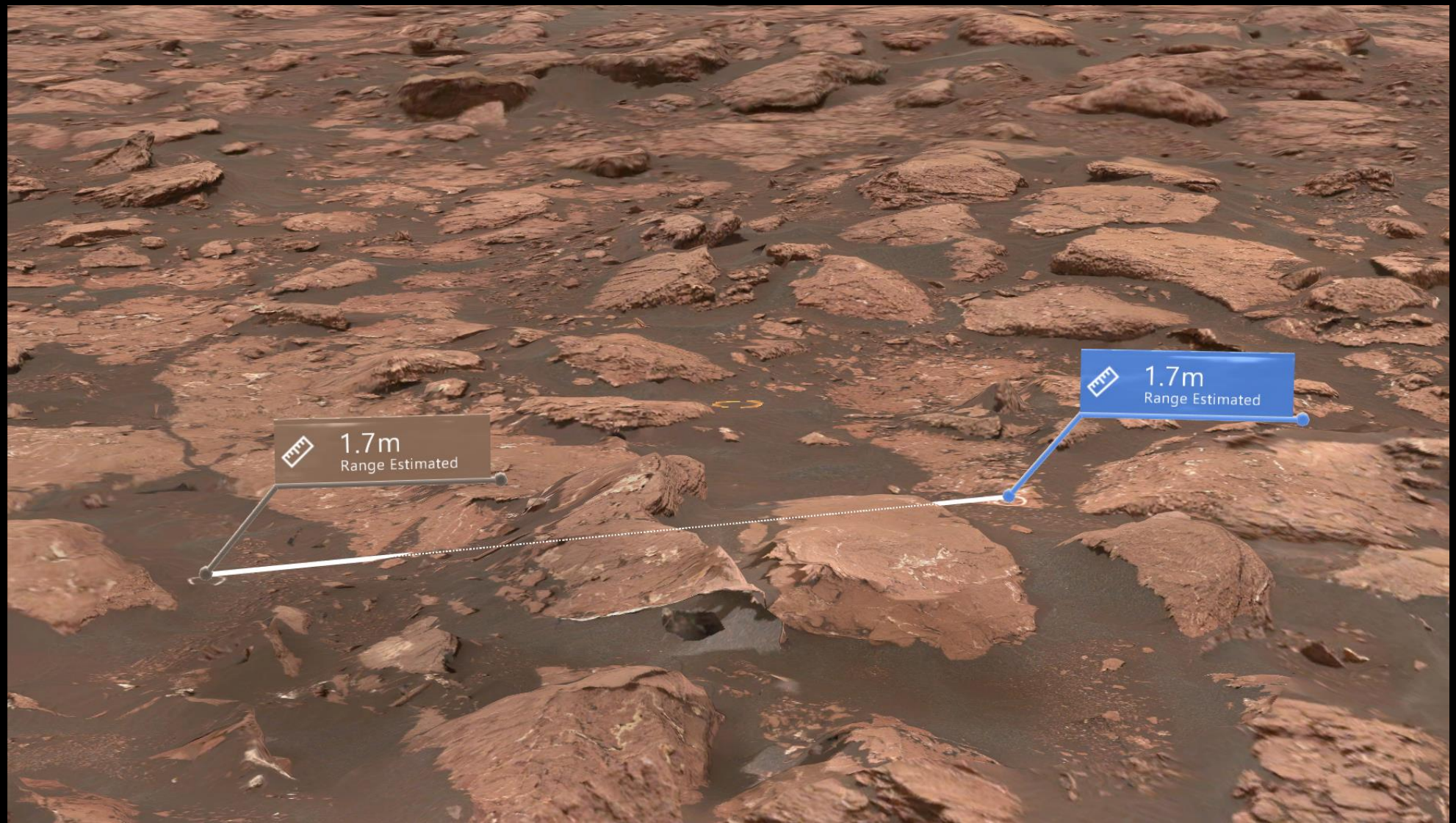
Rover path



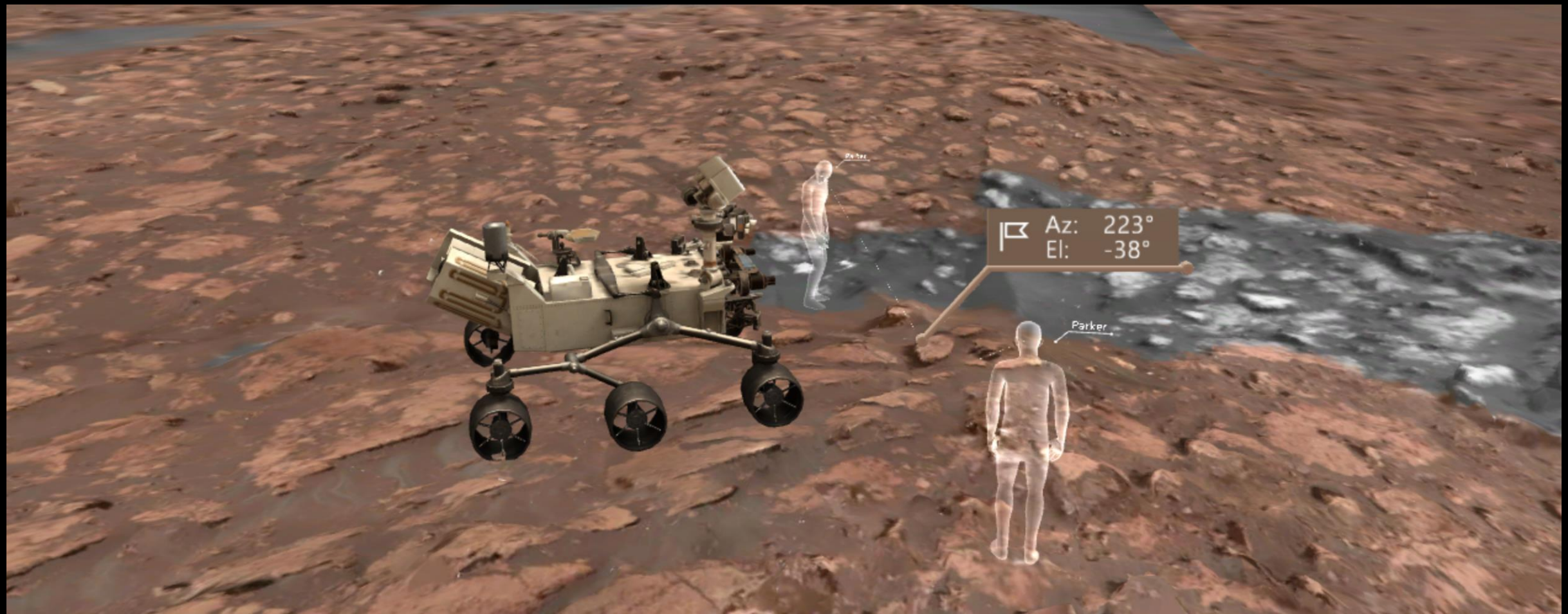
Rover path



Ruler



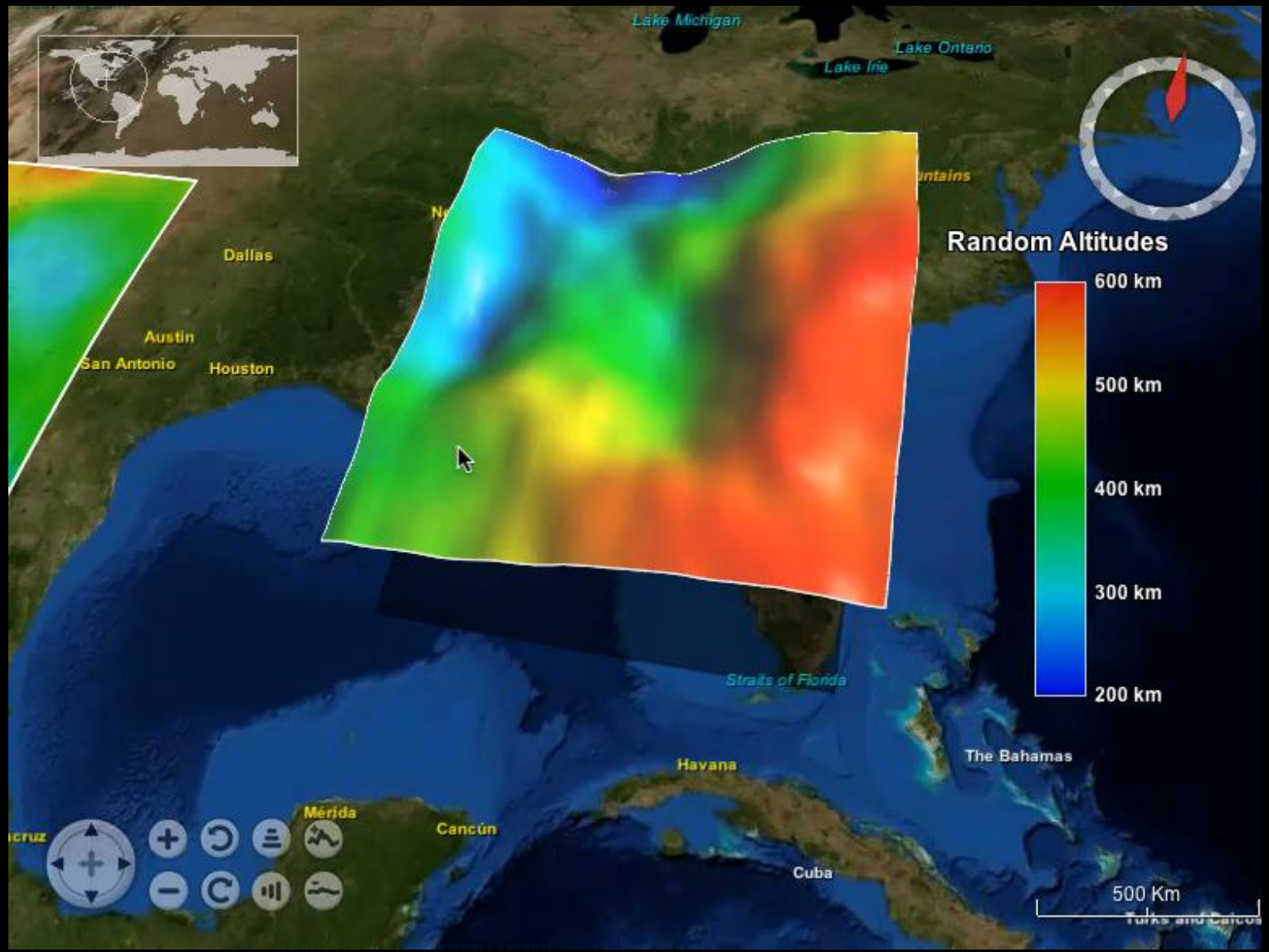
Multiuser



Back to Earth: Lessons Learned

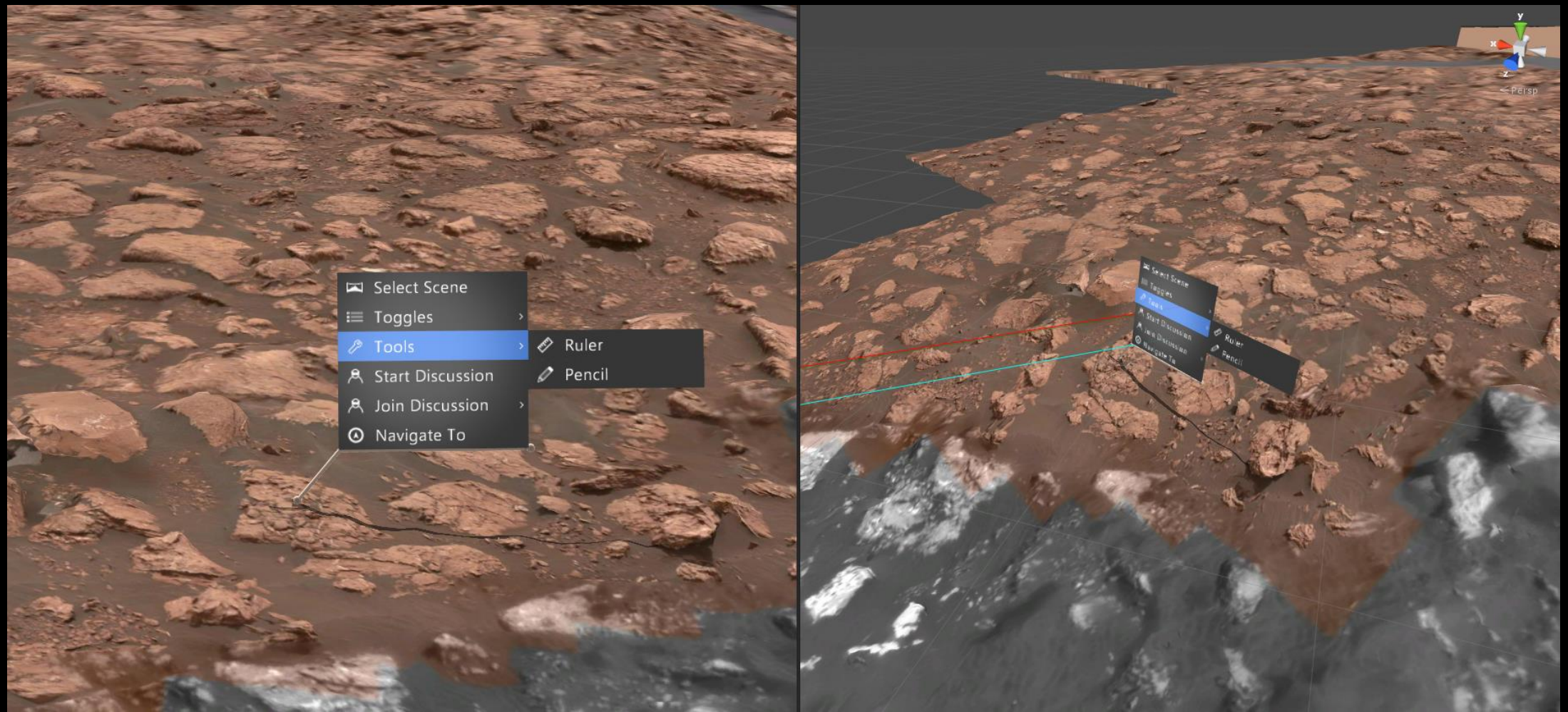
In VR, the user interface is 3D

Heads Up Display

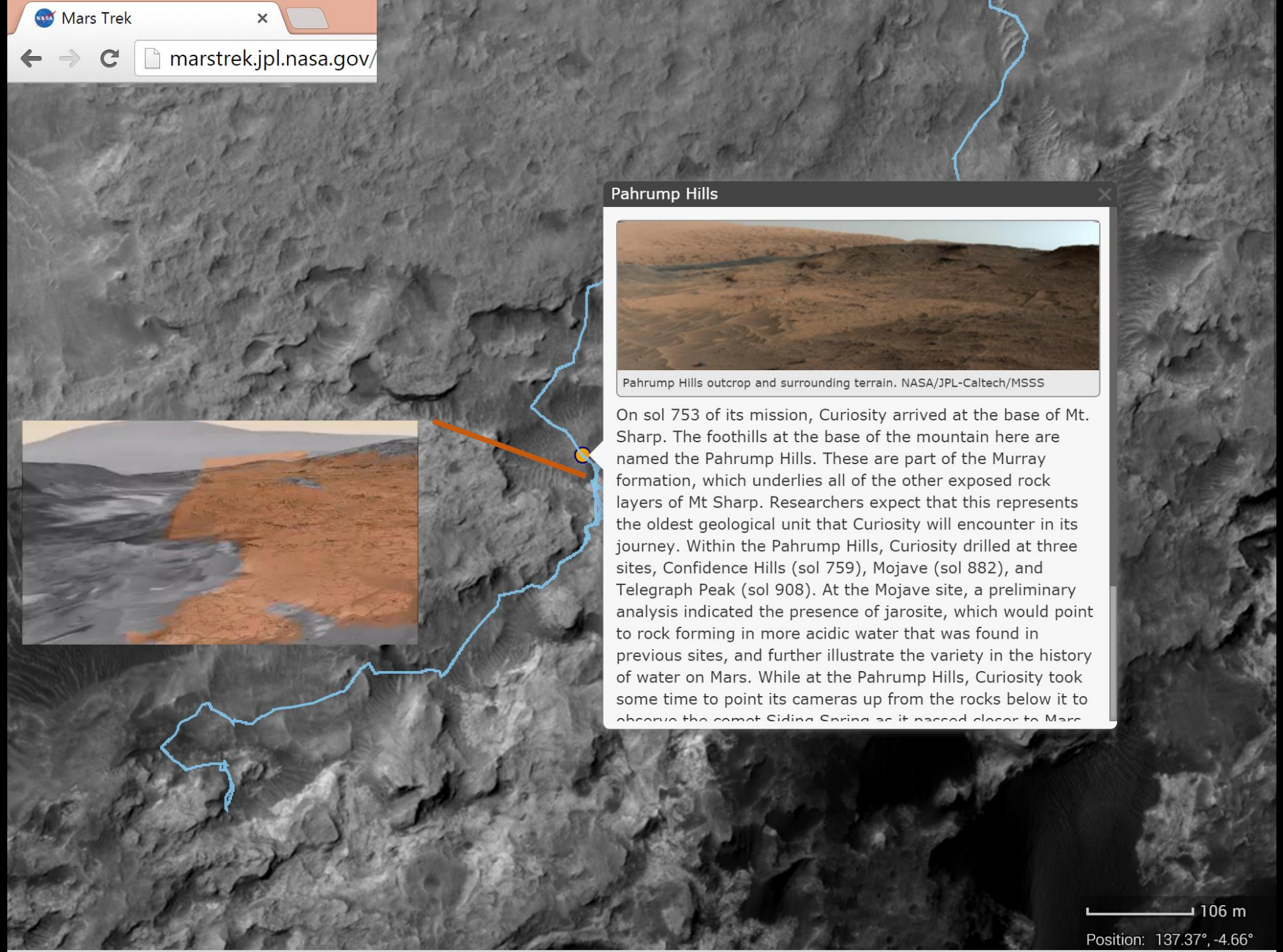


NASA World Wind

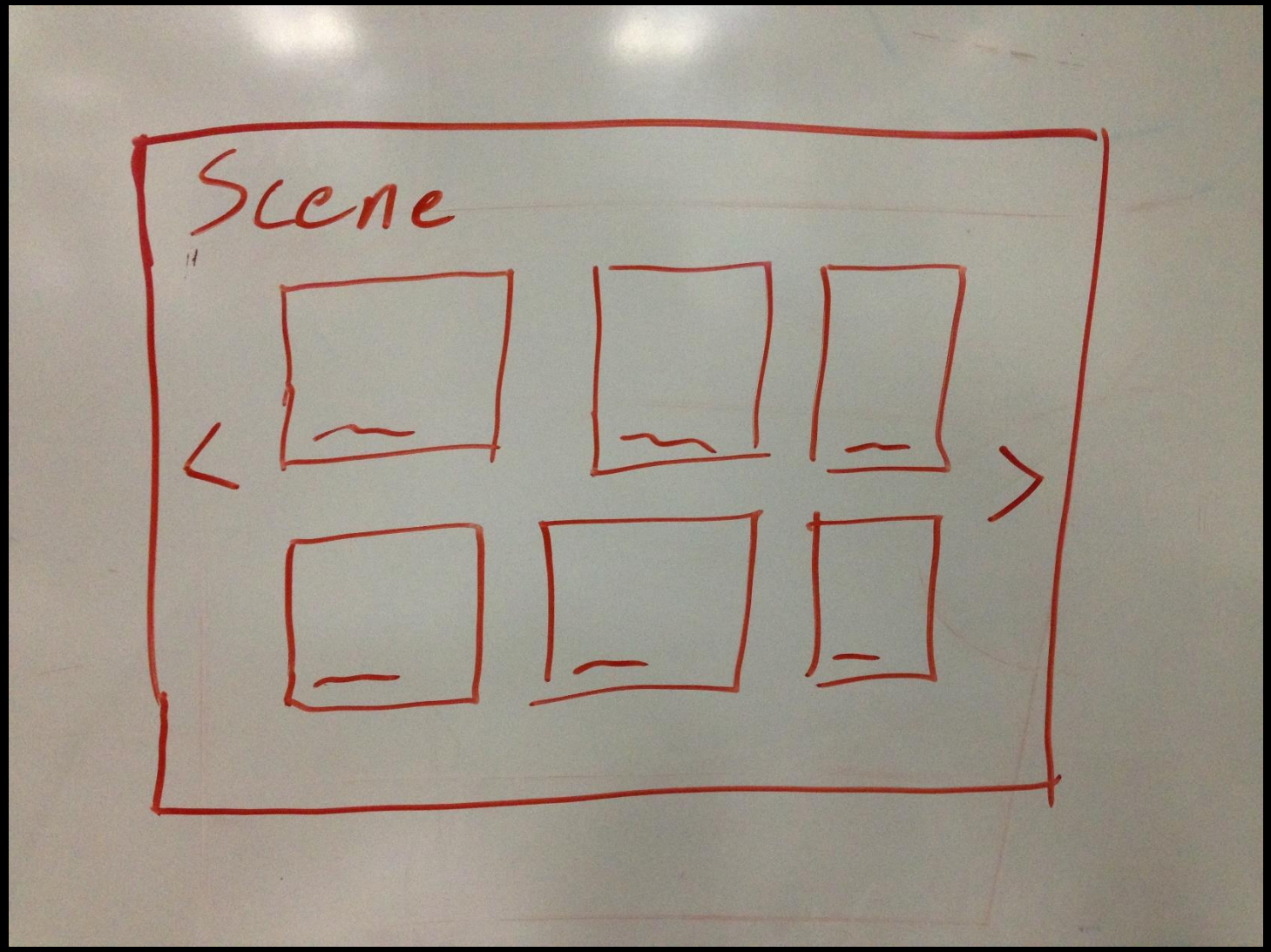
All UI is 3D


Select Scene
Toggles
Tools
Start Discussion
Join Discussion
Navigate To
Ruler
Pencil

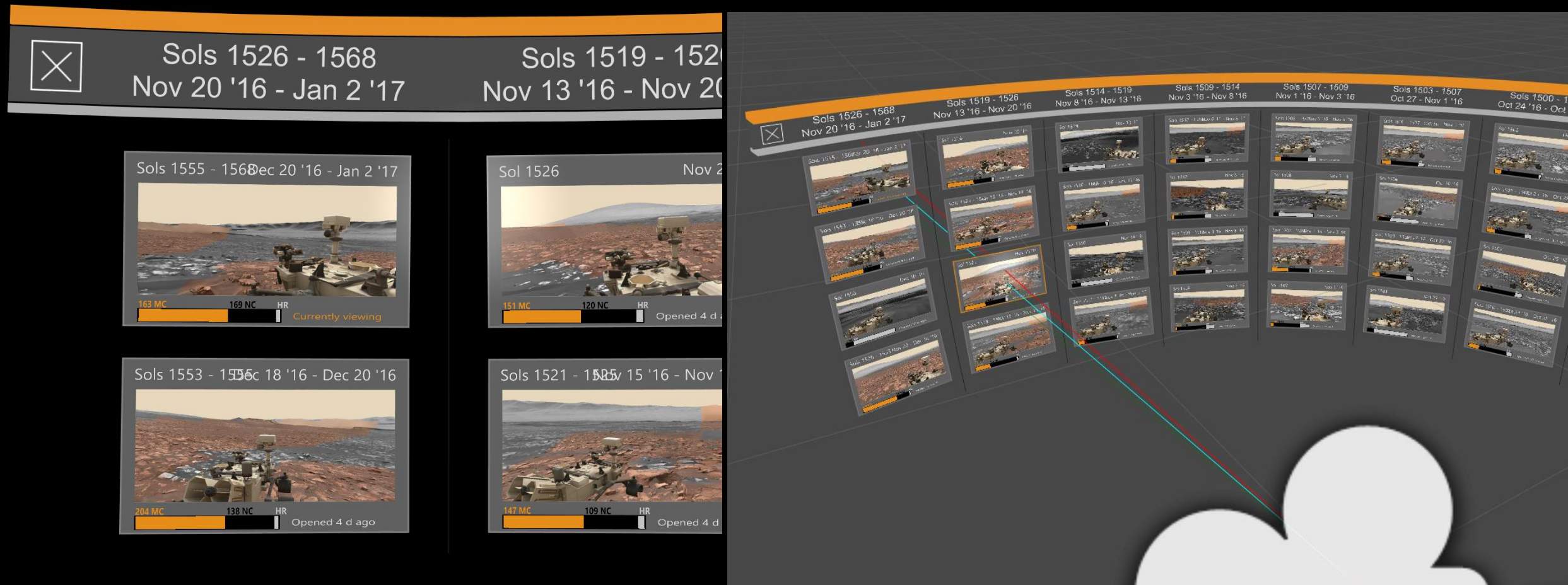
Break out of the screen!


Mars Trek
marstrek.jpl.nasa.gov/
Pahrump Hills
Pahrump Hills outcrop and surrounding terrain. NASA/JPL-Caltech/MSSS
On sol 753 of its mission, Curiosity arrived at the base of Mt. Sharp. The foothills at the base of the mountain here are named the Pahrump Hills. These are part of the Murray formation, which underlies all of the other exposed rock layers of Mt Sharp. Researchers expect that this represents the oldest geological unit that Curiosity will encounter in its journey. Within the Pahrump Hills, Curiosity drilled at three sites, Confidence Hills (sol 759), Mojave (sol 882), and Telegraph Peak (sol 908). At the Mojave site, a preliminary analysis indicated the presence of jarosite, which would point to rock forming in more acidic water that was found in previous sites, and further illustrate the variety in the history of water on Mars. While at the Pahrump Hills, Curiosity took some time to point its cameras up from the rocks below it to
106 m
Position: 137.37°, -4.66°

Break out of the screen



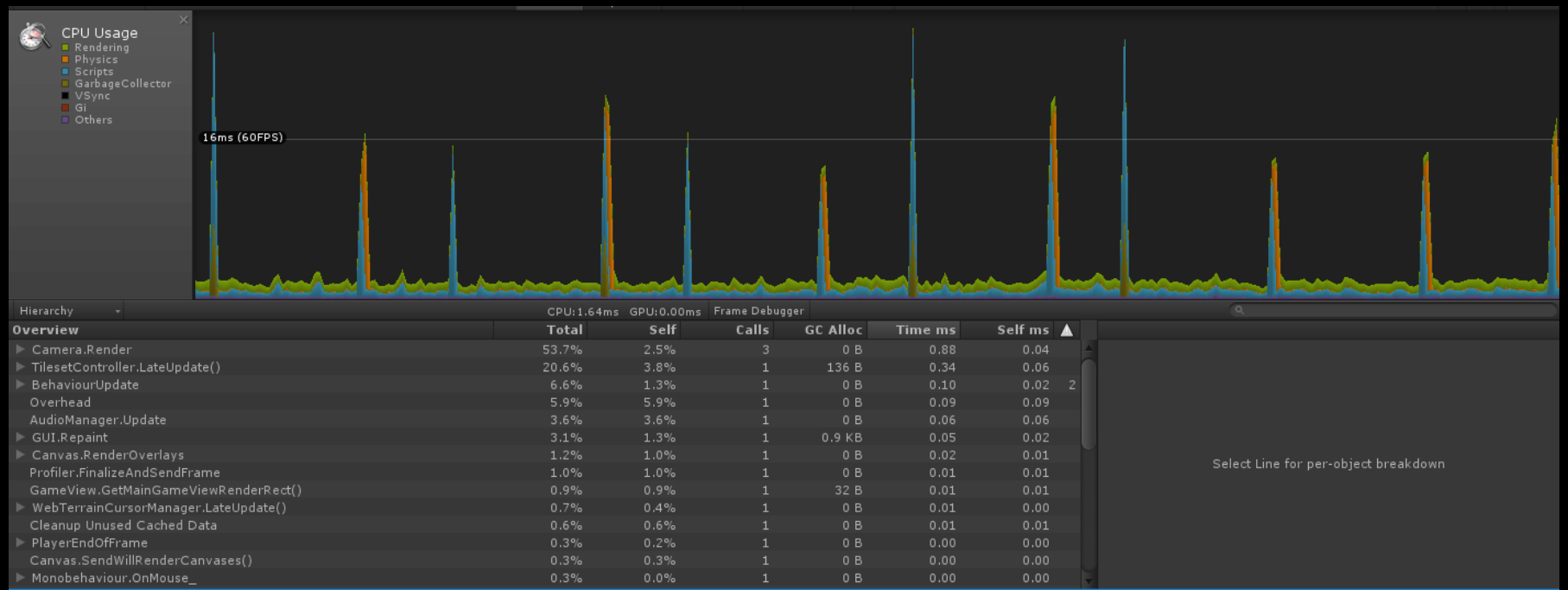
Break out of the screen



Performance matters!

Performance matters!

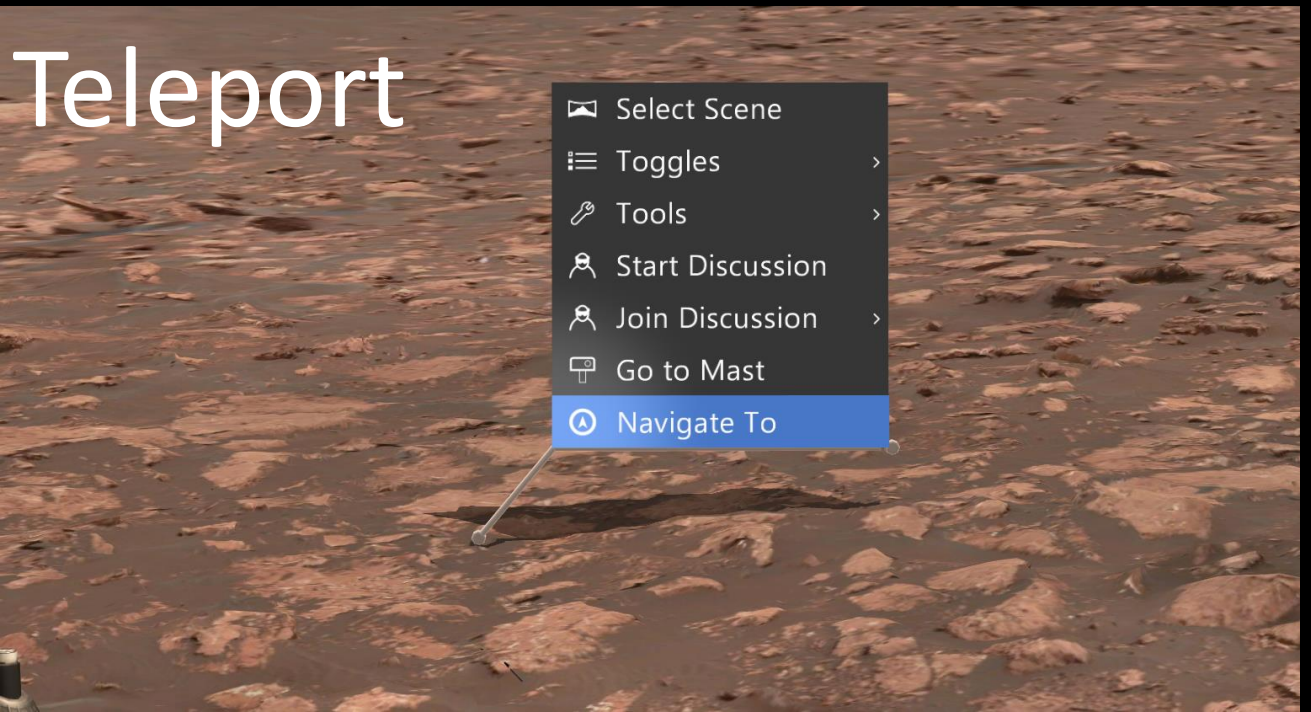
- Bad frame rate can cause nausea
- Demo on best hardware possible
- Aim for 60+ FPS for AR, 90+ FPS for VR

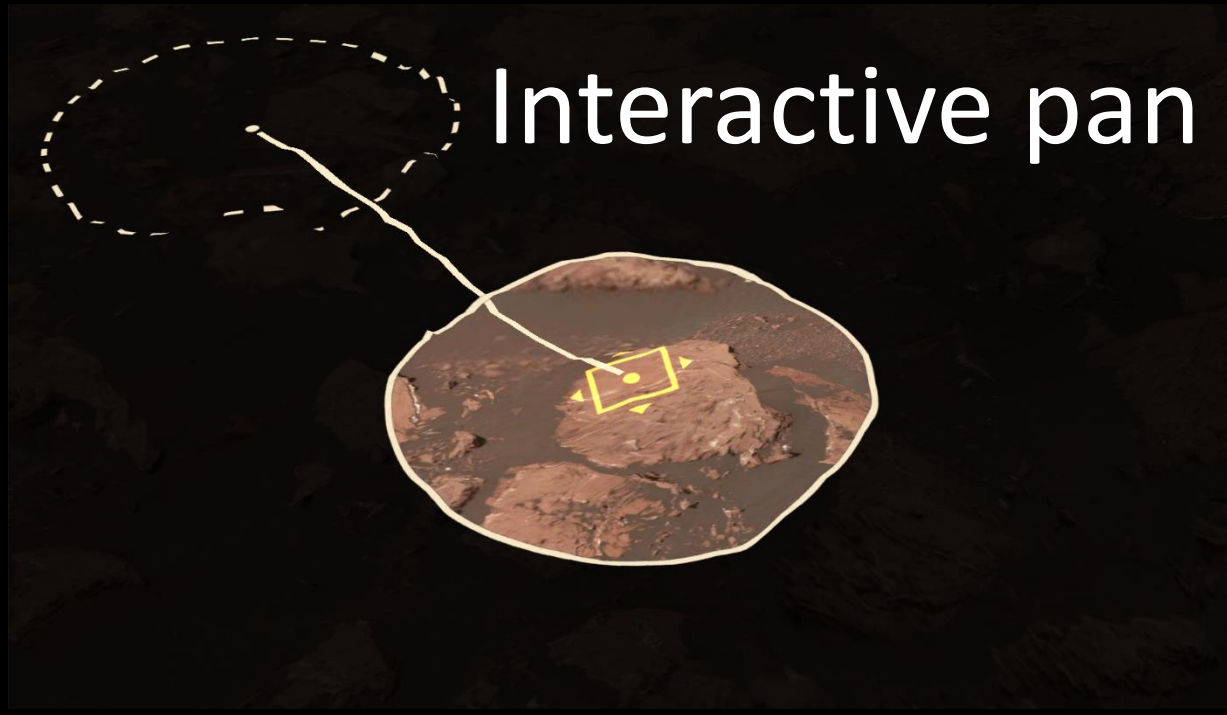


Be careful with navigation

Navigation

Camera motion that doesn’t match head motion can cause nausea





Strengths of VR/AR

- Immersion
- Sense of scale
- See data in true 3D
- Intuitive camera control: “Just move your head”
- Shared spatial context between users

Challenges of VR/AR

- Motion sickness - watch frame rate
- Controllers are not standard
- Visualization and UI standards still emerging
- New technology – adoption challenges

These are solvable!

Thank you!

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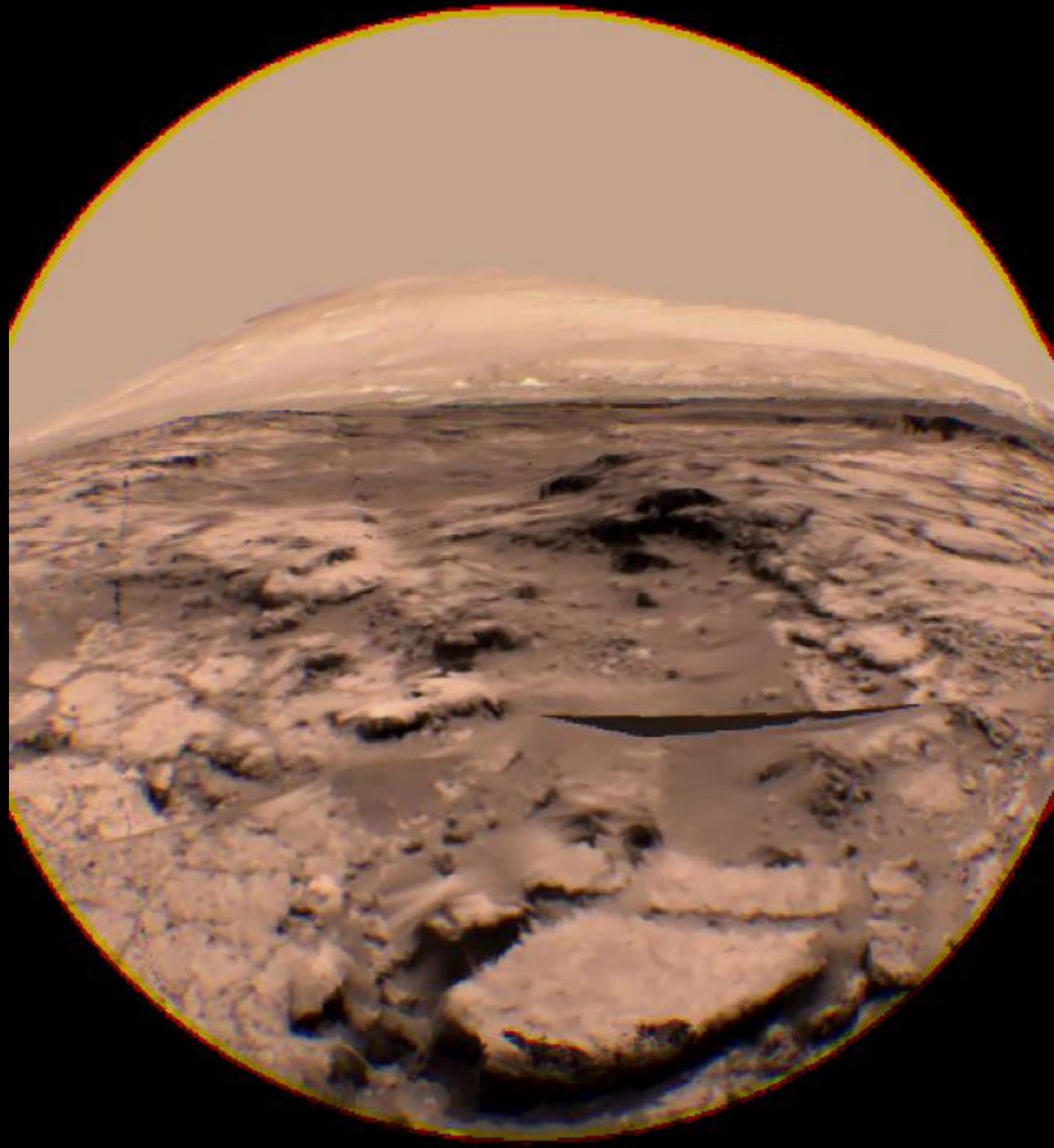
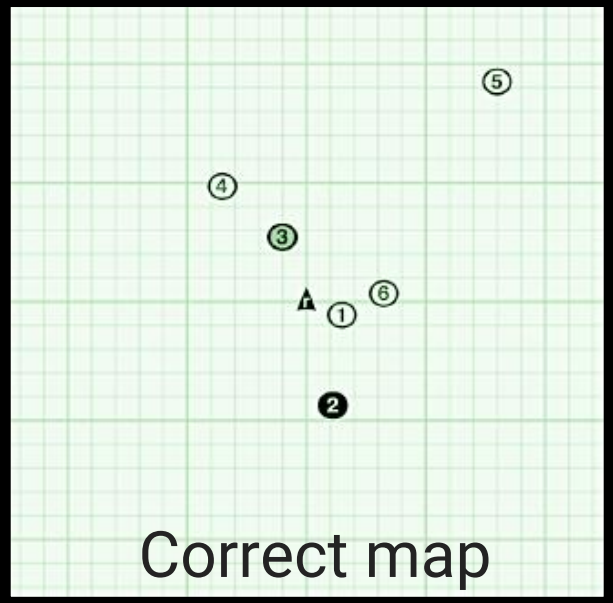
Jet Propulsion Laboratory, California Institute of Technology

Why VR/AR?

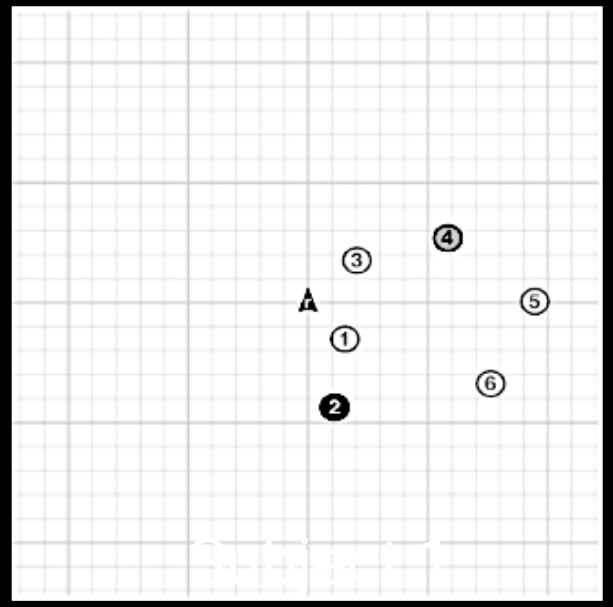
- Spatial data in true 3D
- Render at 1:1 scale
- Shared spatial context
- Explore the way humans are meant to explore



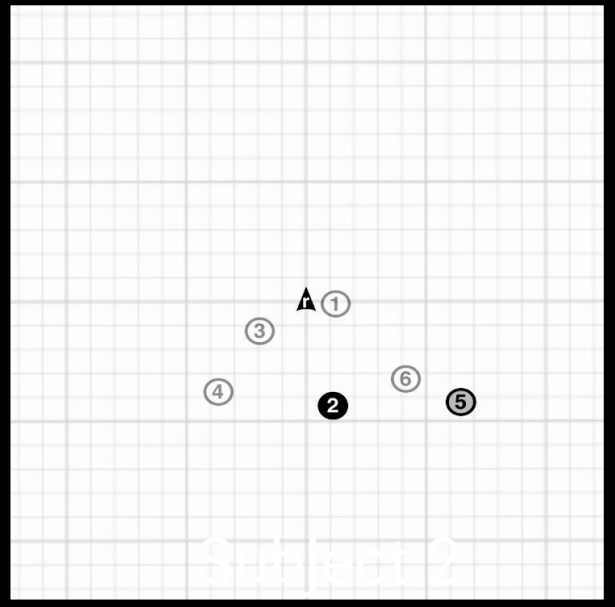
Maps produced by the last three participants when using the official mission tool.



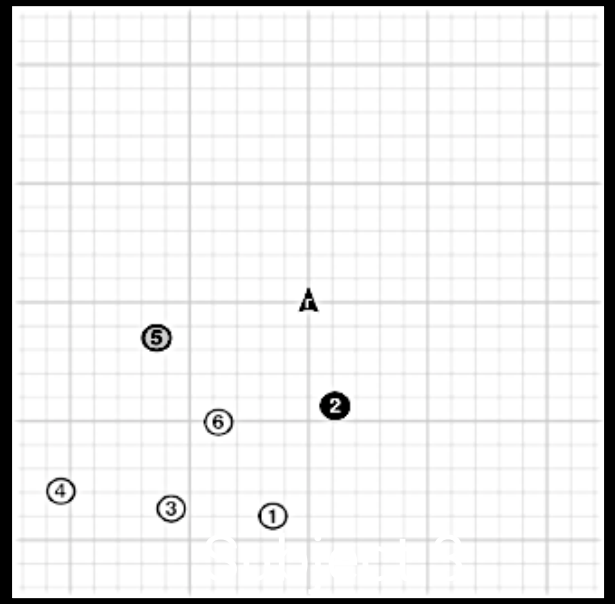
Correct map



Subject 1

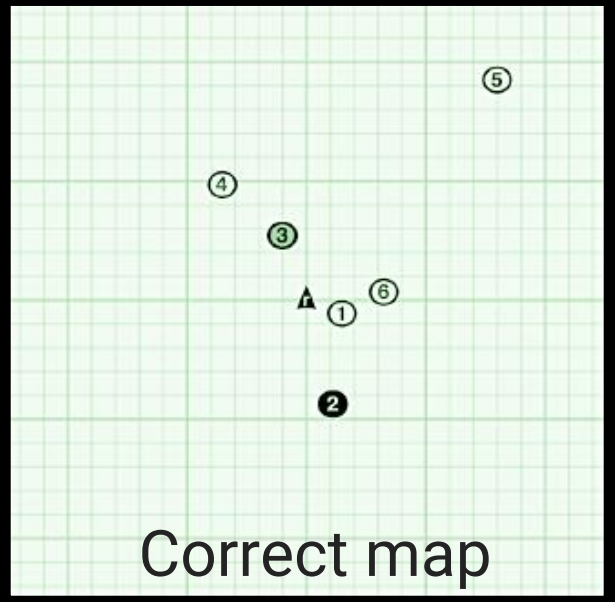


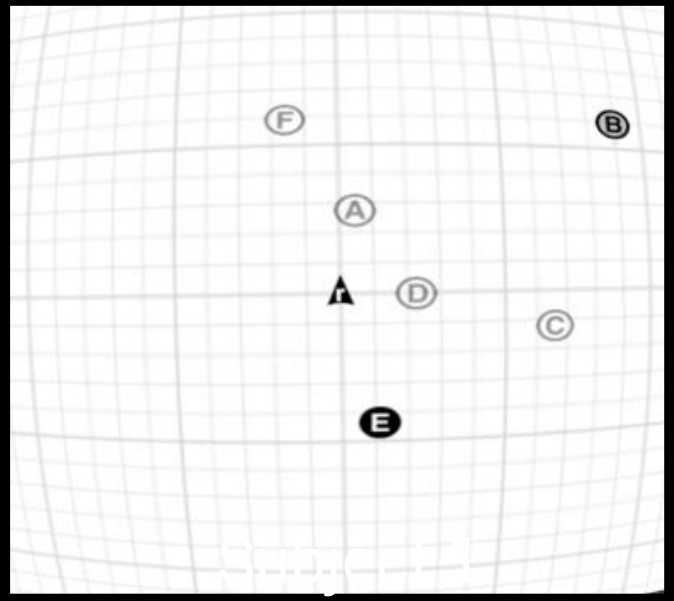
Subject 2

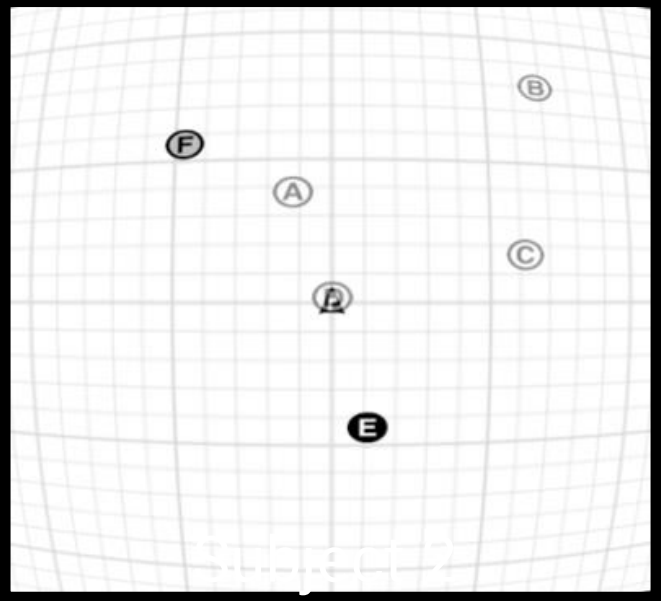


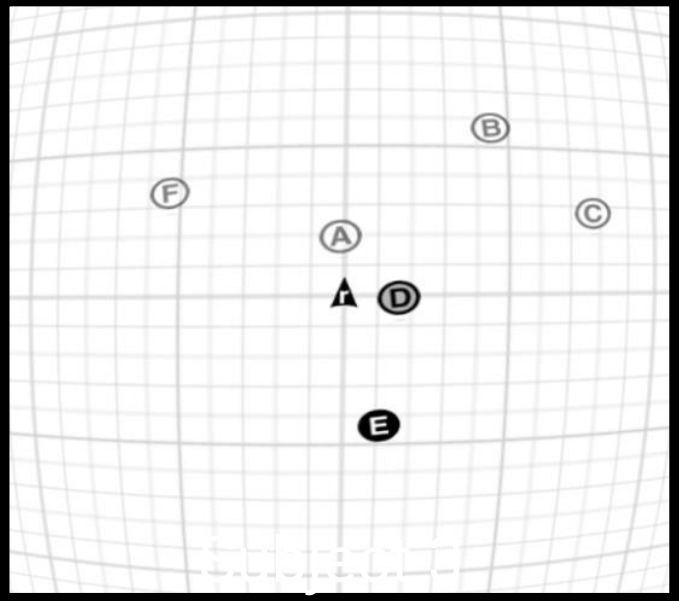
Subject 3

Maps produced by the same three participants when using the prototype immersive system.

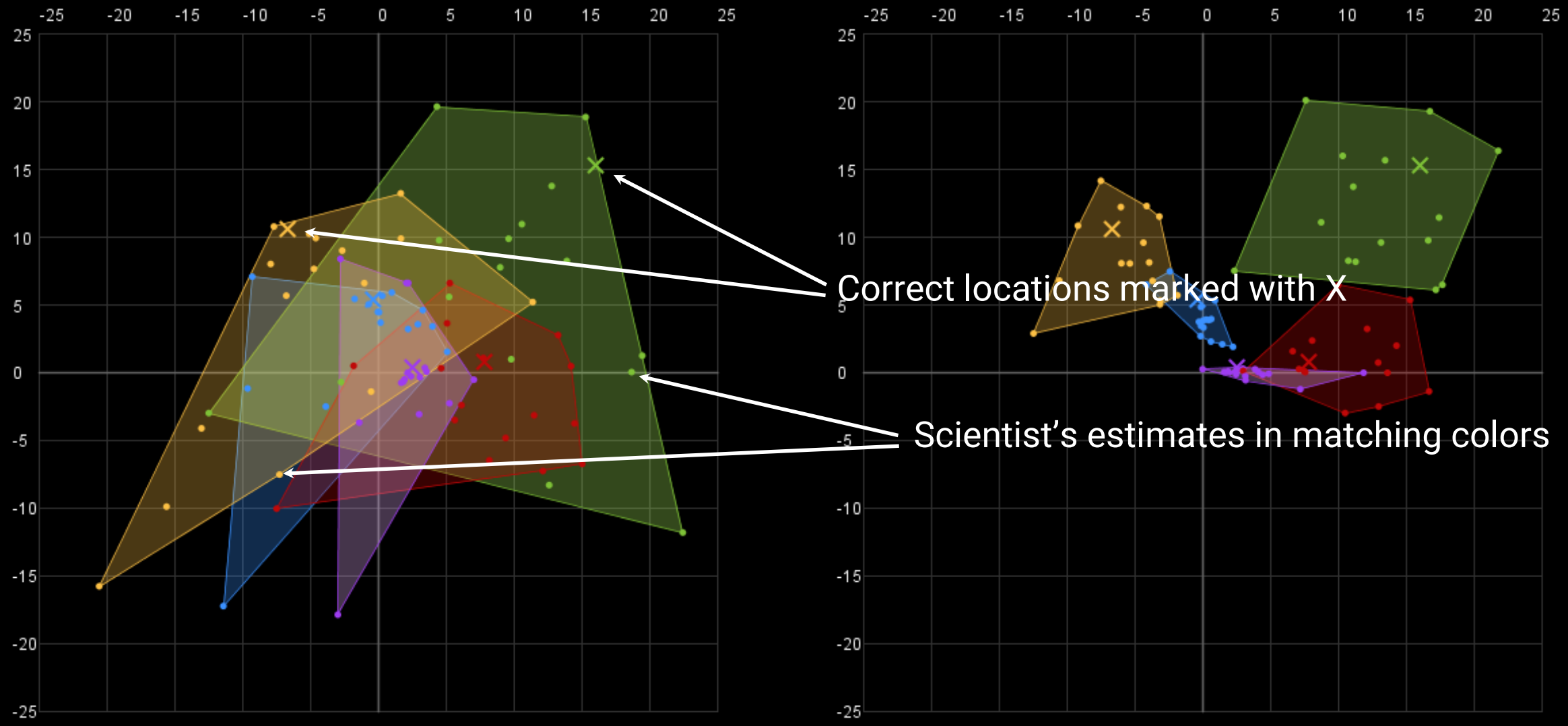








spherical distortion due to immersive system rendering, not visible to particip



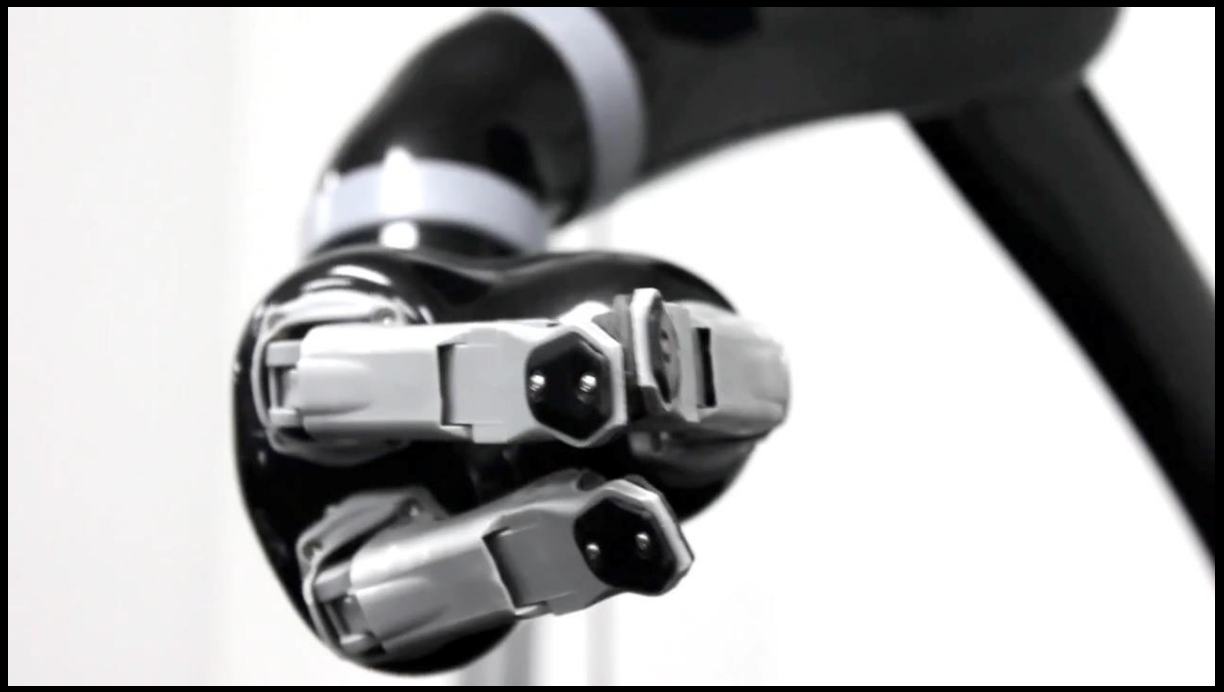
Official Mission Tool

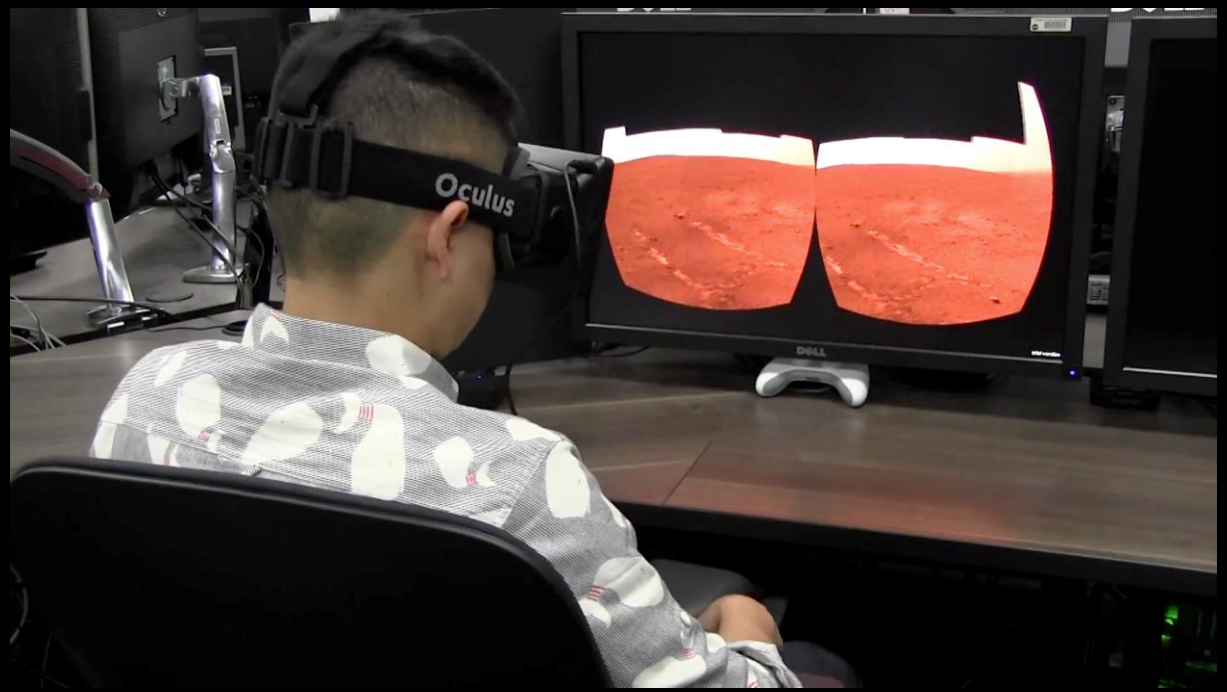
Prototype Immersive System

8 out of 17 participants thought they had performed equally well with both systems.

OPSLAB

DRIVING WITH
TIME DELAY




Oculus

Microsoft HoloLens