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Wheels, Tracks and Reciprocal Walking: Challenges to Loose and Steep Slopes

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- Introduction
 - A Big Wheel Rover
 - *Test fields*
 - *Field testing results*
 - Mobility Design Alternatives
 - *BladeWalker*
 - *TrackWalker*
 - *Field testing results*
 - Summary
-

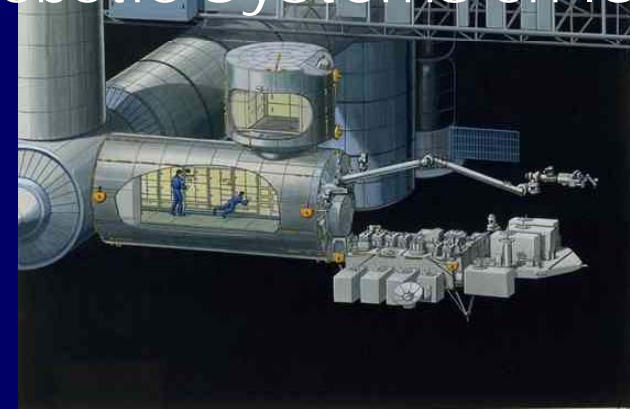
The Space Robotics Lab.
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<http://www.astro.mech.tohoku.ac.jp/home-e.html>

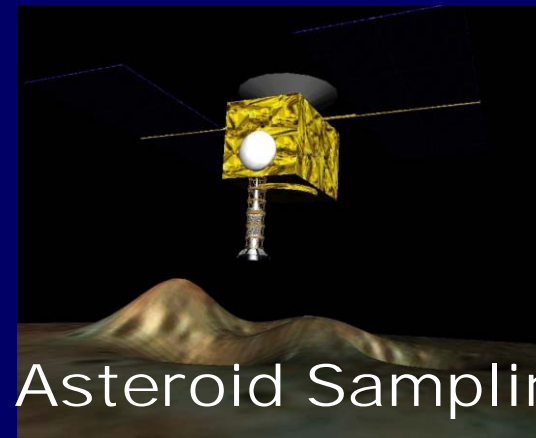
Free-Flying Space Robot



Robotic Systems on ISS



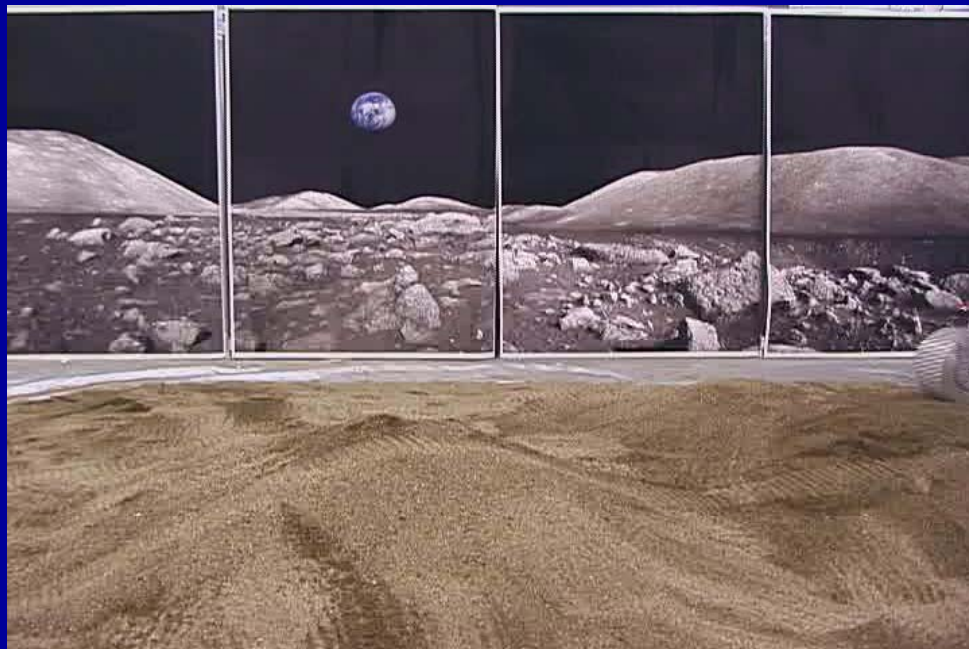
The **S**PACE
ROBOTICS
Lab.

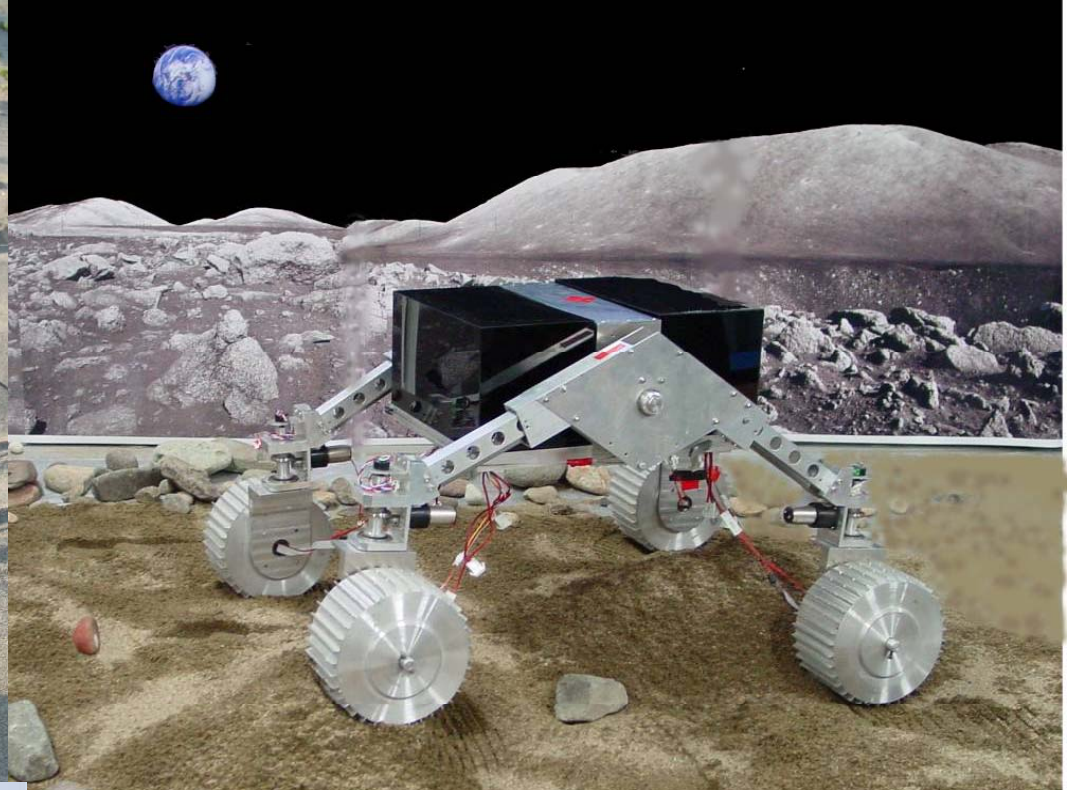
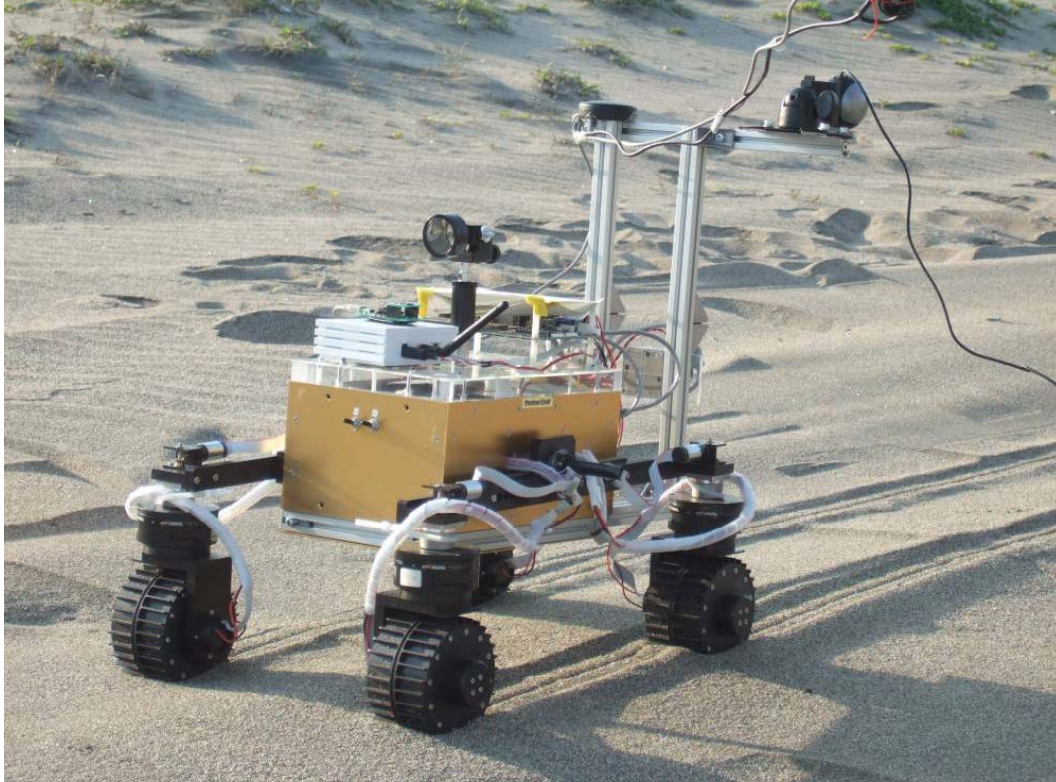


Planetary Exploration Rovers

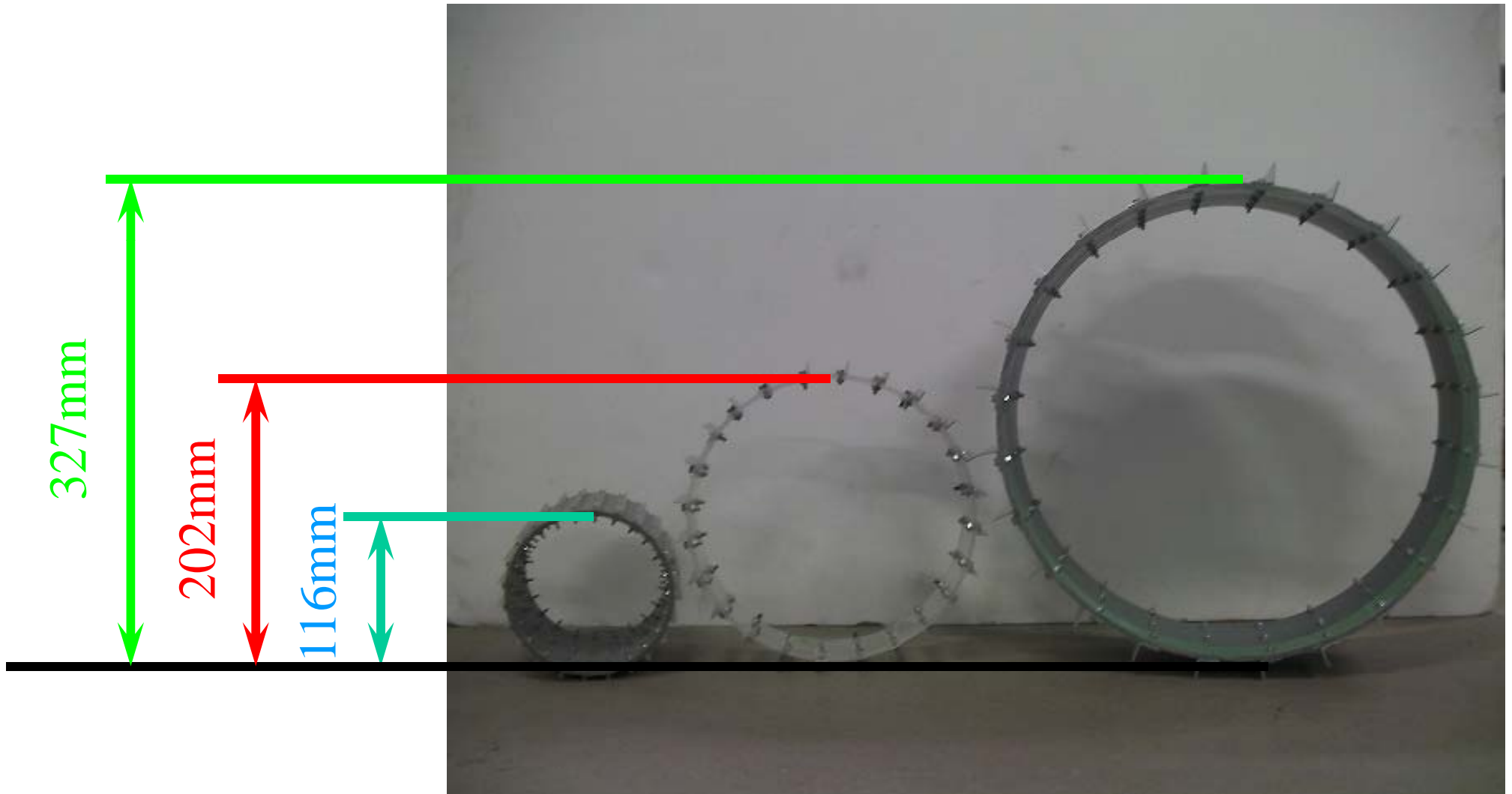
Asteroid Sampling

Rover Test Beds in Tohoku Univ. *since 1997*



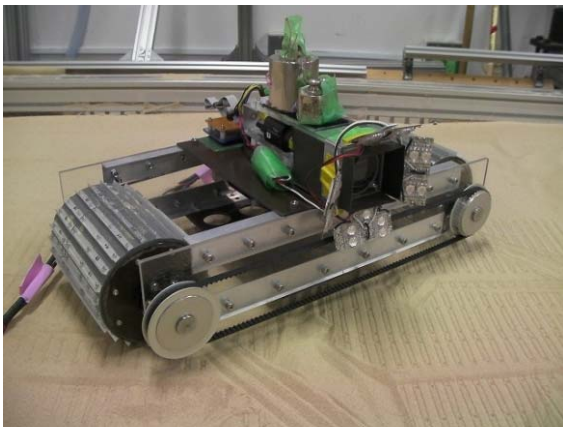


Q: How can we improve the traction performance of the wheels?

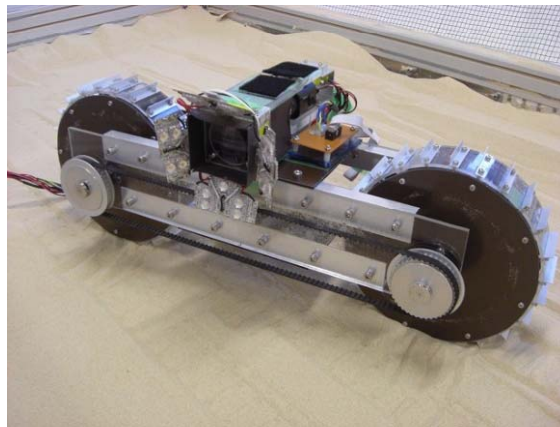


Wheels with Different Dimensions

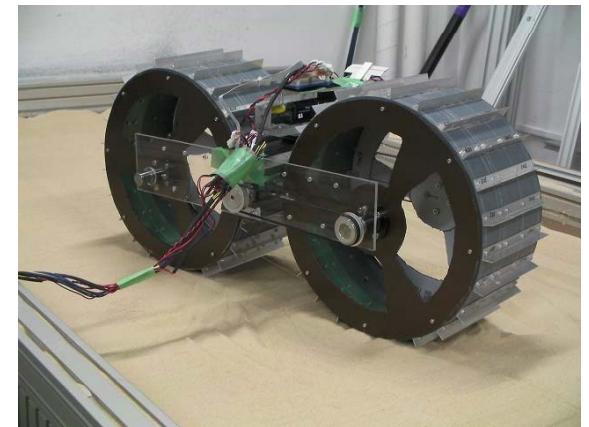
	D=100mm	D=200	D=300
diameter [mm]	116	202	327
lug height [mm]	5	9	15
number of lugs	24	24	24
width [mm]	50, 100, 150	50, 100, 150	50, 100, 150



D=100

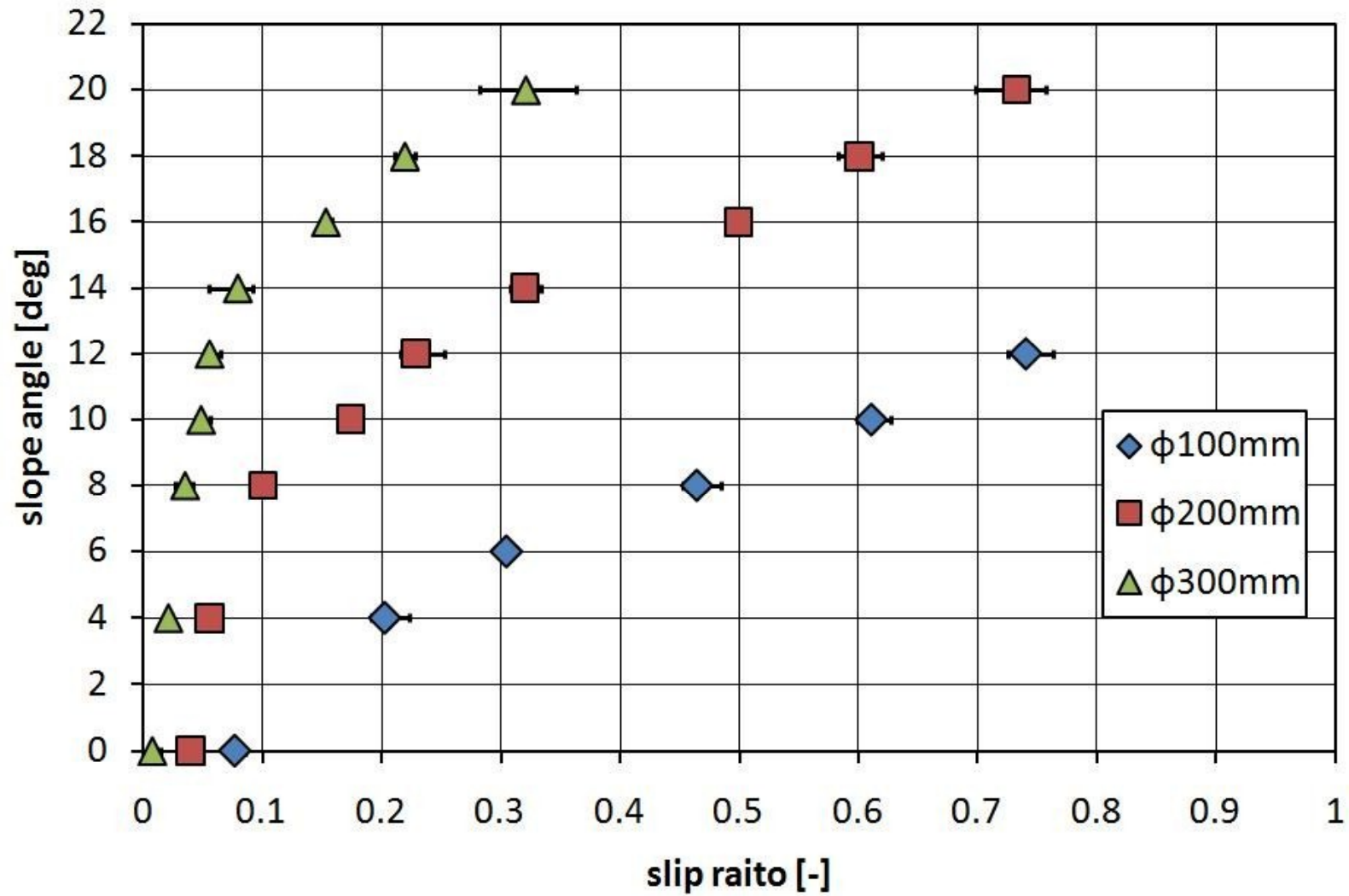


D=200



D=300

With Larger Diameter

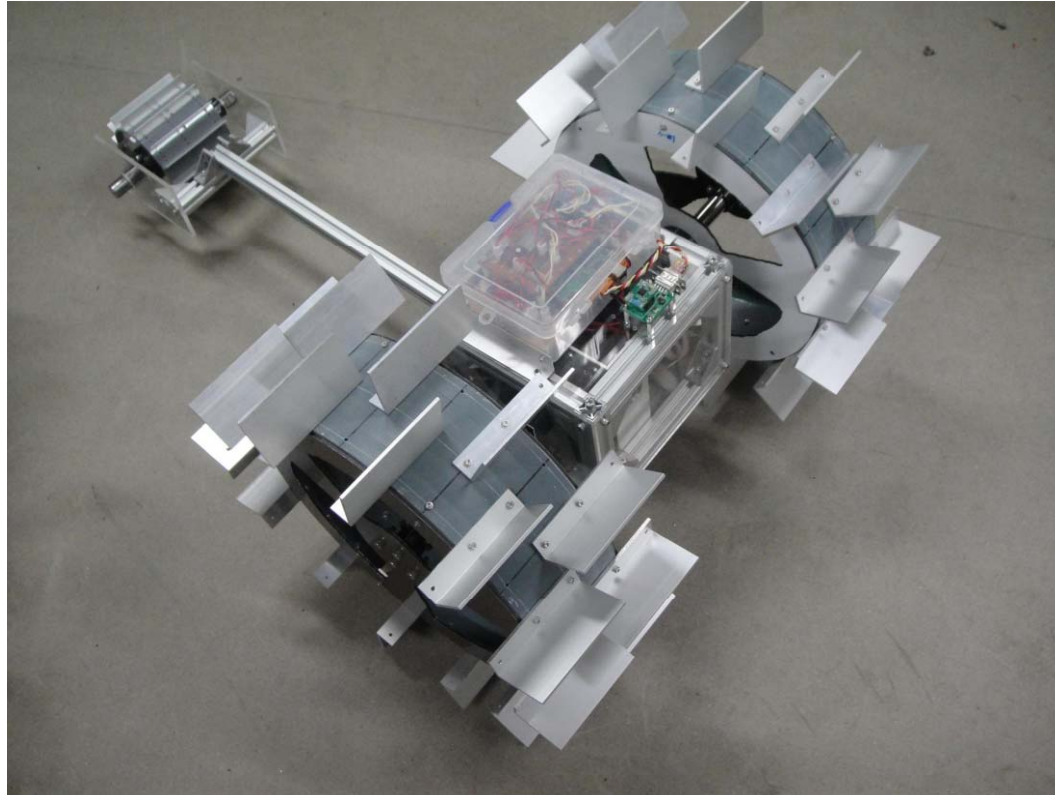


(width = 100mm)

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A Big Wheel Rover



Two large active wheels
Paddle-like grouser

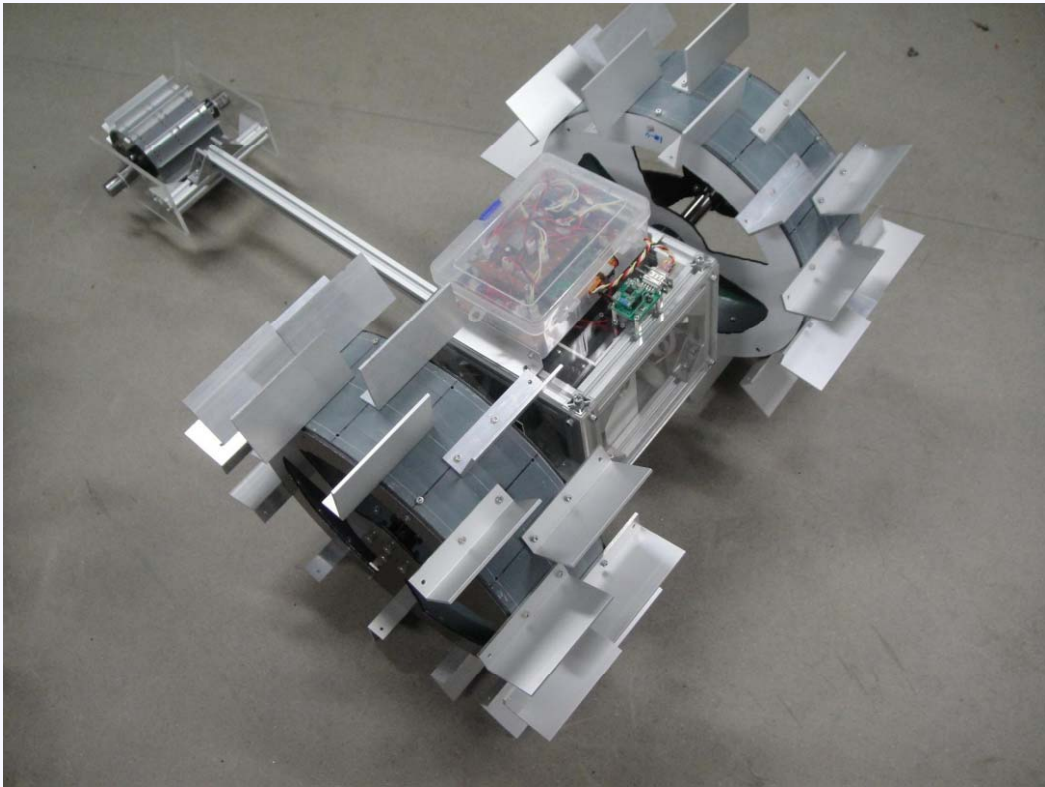
© Wheel diameter :
420.0 [mm]

© Lug length:
50.0 [mm]

© Wheel width:
100.0 [mm]

© Mass:
14.6 [kg]

A Big Wheel Rover



The Big Wheel Rover

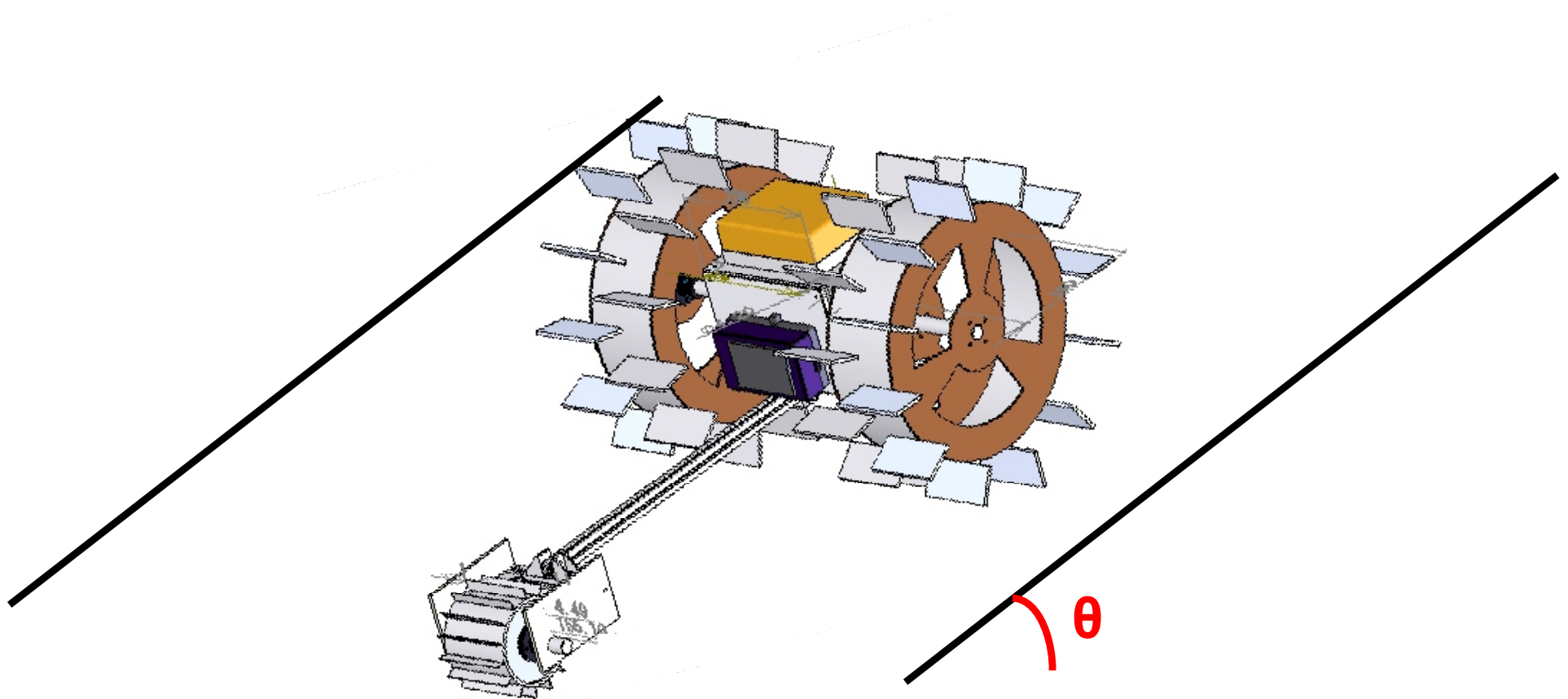


El-Dorado-II

	Wheel diameter [mm]	No. of grouser	Height of grouser [mm]	wheel width [mm]	Rover mass [kg]
El-Dorado-II	200	72	10	100	21.0
Big Wheel Rover	420	24	50	185	14.6

A Big Wheel Rover

Evaluate the climbing performance
by **Slip Ratio** with difference **Slope Angle**



Test Field



2010.9.26 小浅間山 山頂

1. Mt. Asama (volcano)

(Nagano prefecture)

- Scoria (volcanic pebbles)
- tested slope angle: 20 [deg]
- density: 1.18 [g/cm³]



2011.1.11 関上海岸 砂浜

2. Beach sand

(Yuriage, Miyagi prefecture)

- beach sand with moisture
- tested slope angle: 20, 30 [deg]
- density: 1.29 [g/cm³]

Test Field



3. SandBox-A

- 1.0 [m] × 2.0 [m]
- "Toyoura" sand (dry silica sand)
- tested slope angle: 0, 10, 20 [deg]
- density: 1.45 [g/cm³]



4. SandBox-B

- 0.8 [m] × 3.0 [m]
- pebbles for gardening
- tested slope angle: 20, 30, 40 [deg]
- density: 0.34 [g/cm³]

Field Testing Result

Mt. Asama filed on Scoria (angle – 20 [deg])



Resultant slip ratio: 0.3~0.4

Field Testing Result

Yuriage Beach sand slope (angle = 20, 30 [deg])



20 [deg]





Slip ratio = 0.1



30 [deg]

Slip ratio = 0.3~0.4

Summary of Big Wheel Rover test results

	Outdoor testing ("Yuriage" beech, Sendai, Japan)	Indoor testing ("Toyoura" sand, a type of dry quartz sand)
<p>El-Dorado-II (wheel diameter = 200 mm)</p>	<p>Slope angle = 20 deg Slip ratio = 0.7</p> 	<p>Slope angle = 16 deg Slip ratio = 0.9</p> 
<p>Big Wheel Rover (wheel diameter = 420 mm)</p>	<p>Slope angle = 20 deg Slip ratio = 0.1</p> 	<p>Slope angle = 20 deg Slip ratio = 0.3</p> 

Mobility Design Alternatives

Tracks!



Packbot (iRobot)



Taron (QinetiQ)



Quince (Chiba Institute – Tohoku Univ.)

Mobility Design Alternatives

Stomping Walk



BladeWalker (Yoshida et al. 2009)

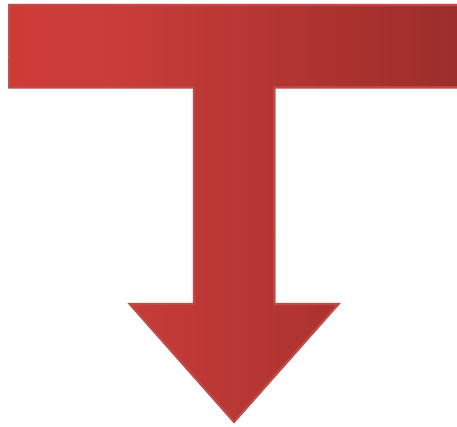
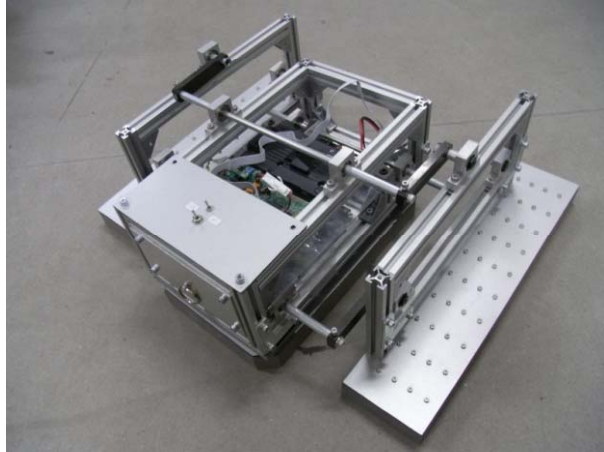
Mobility Design Alternatives

Stomping Walk



BladeWalker (Yoshida et al. 2009)

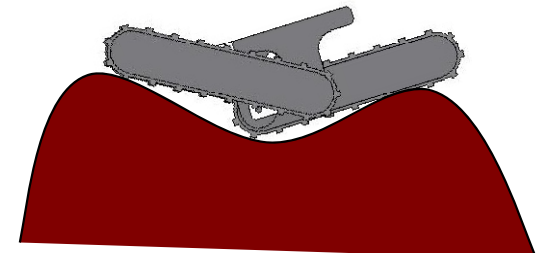
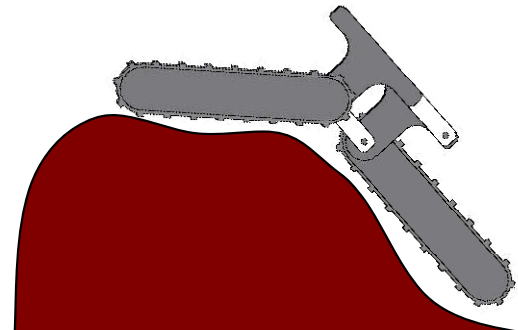
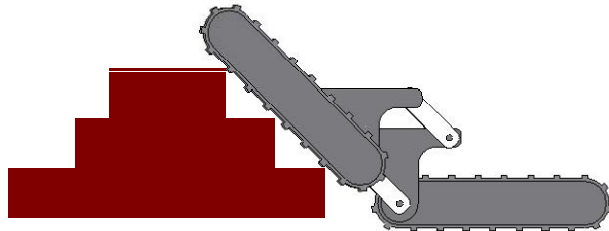
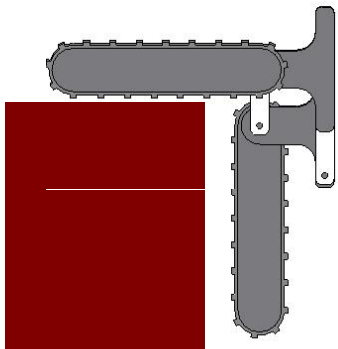
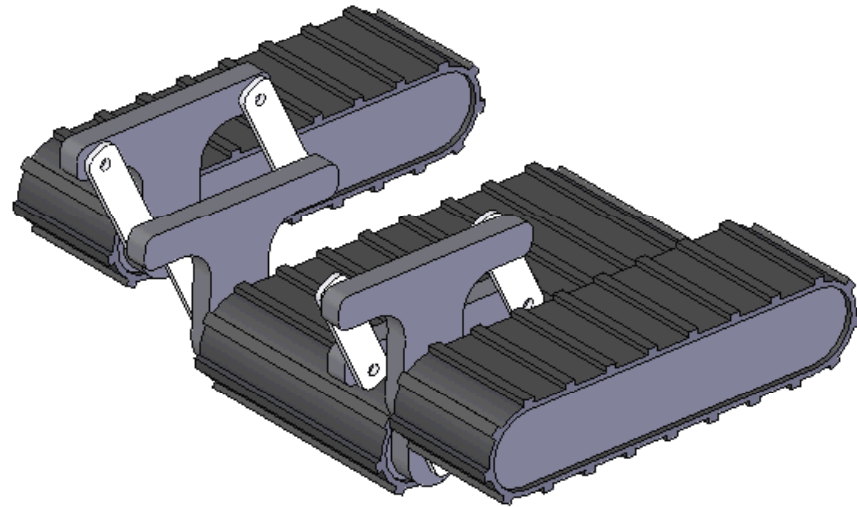
Mobility Design Alternatives



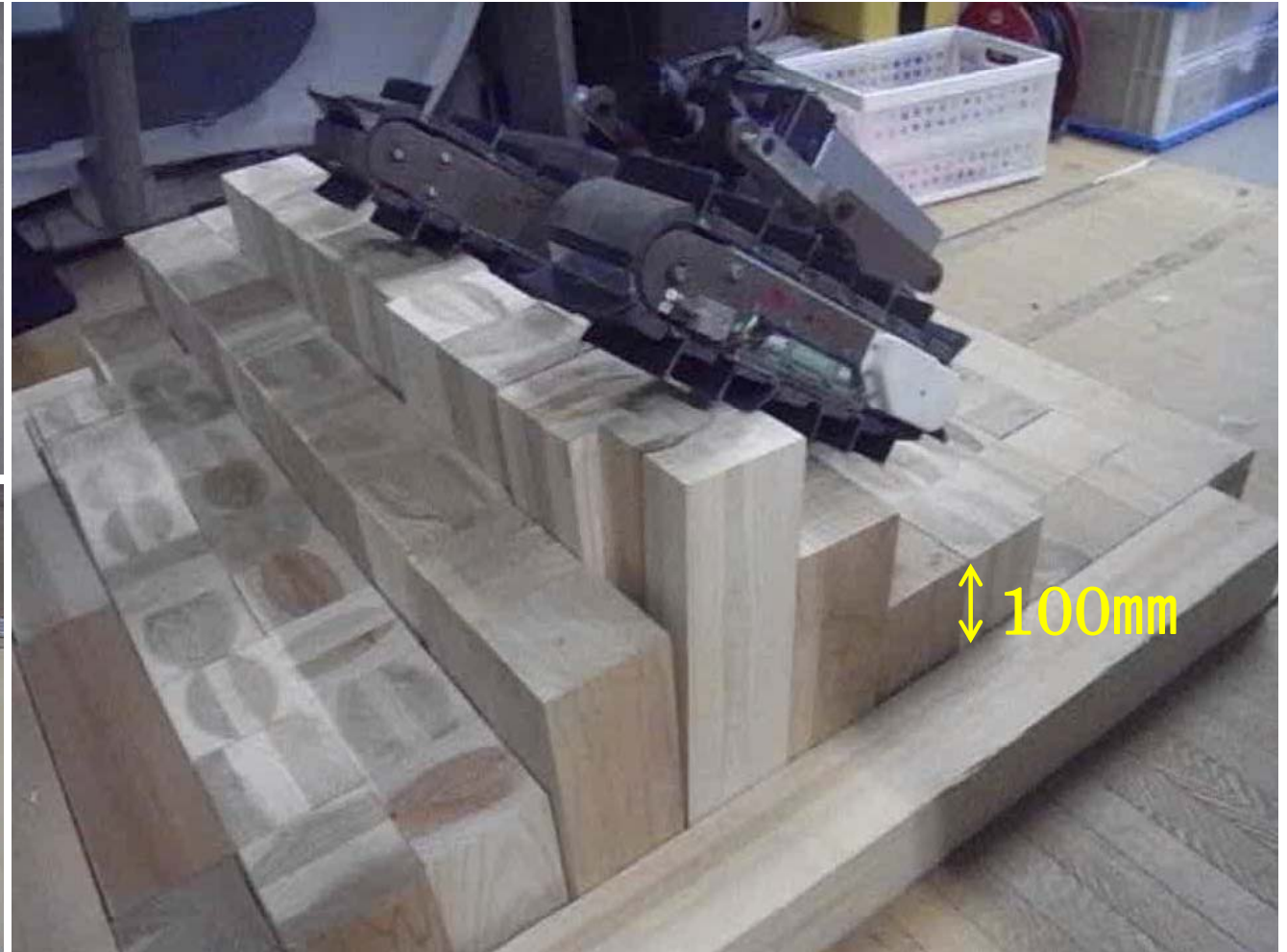
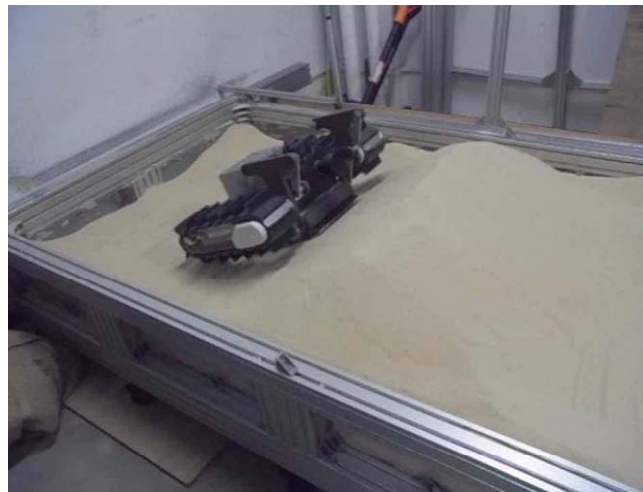
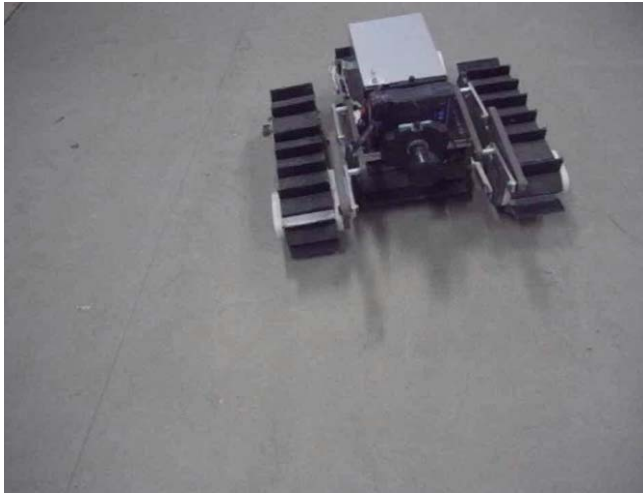
Hybrid of Track and Stomping Walk

TrackWalker

The TrackWalker



Performance Testing of the TrackWalker



Field Testing of the TrackWalker



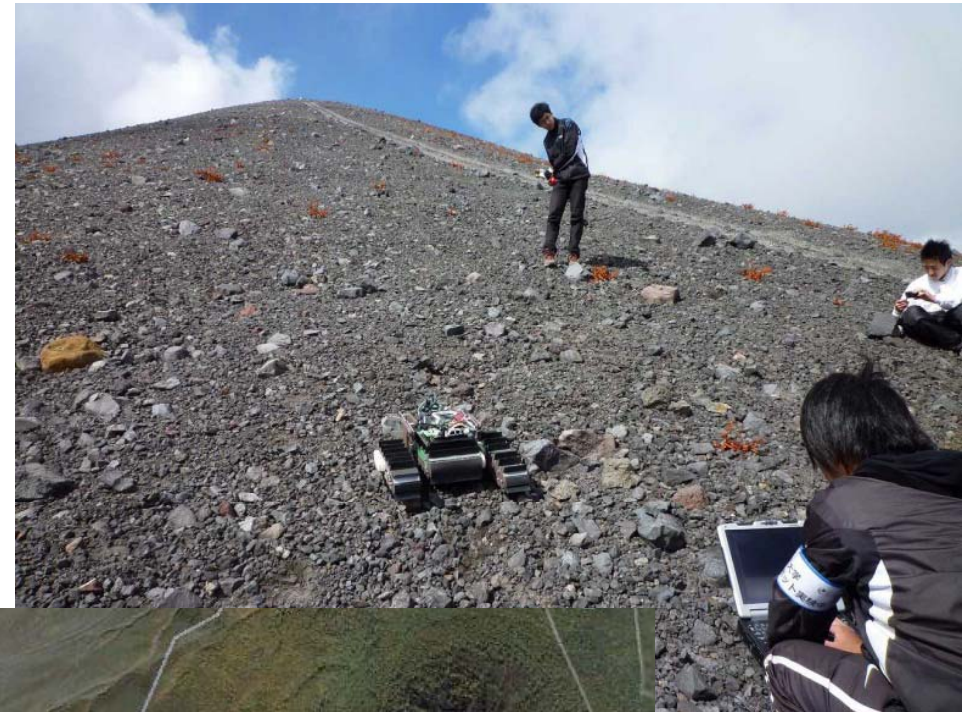
40 [deg]



30 [deg]

Field Testing of the TrackWalker

Mt. Asama
an active volcano in Japan



Field Testing of the TrackWalker

- Piles of 20 mm – 100 mm volcanic rubbles
- 25 - 30 degree slope inclination

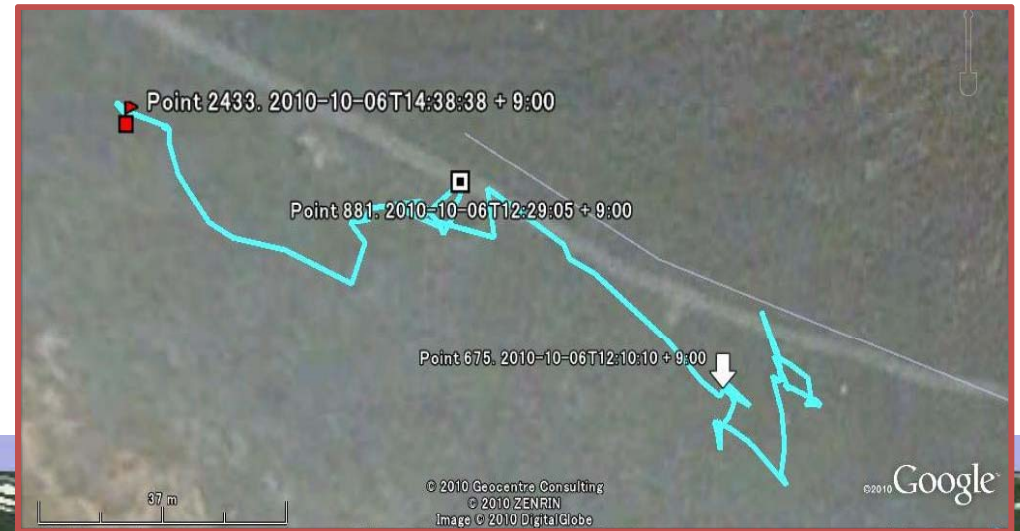


Max velocity is about 8cm/sec

Field Testing of the TrackWalker



Field Testing of the TrackWalker



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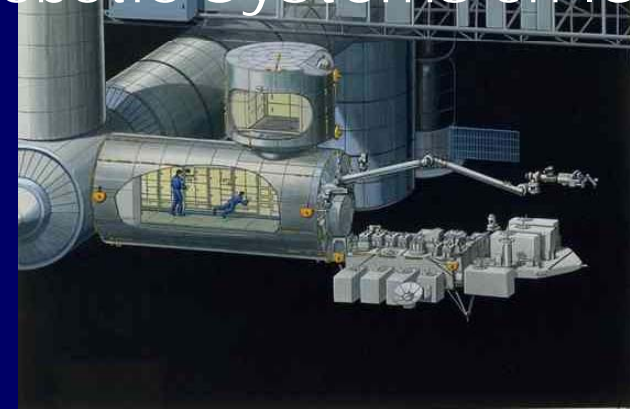
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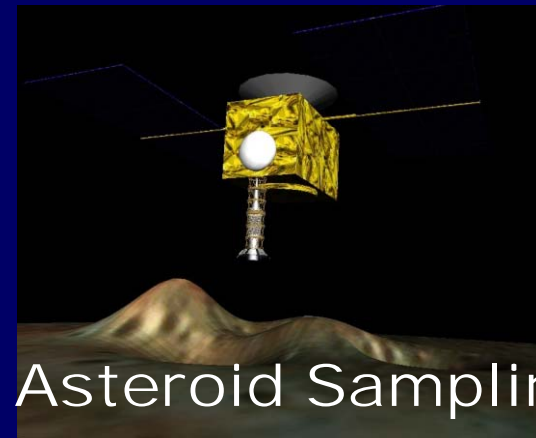
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Robotic Systems on ISS



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Planetary Exploration Rovers

Asteroid Sampling