2013 IEEE ICRA Planetary Robotics Workshop
Karlsruhe, Germany, May 10th, 2013

Development and Field Testing of MoonRaker, a Four-Wheel Rover in Minimal Design

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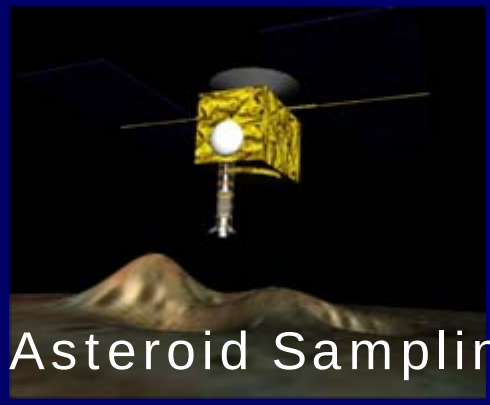
http://www.astro.mech.tohoku.ac.jp/home-e.html

Free-Flying Space Robot

Robotic Systems on ISS

The SPACE ROBOTICS Lab.

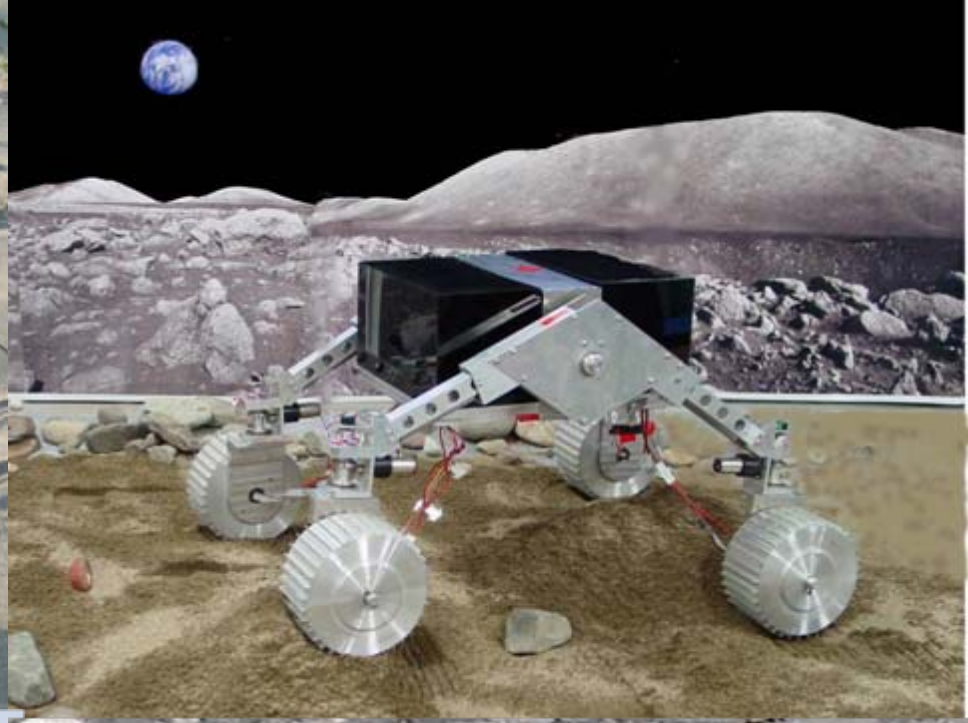
Planetary Exploration Rovers



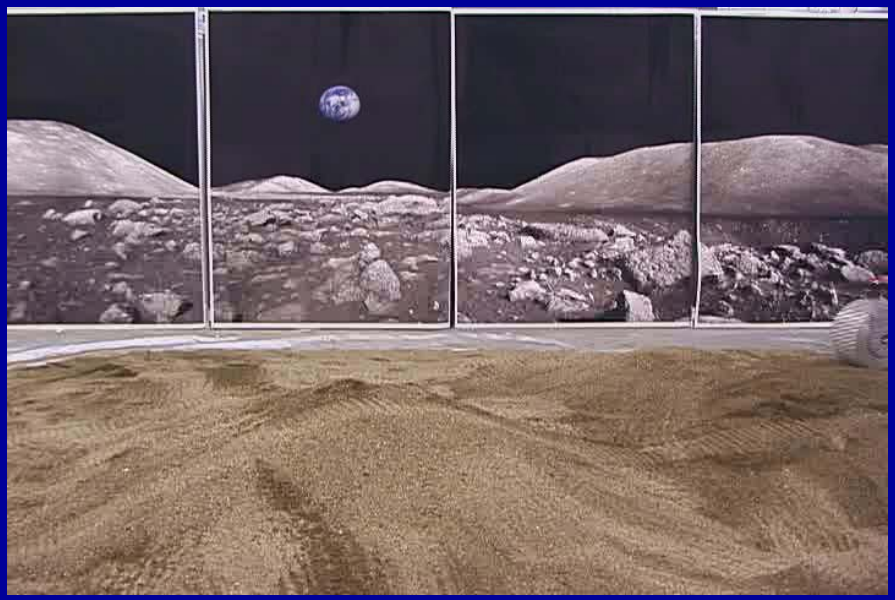
Asteroid Sampling

Agenda

- Background
  - Previous research on Planetary Rovers
  - El-Dorado-II at ICRA 2008 & 2009
- MoonRaker
  - Google Lunar X-Prize
  - Design Concept
  - Field Testing
  - Sensors, Localization and Mapping
  - Teleoperation

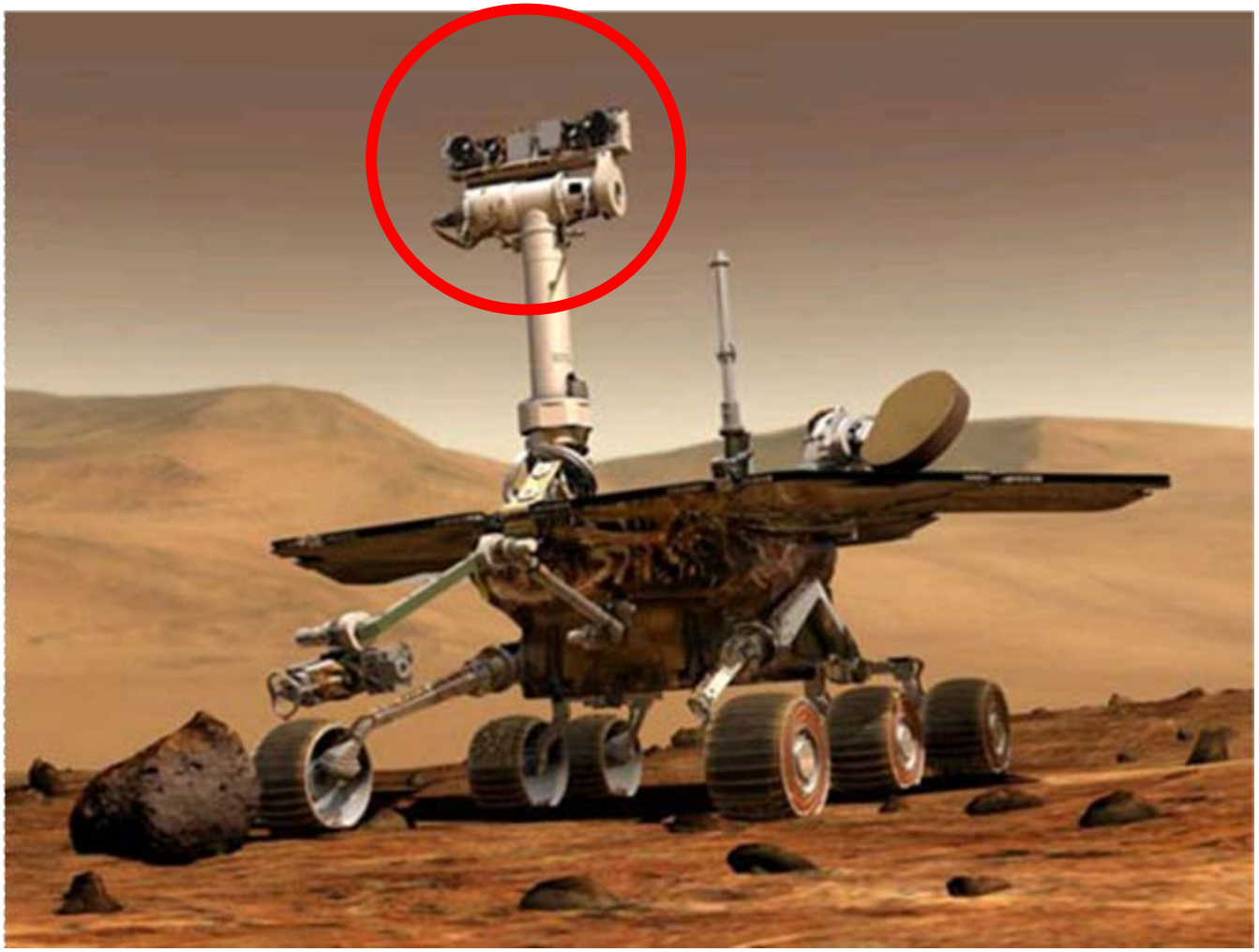


Rover Test Beds in Tohoku University *since 1997*



Robotics Technology for Lunar / Planetary Exploration

- **Mobility**
  - Chassis design
  - Traction mechanics on loose soil
  - Control to minimize and compensate the slippages
- **Sensing and Navigation**
  - Laser range sensor
  - Path planning
  - Localization and Mapping



Sensing and Navigation

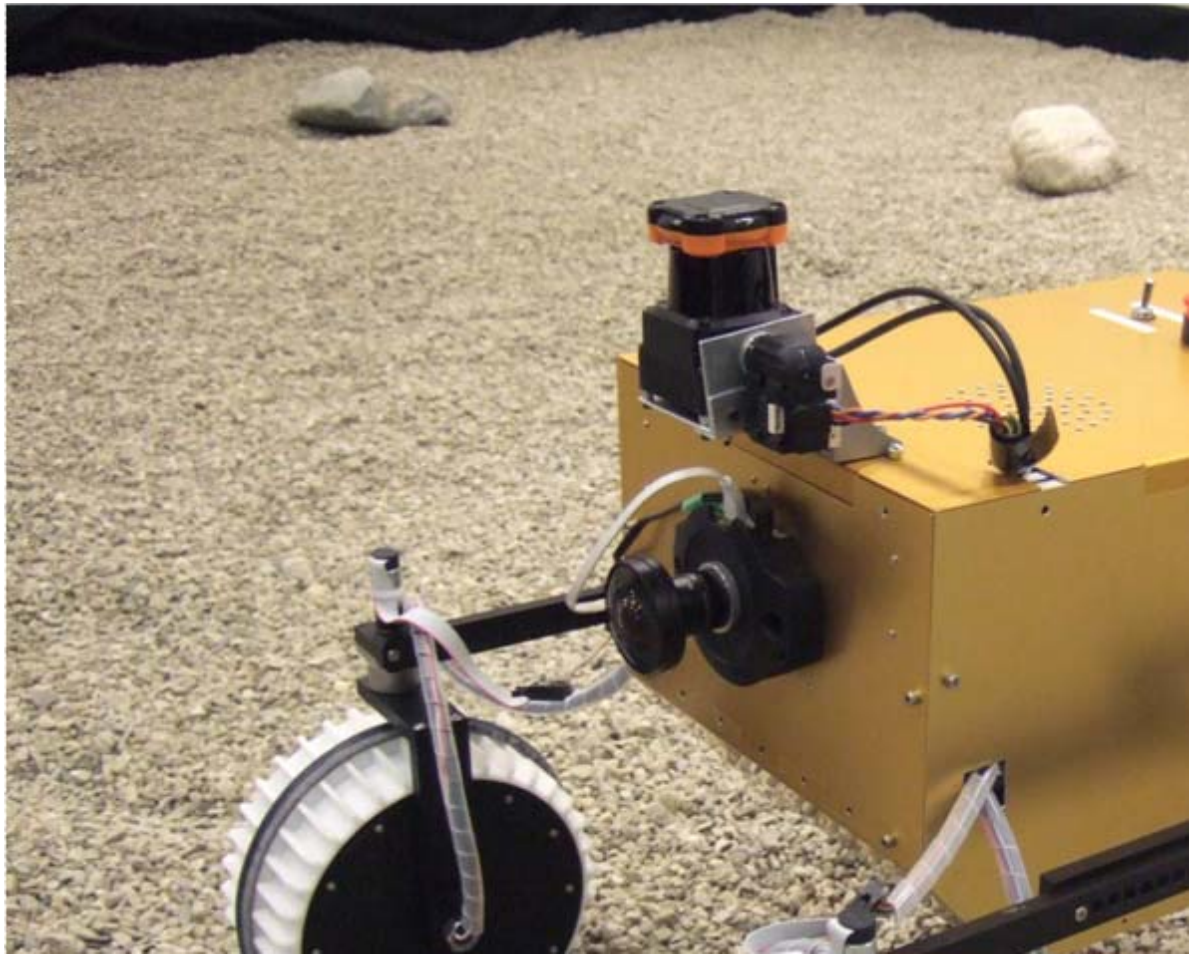
Laser 3-D range sensor

Hokuyo UTM-30LX

“Top-URG” (30m range sensing)

Dynamixel DX-117

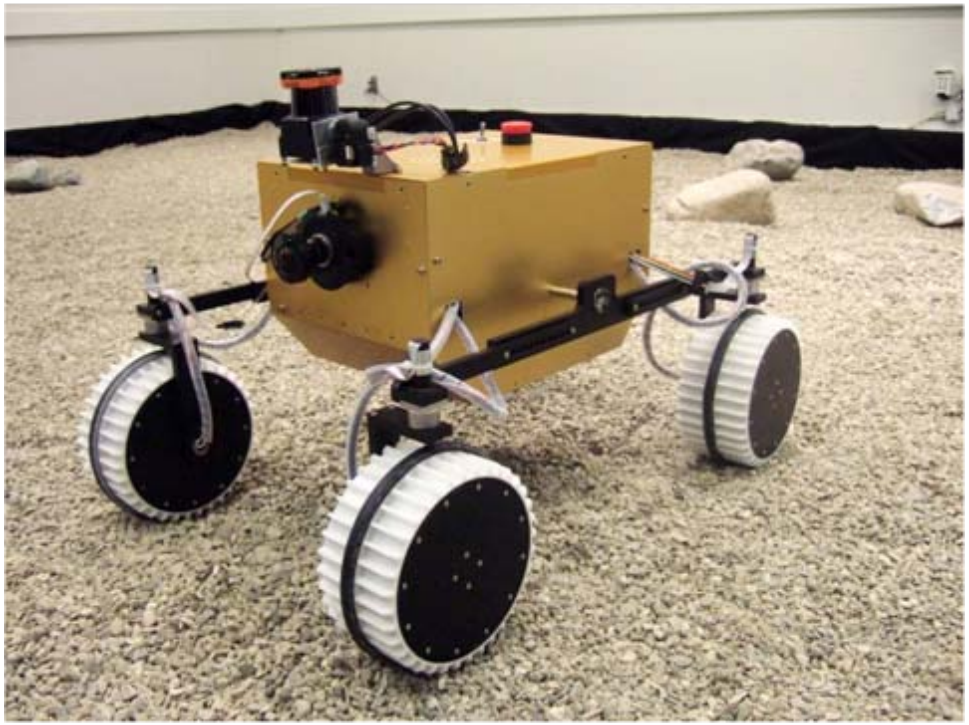
Servo Motor

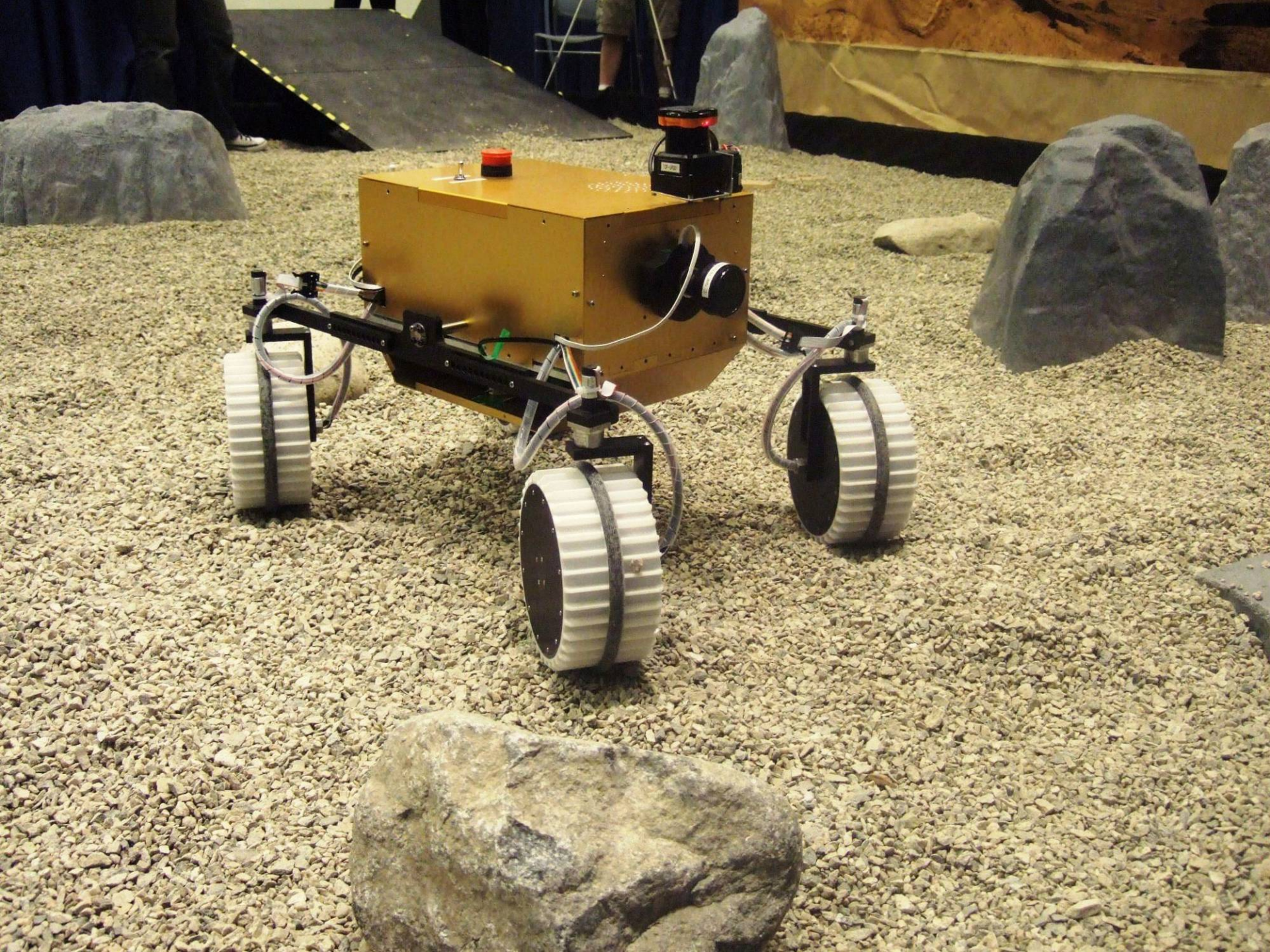


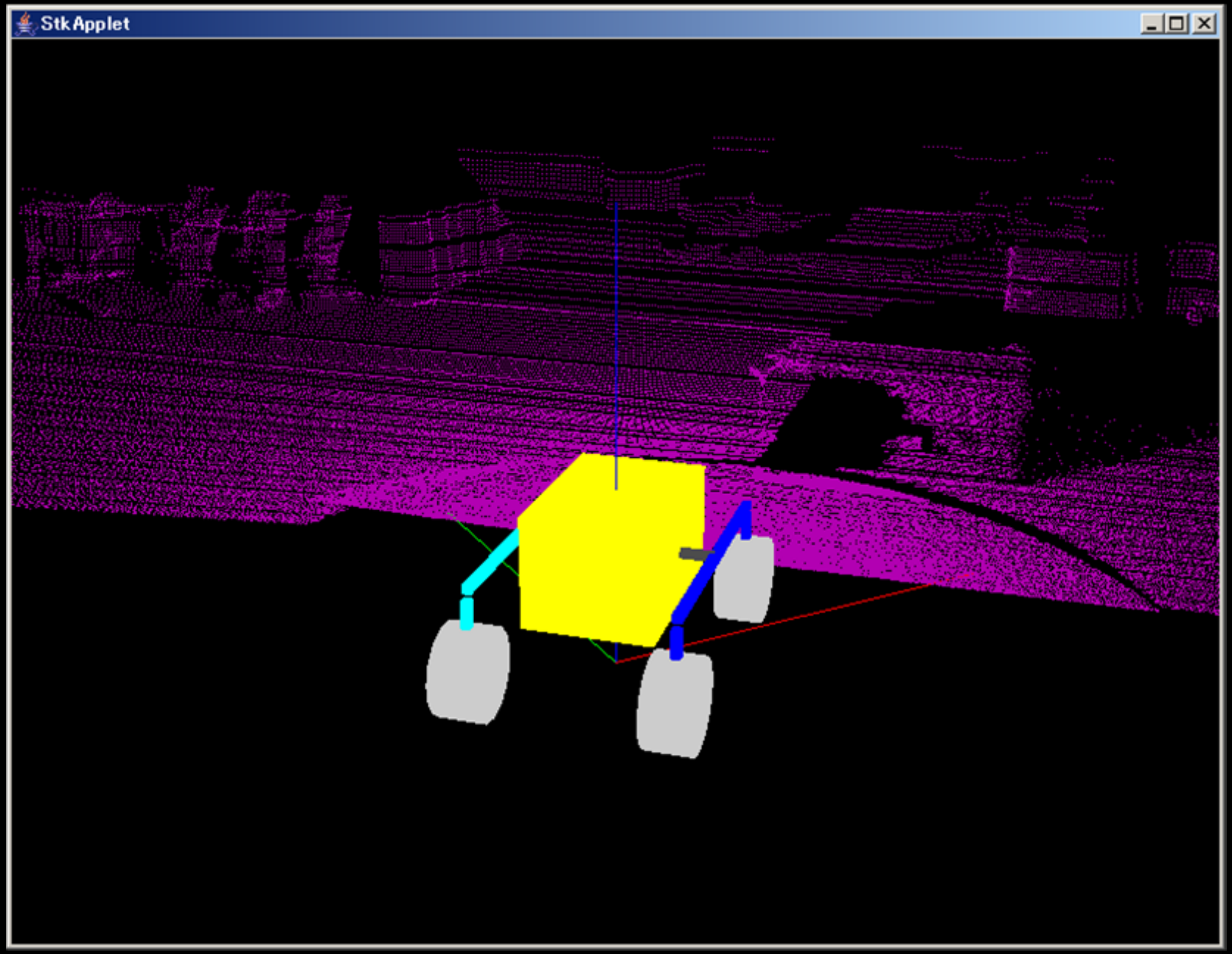
El Dorado-II

Research test bed of a Lunar/planetary rover, developed at Tohoku University, Japan

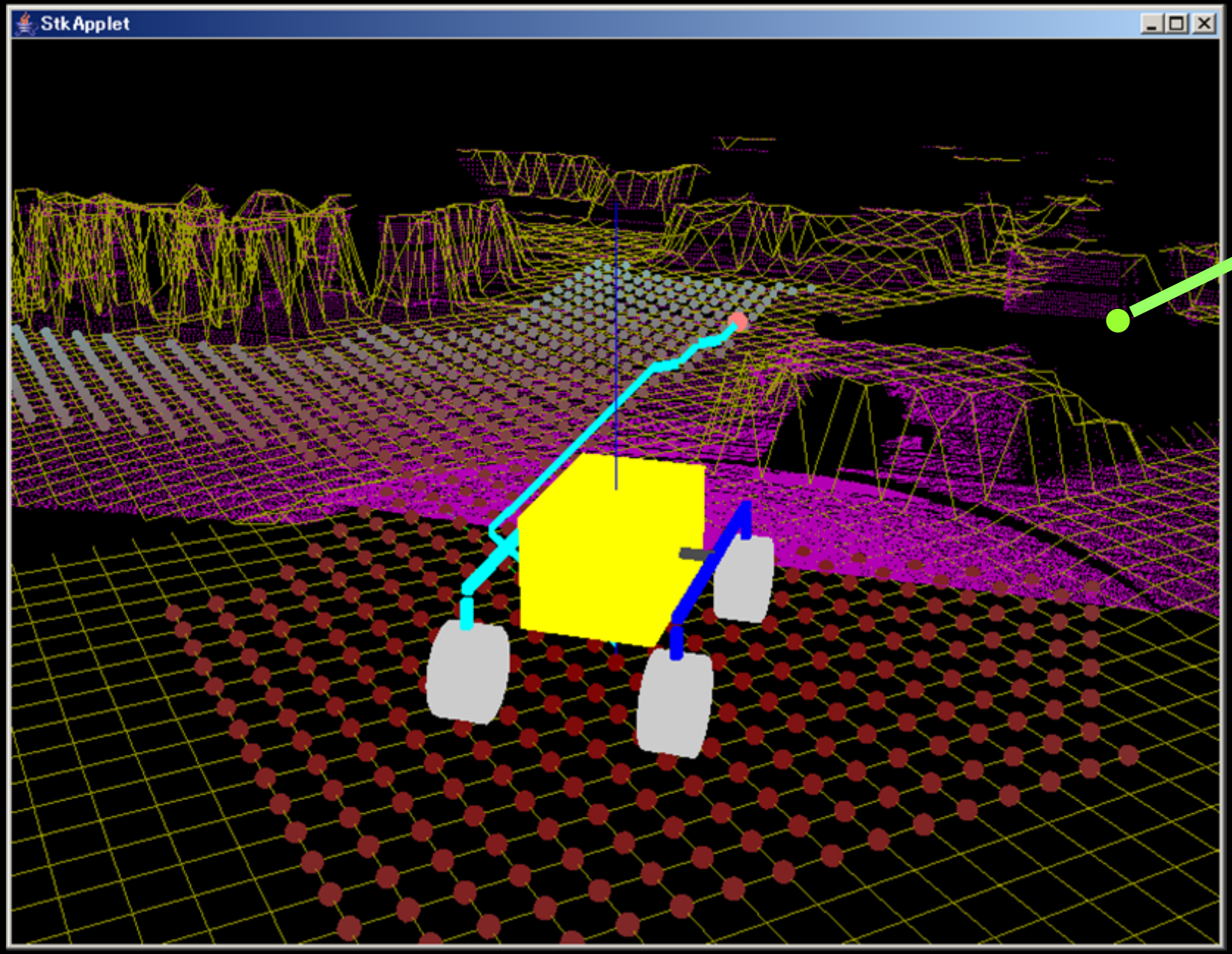
- Size: 56 (w) x 77 (l) x 44 (h) cm
- Weight: 21 kg
- Four-wheel drive, Four-wheel steering
- Rocker-type passive suspension
- Laser range sensor, Optical cameras (2), Gyroscope, Wireless internet







1. Scan the environment

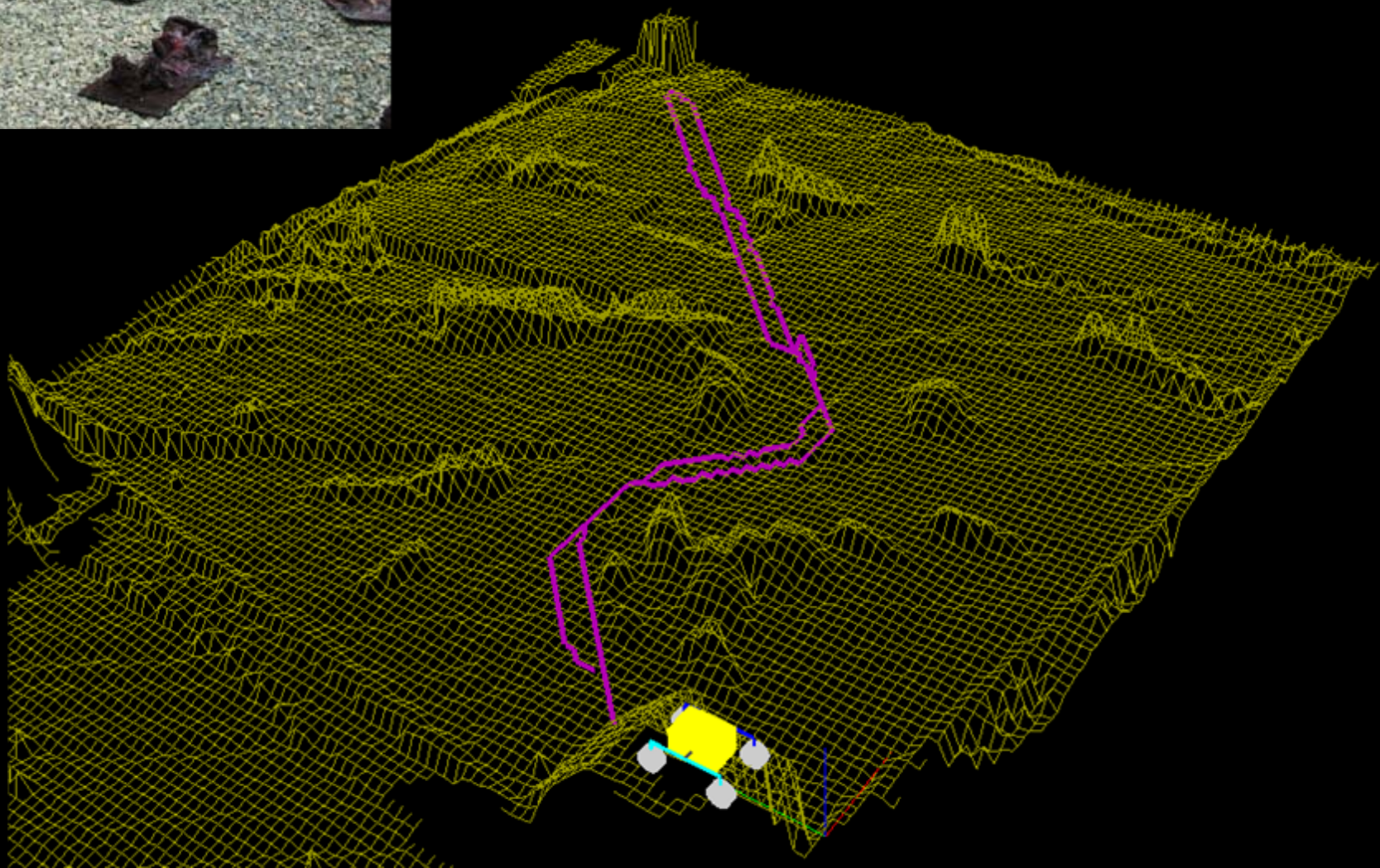


4. Generate a candidate path based on Distance Transform Method.


ICRA2009 Robot Competition
Planetary Exploration Challenge
2009 IEEE Internatioinal Conference on Robotics and Automation, Kobe, Japan, May 12-17, 2009

Public Demo at International Robotics Conference

Space Robotics Laboratory



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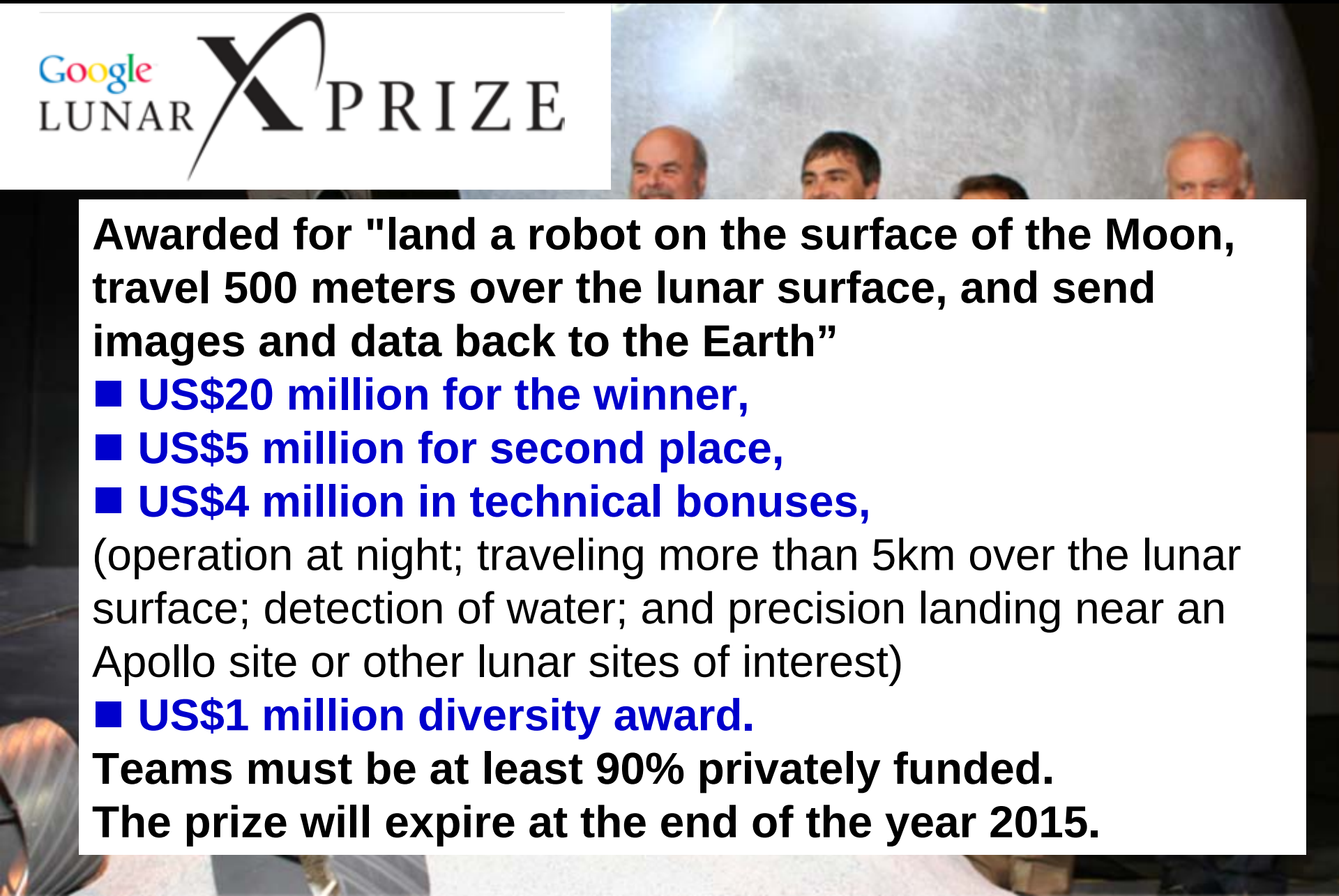
Google Lunar X Prize (GLXP)

Google LUNAR X PRIZE

- 30M USD Cash Prize
- Private activities
- 500m travel on Moon
- HDTV video transmission

Google Lunar X Prize (GLXP)



Awarded for "land a robot on the surface of the Moon, travel 500 meters over the lunar surface, and send images and data back to the Earth"

- **US$20 million for the winner,**
- **US$5 million for second place,**
- **US$4 million in technical bonuses,**

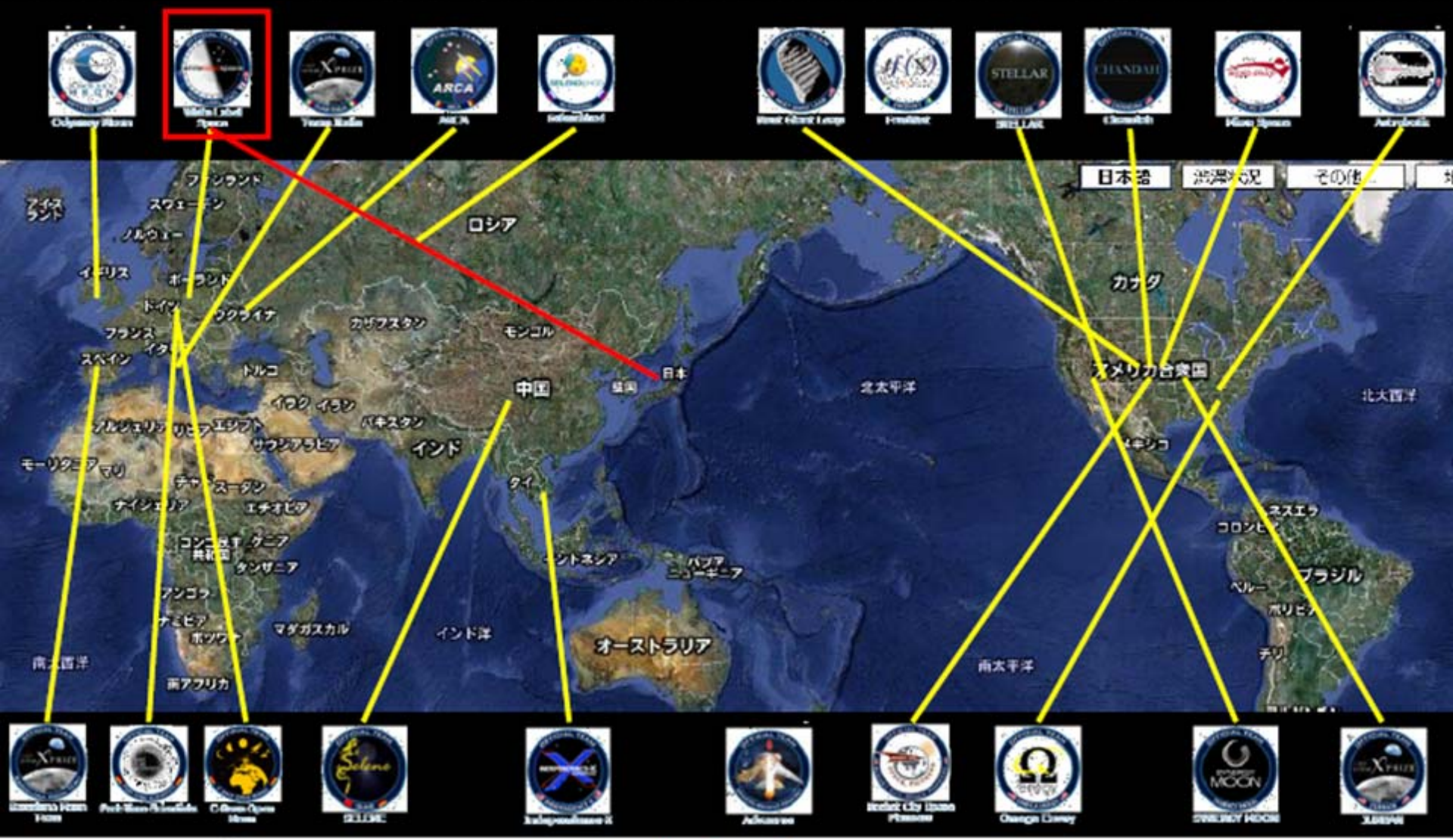
(operation at night; traveling more than 5km over the lunar surface; detection of water; and precision landing near an Apollo site or other lunar sites of interest)

- **US$1 million diversity award.**

Teams must be at least 90% privately funded.

The prize will expire at the end of the year 2015.

29 teams from the world



Google LUNAR XPRIZE

whitelabelspace

Diversity of Ideas!

MoonRaker

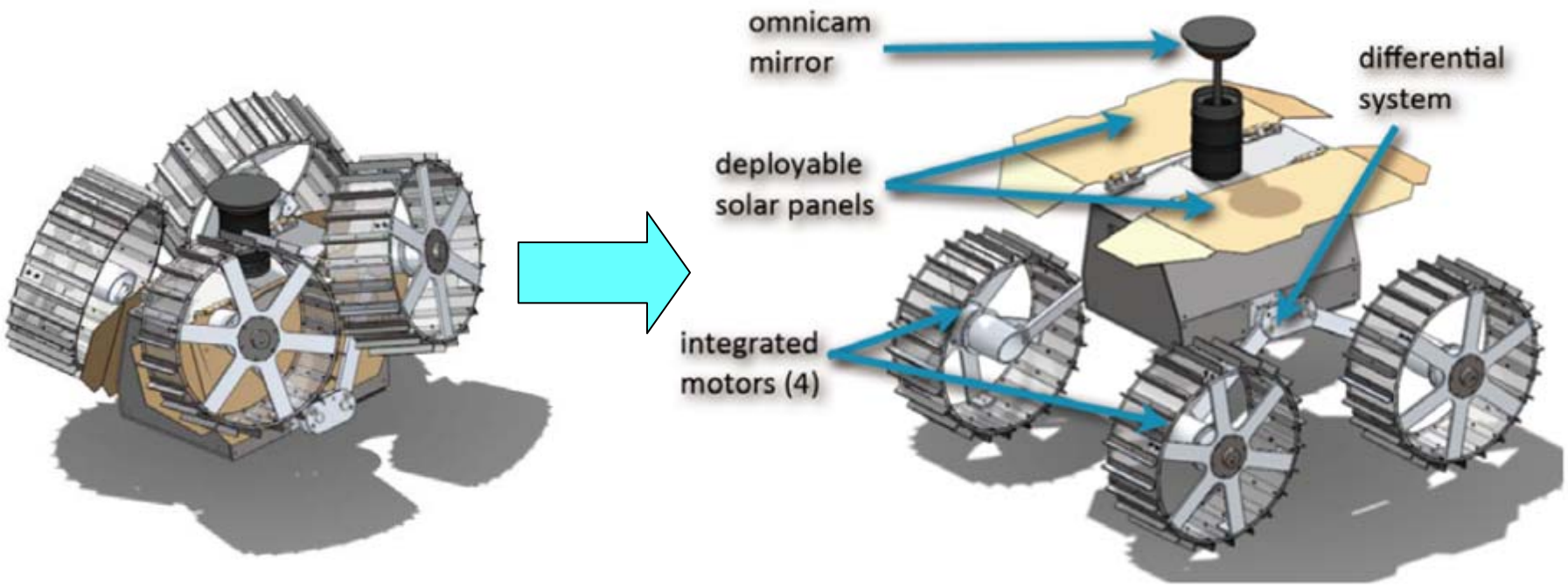
A Rover test bed for ground testing

MoonRaker: Design Concept

A Rover test bed for ground testing

- Compact & Light weight (10kg)
- Minimum number of actuators
  - Four wheel drive
  - Skid-steer
  - Omni-camera (no pan/tilt)
  - Laser sensor (with a MEMS mirror)

Compact body

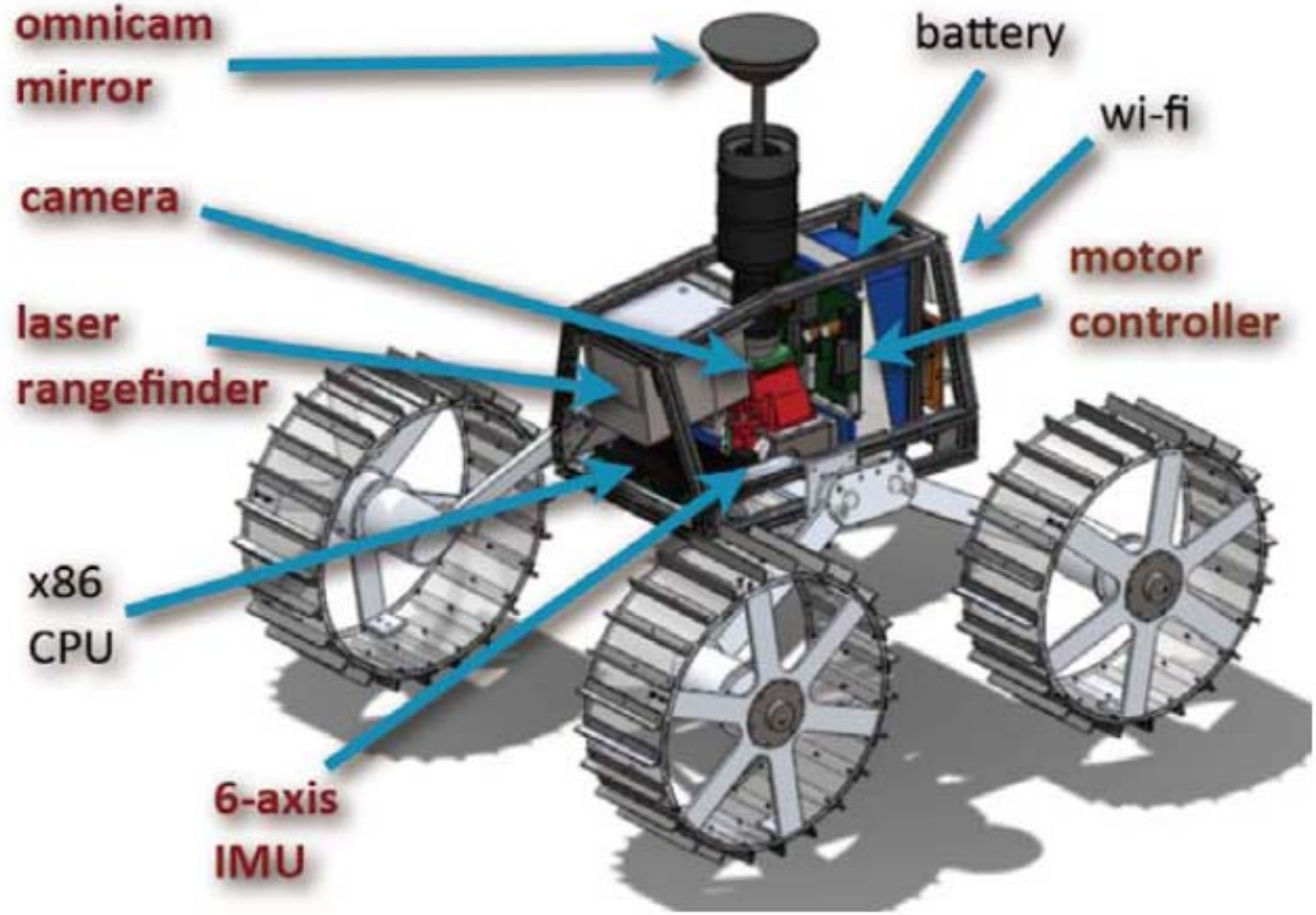


50 x 40 x 30 cm

55 x 46 x 49 cm

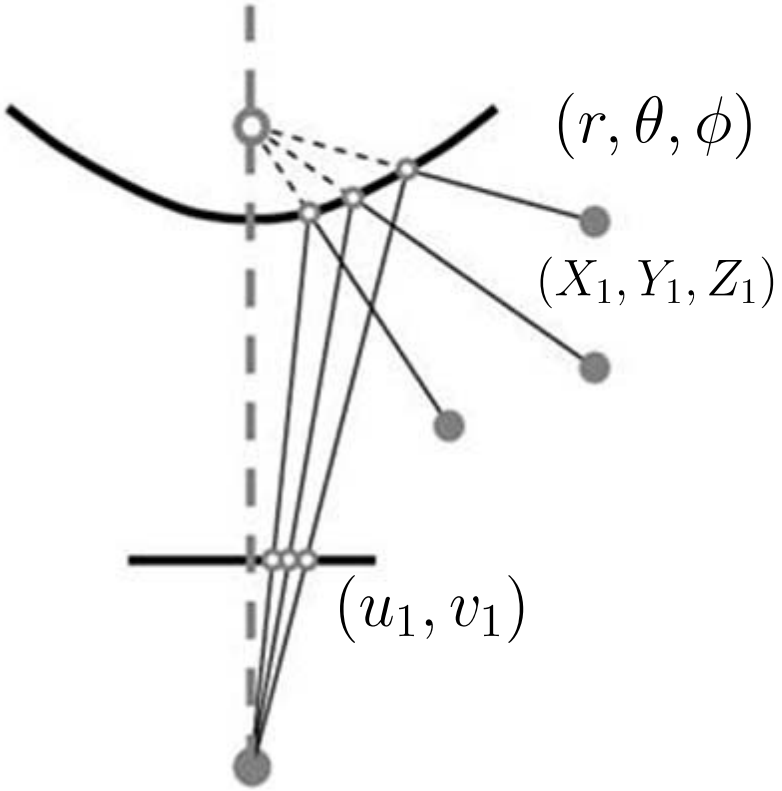
Total mass: 10 kg

Interior Design



Omni-directional camera

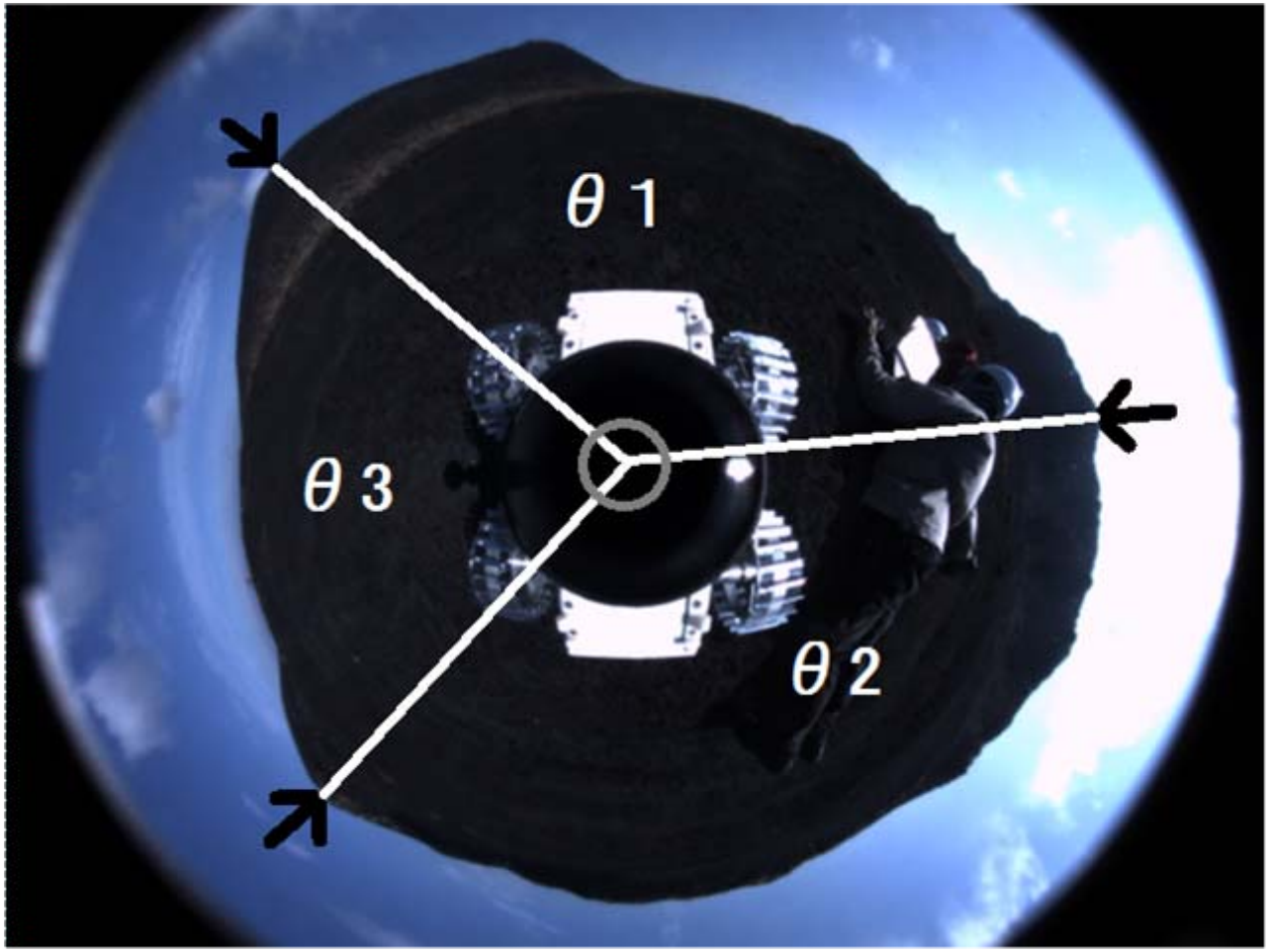
Omni-directional camera



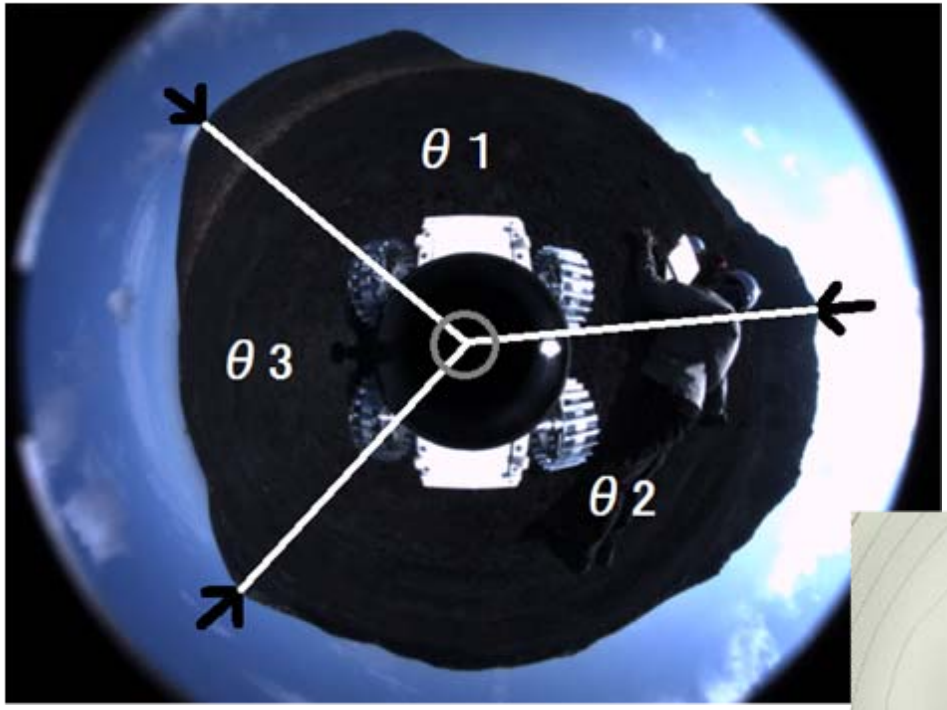
MoonRaker: Field Testing

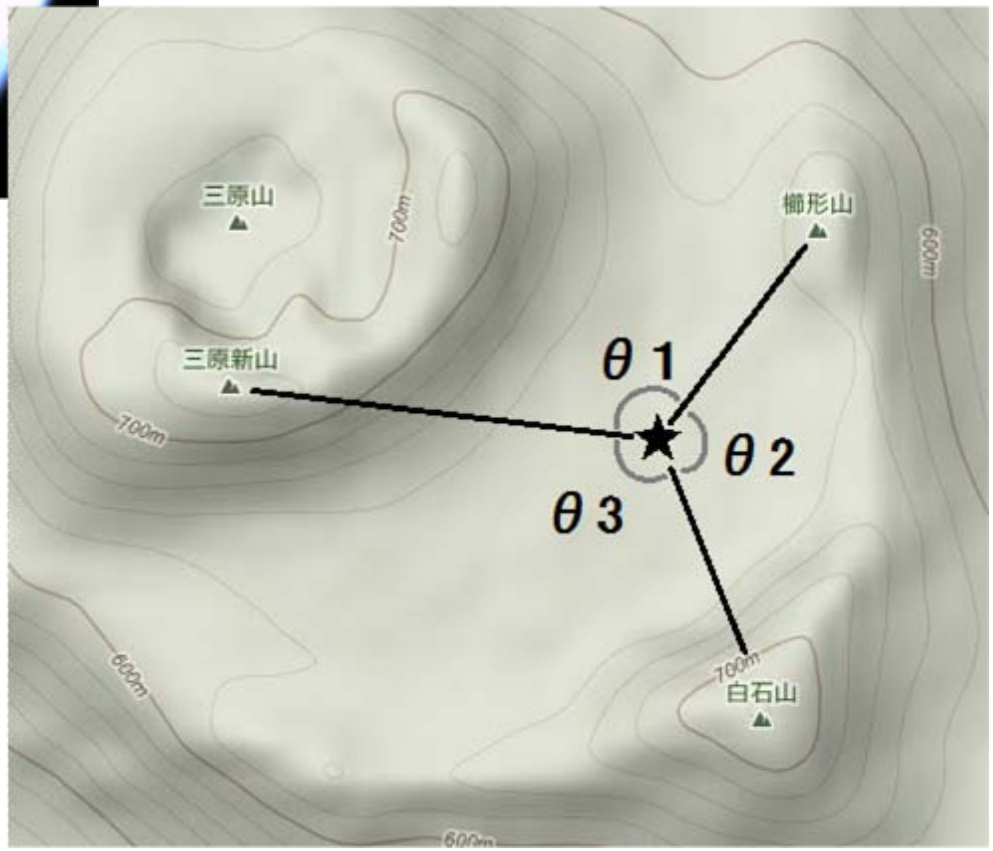
Four-wheel drive, Skid steering, 10 kg, Omini-Cam

Omni-directional camera



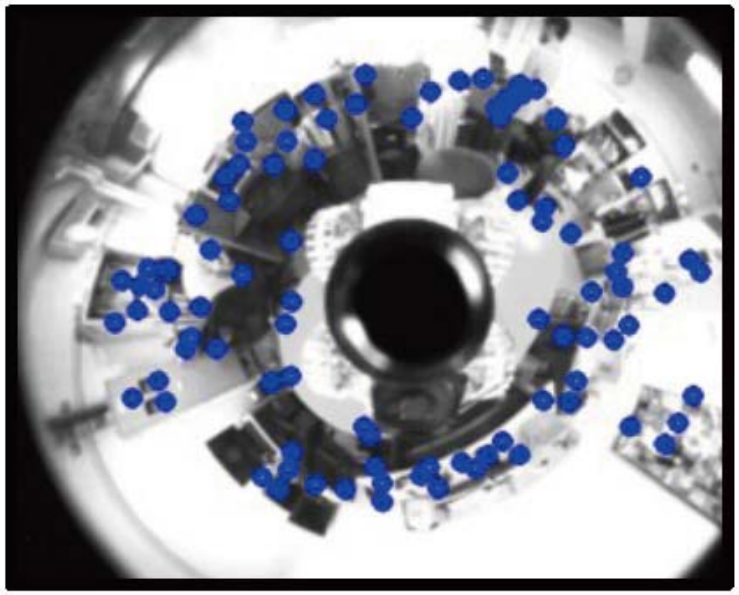
- Self-portrait
- Skyline & mountain peaks
- Nearby obstacles

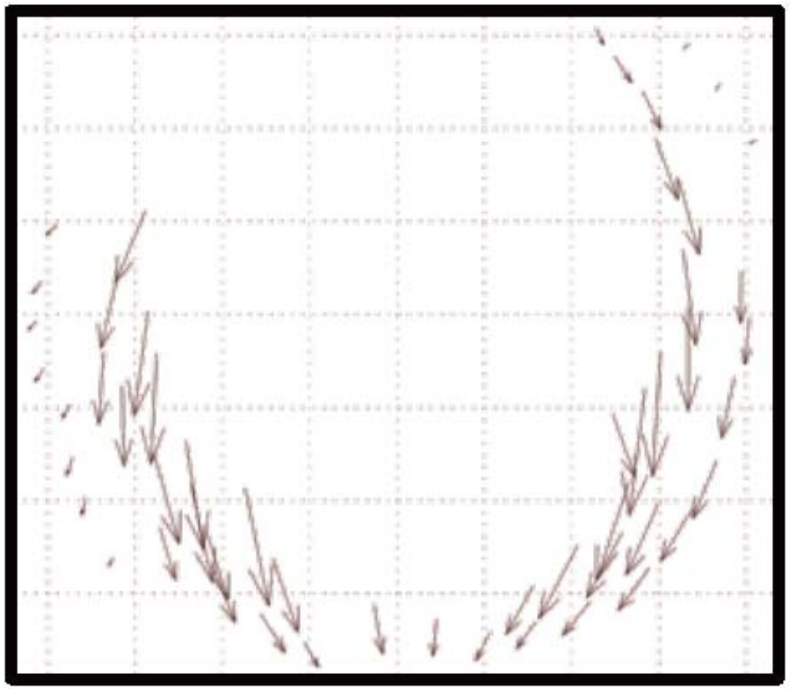

θ1
θ3
θ2


三原山
700m
櫛形山
600m
三原新山
θ1
700m
θ2
θ3
600m
700m
白石山
600m

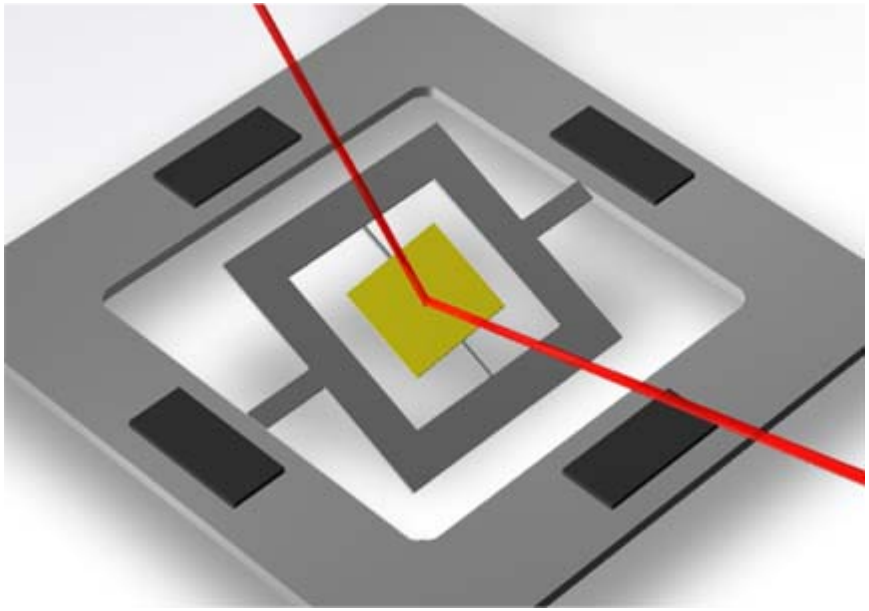
Optical Flow

- Previous work was towards localization of rover: Feature Tracking and Optical Flow:
    1. Detect features at $t = t_1$
    2. Detect features at $t = t_2$
    3. Compute movement *and* 3D position of features





MEMS-Mirror Laser: FX8



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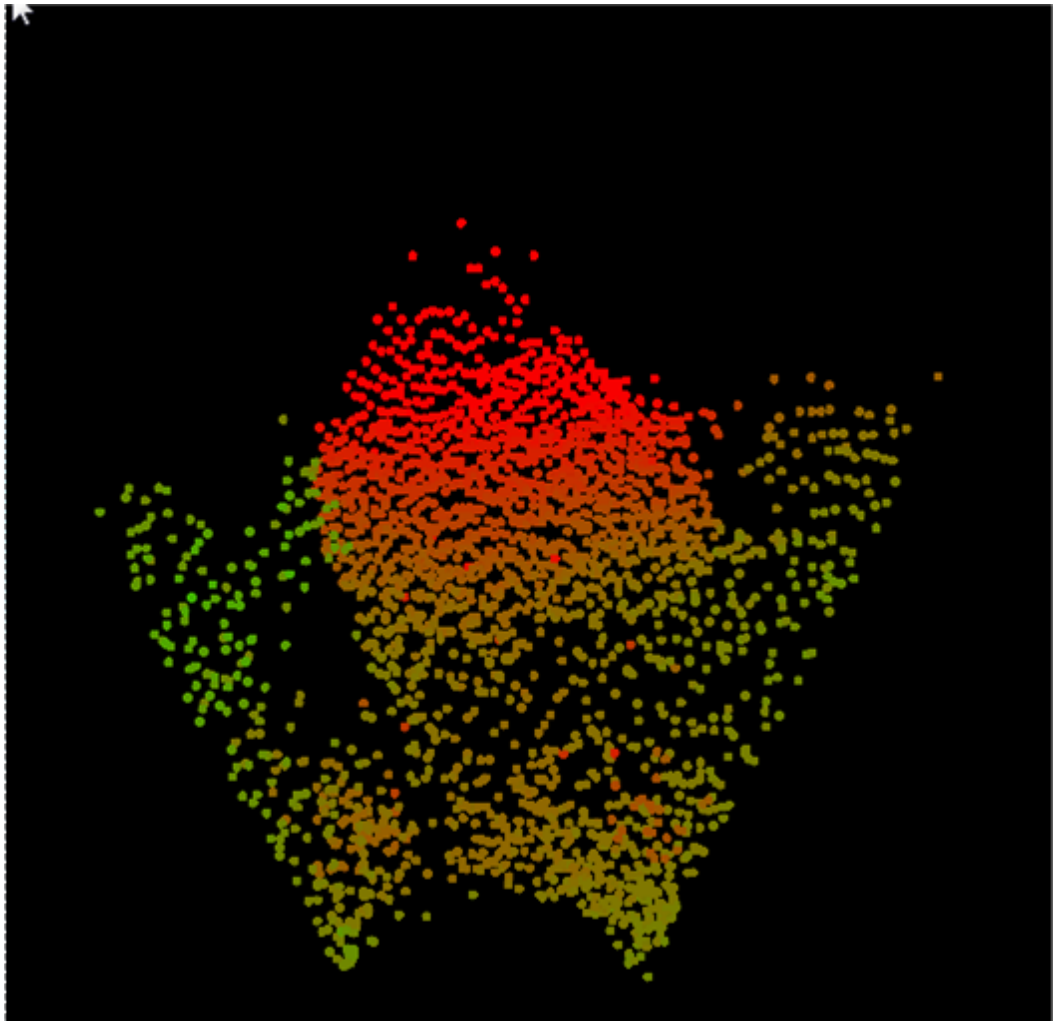

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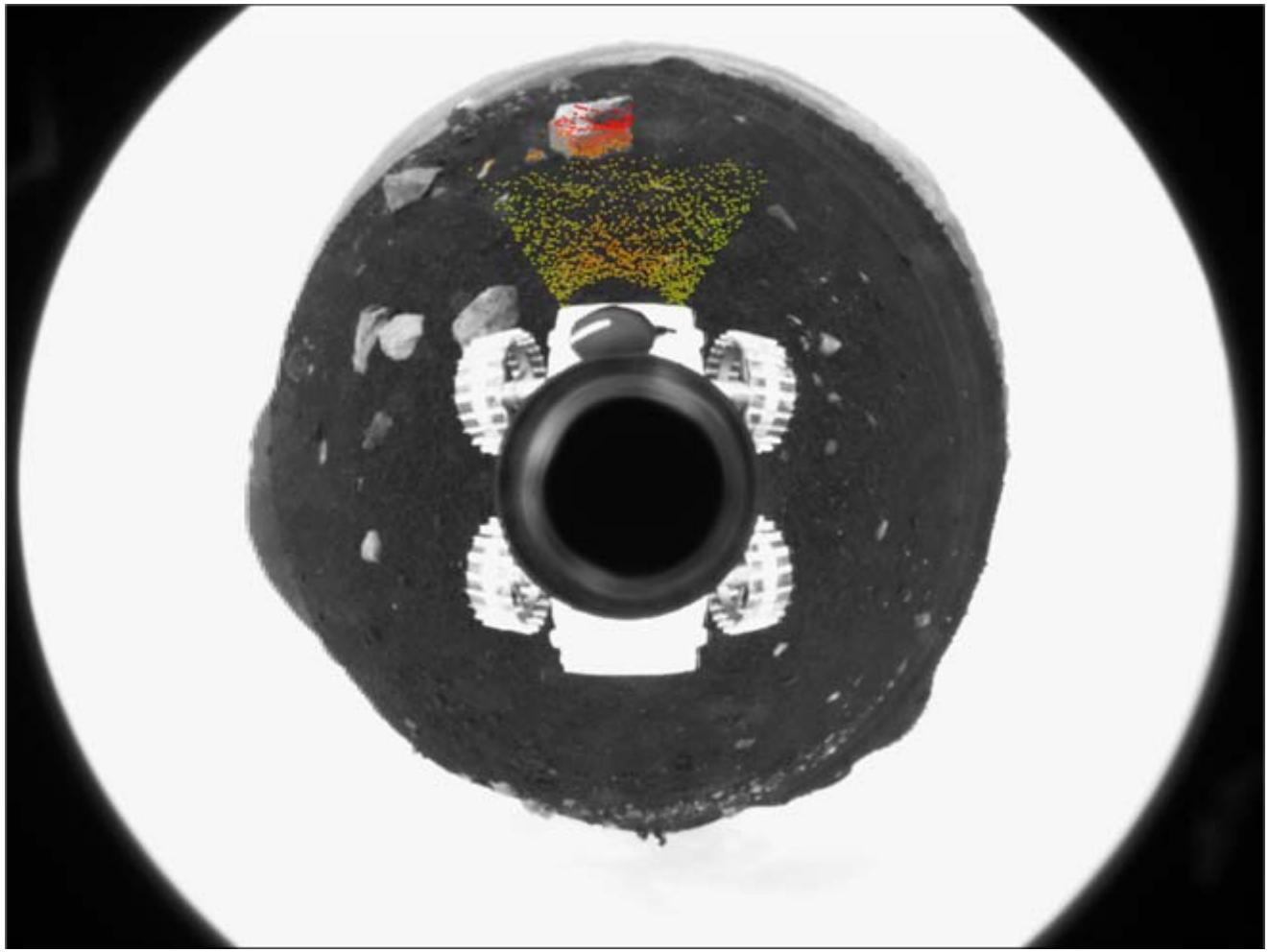
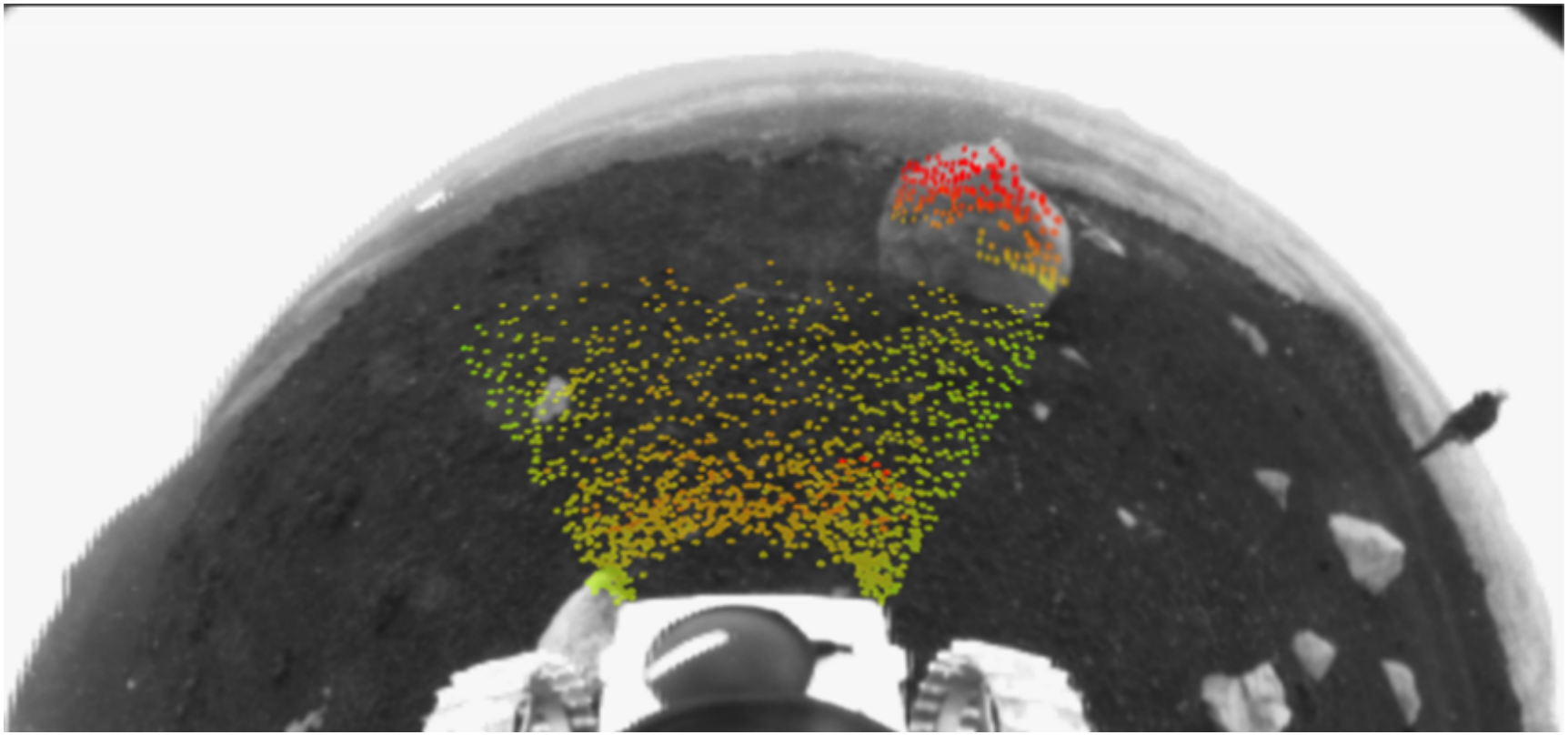
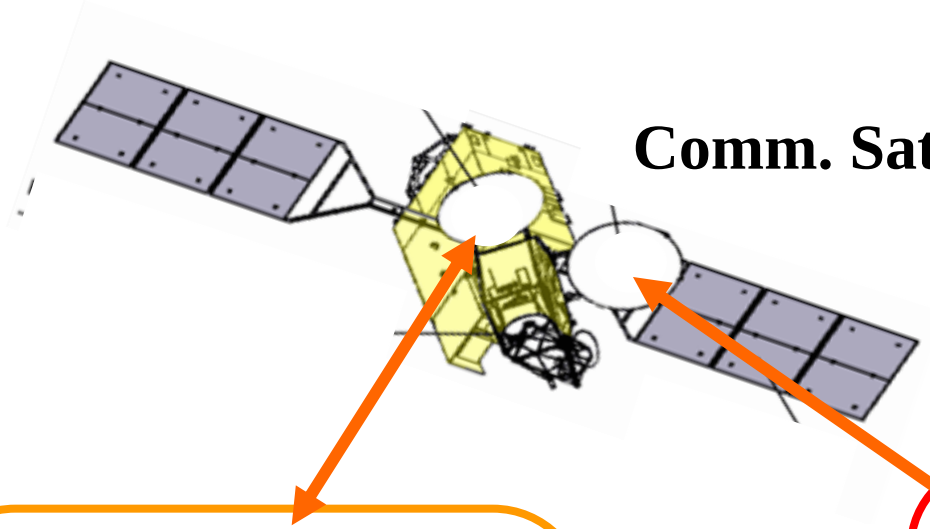


MEMS-Mirror Laser: FX8

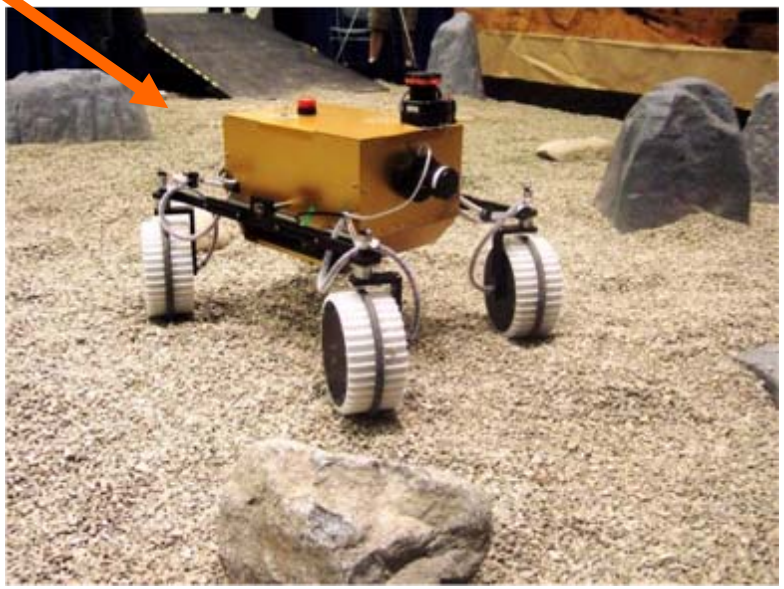


Remote Operation via Satellite Communication Network

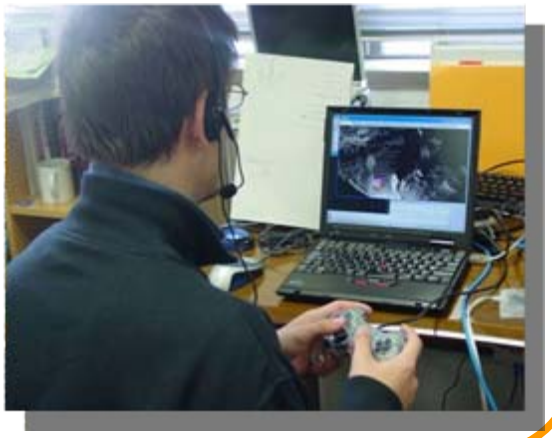


Comm. Sat. (IP-based communication)

Demo site



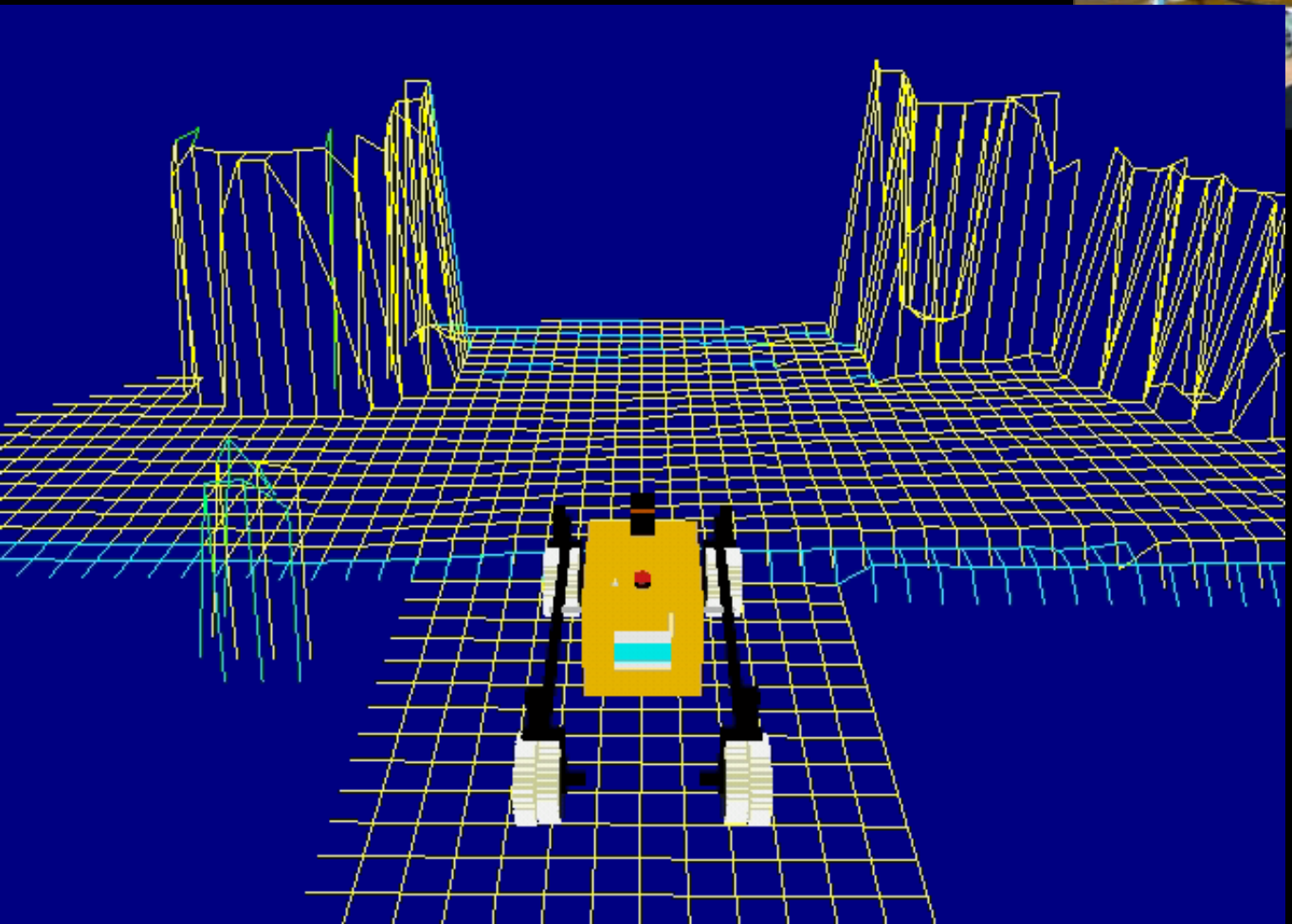
Remote operator



Ground station

Teleoperation

- Latency
- Band width



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