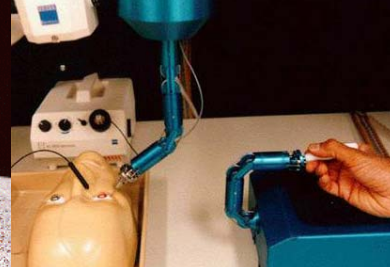
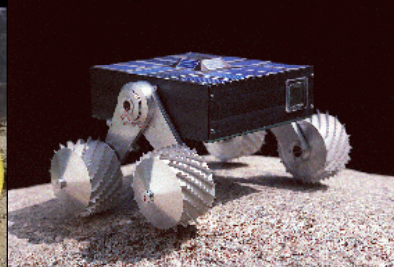
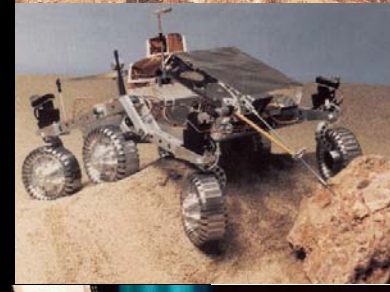


ICRA 2010

# Planetary Rovers Workshop

Organized by  
**Richard Volpe**  
*Mobility & Robotic Systems Section  
NASA's Jet Propulsion Laboratory,  
California Institute of Technology*

May 2010



# Today's Agenda

## ICRA 2010 Planetary Rover Workshop, 3 May 2010, 9:00am-5:30pm

	Lastname	Firstname	Topic	Org	duration	start	end
1	Volpe	Richard	Intro	NASA JPL	0:15	9:00	9:15
2	Matthews	Jaret	ATHLETE	NASA JPL	0:35	9:15	9:50
3	Bluethmann	Bill	LER / Robonaut2	NASA JSC	0:35	9:50	10:25
4	Krenn	Rainer	Rover Simulation	DLR	0:35	10:25	11:00
			<i>coffee 1</i>		0:10	11:00	11:10
5	Sherman	Alana	Benthic Rover	MBARI	0:35	11:10	11:45
6	Yoshida	Kazuya	Traction Performance	Tohoku Univ.	0:35	11:45	12:20
7	Pradalier	Cedric	High Mobility Rovers	ETH Zurich	0:35	12:20	12:55
			<i>lunch</i>		1:20	12:55	14:15
8	Barfoot	Tim	Field Testing GN&C	Univ Toronto	0:20	14:15	14:35
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10	Kubota	Takashi	Robotics Technology	ISAS,JAXA	0:20	14:55	15:15
11	Tunstel	Eddie	Asteroid Roving	APL	0:20	15:15	15:35
			<i>coffee 2</i>		0:10	15:35	15:45
12	Williams	Stephen	Visual Navigation	GT	0:20	15:45	16:05
13	Cordes	Florian	Robot Teams	DFKI	0:20	16:05	16:25
14	Dasgupta	Prithviraj	Modular Robots	Omaha	0:20	16:25	16:45
15	Pivtoraiko	Mihail	Trajectory Planning	CMU	0:20	16:45	17:05
16			wrap up		0:20	17:05	17:25
			<i>dinner</i>				

# Related Past Workshops

- [Planetary Rover Workshop](#), IEEE International Conference on Robotics and Automation (ICRA), Pasadena CA USA, 19 May 2008
- [Space Robotics Workshop](#), IEEE International Conference on Robotics and Automation (ICRA), Rome Italy, 14 April 2007.
- [Planetary Rover Workshop](#), IEEE International Conference on Robotics and Automation (ICRA), Barcelona Spain, 22 April 2005.
- [Mars Rover Technology Workshop](#), IEEE Aerospace Conference, Big Sky Montana, March 7-15 2004.
- [Planetary Rover Workshop](#), IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Grenoble France, 7 September 1997.

# Archiving Presentation Material

- As in previous years, all presentations and supporting material will be posted on the website for future reference. Please see

<http://ewh.ieee.org/conf/icra/2010/workshops/PlanetaryRovers/>

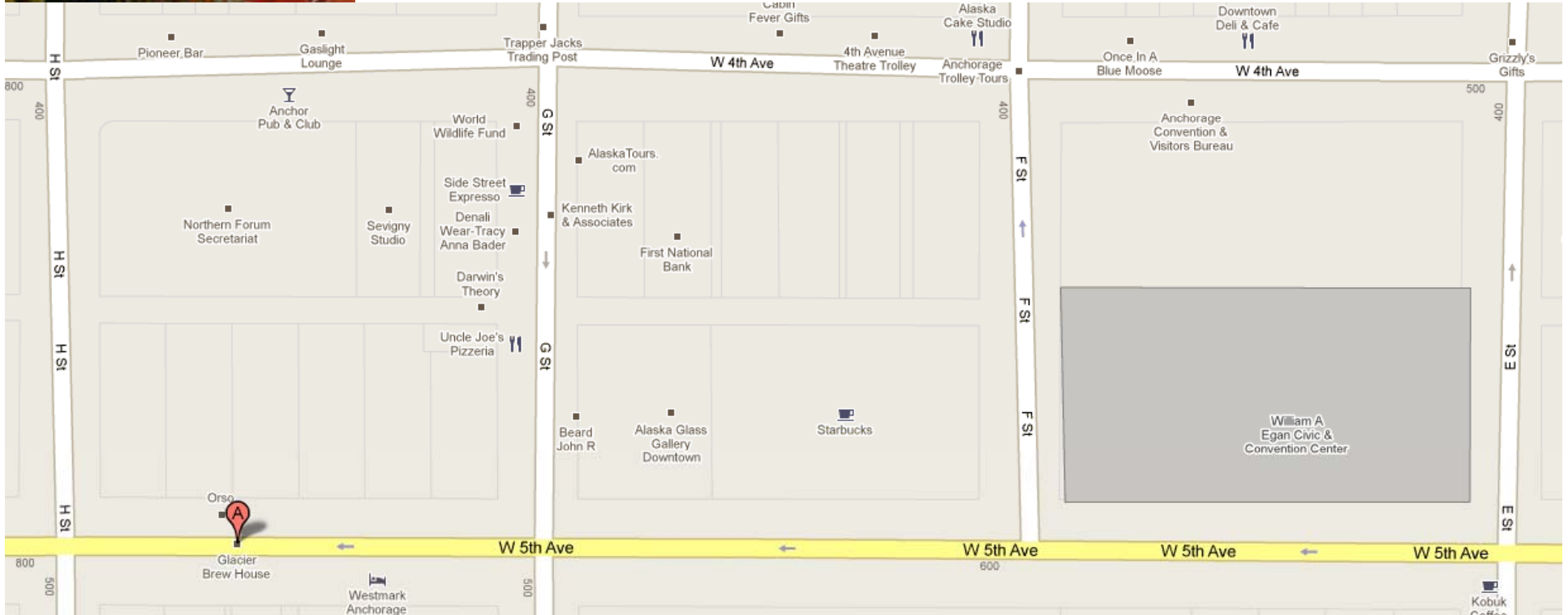
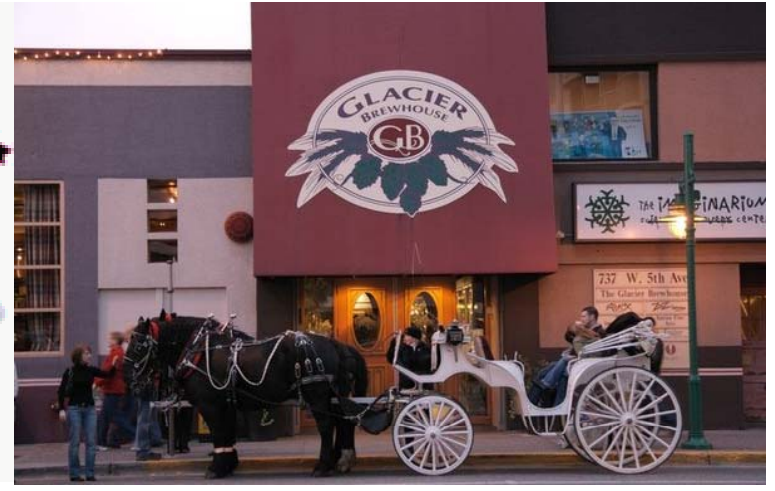
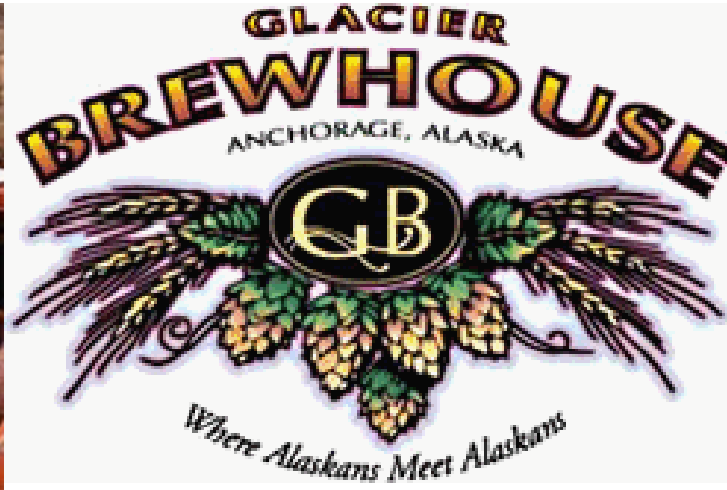
- Or follow the link from the ICRA 2010 tutorials webpage.
- Please put your talk and supporting material (e.g. movies) on the memory stick after each talk.

# Workshop Logistics

- Speakers are requested to finish within allocated time, and allow for a few questions.
- Audience is requested to return from breaks promptly, to allow the schedule to proceed without delay or distraction.
- Some end of day discussion time is allocated, but could extend to dinner if desired by the group.
- Please put the requested information on the sign-up sheet which will be passed around. This will be used to contact you for follow-up communications.



# Dinner at Glacier Brewhouse? 6:30pm?



# Discussion Topics

- What aspects of the problem might we consider solved?

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- What aspects of the problem might we consider solved?
- What are the key outstanding problems to be solved?



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- What aspects of the problem might we consider solved?
- What are the key outstanding problems to be solved?
- How does the technology apply to other targets (Jovian moons, Venus, Earth(?), etc.)

# Related Conference

*If you like Alaska, you'll like Montana...*

## **2011 IEEE Aerospace Conference**

AIAA, Technical Co-Sponsor

March 5-12, 2011

Big Sky, Montana

<http://www.aeroconf.org/>

Track 2: Space Missions, Systems, and Architecture

Session 2.09: **Mobility and Robotics Systems for In Situ Exploration**

Chairs: R. Volpe & W. Zimmerman

Abstract (300–500 words) due:

Draft paper (6–20 pages) deadline:

Reviewed paper returned to author:

Final paper deadline:

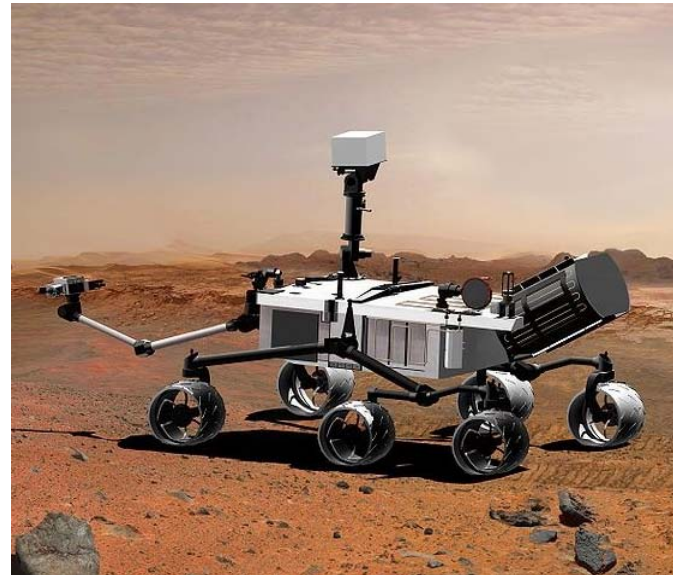
**July 1, 2010**

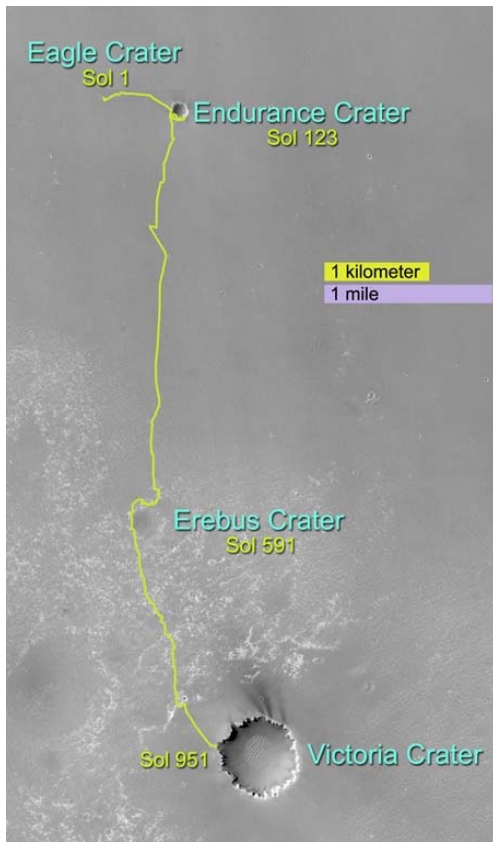
**October 26, 2010**

November 12, 2010

January 11, 2011

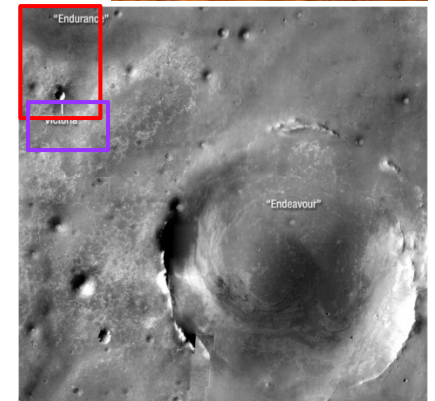
# Mars Rovers Status Update





## MER Mars Rover Update – *Opportunity*

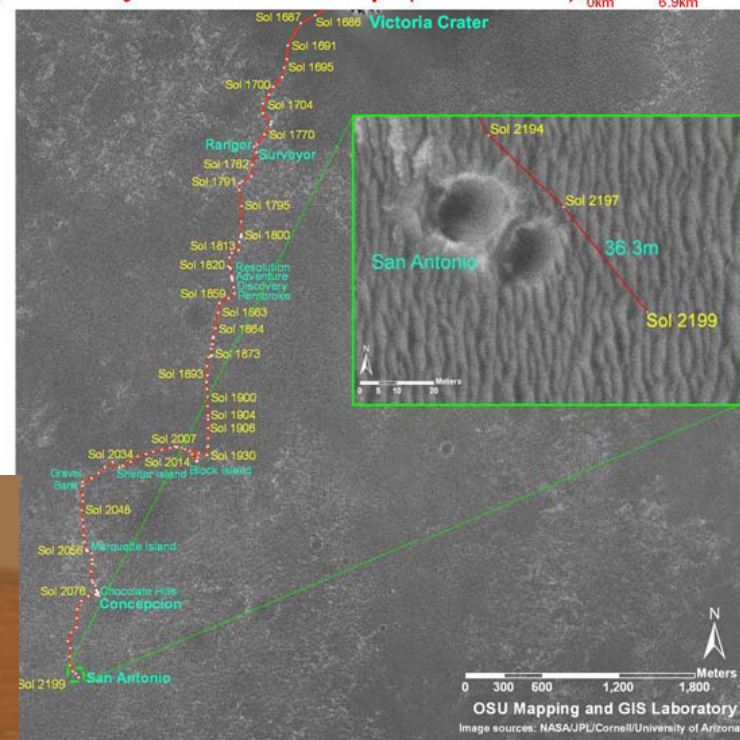
- **Mission:** Prime mission was 90 days and 600m, but... now at 2226 sols and 20.6 km.
- **Plans:** Next objective is entrance to Endeavor crater which is 13 km away (still)!
- **Best Performance:** 390 m over 3 sols
- **Technologies:** stereo, VO, D\*, onboard science, etc.
- **System:** One dead steering joint, and problems with one manipulator shoulder joint and one wheel drive
- **Terrain:** Relatively flat in general, but large dune fields are a proven obstacle.



### Opportunity Traverse Map (Sol 2199)



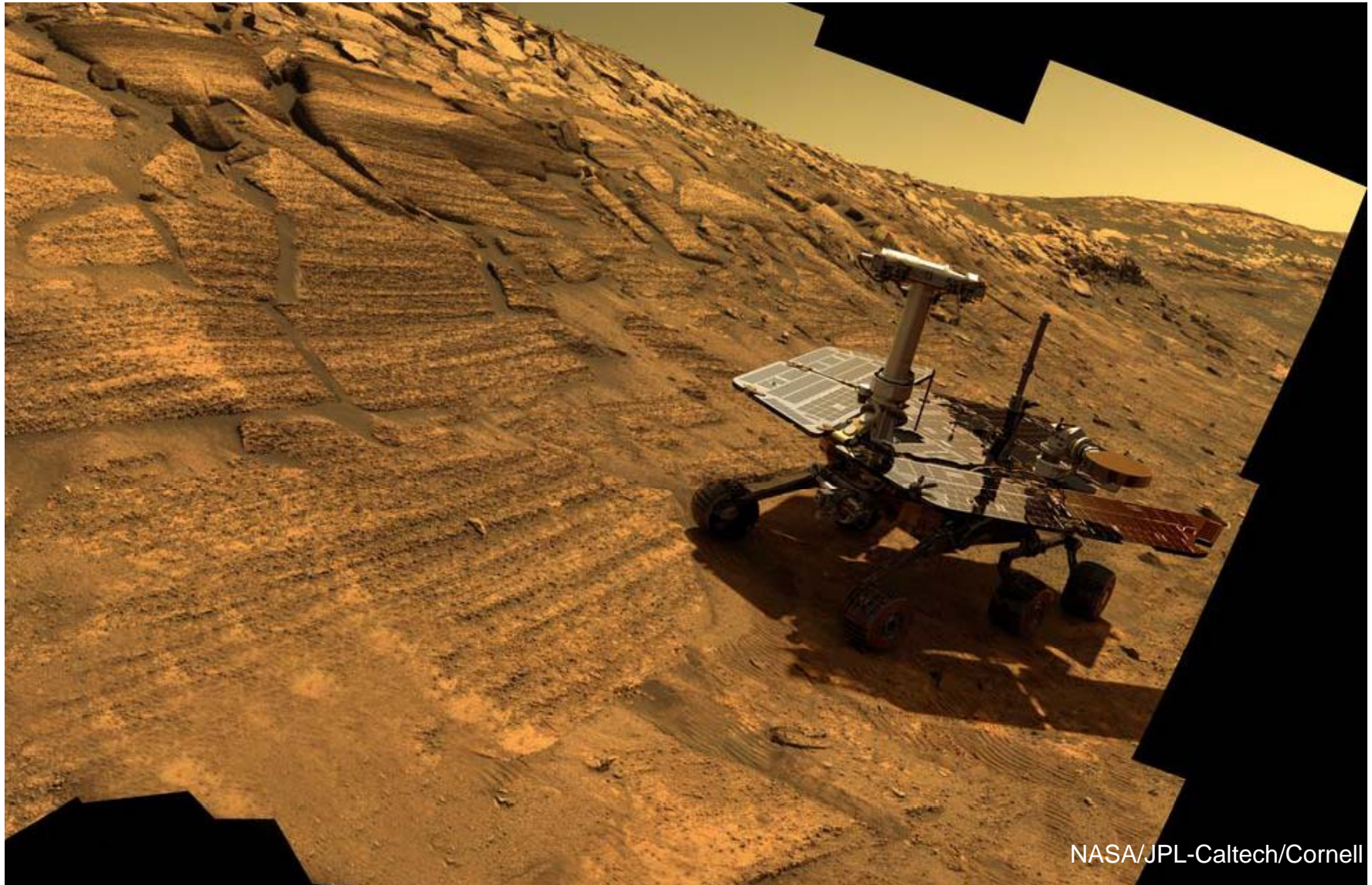
Rover viewed  
from orbit







# Opportunity at 25-30° in Endurance Crater

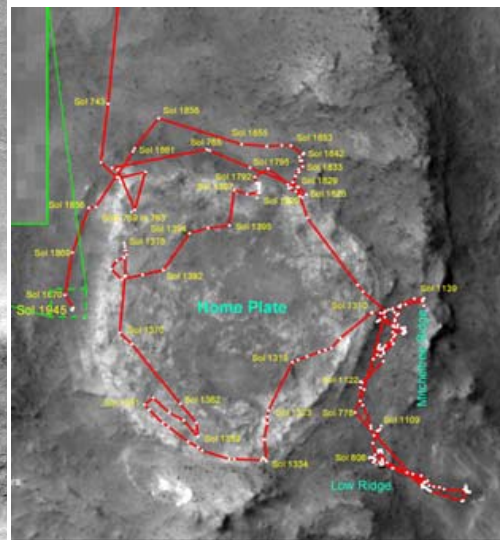
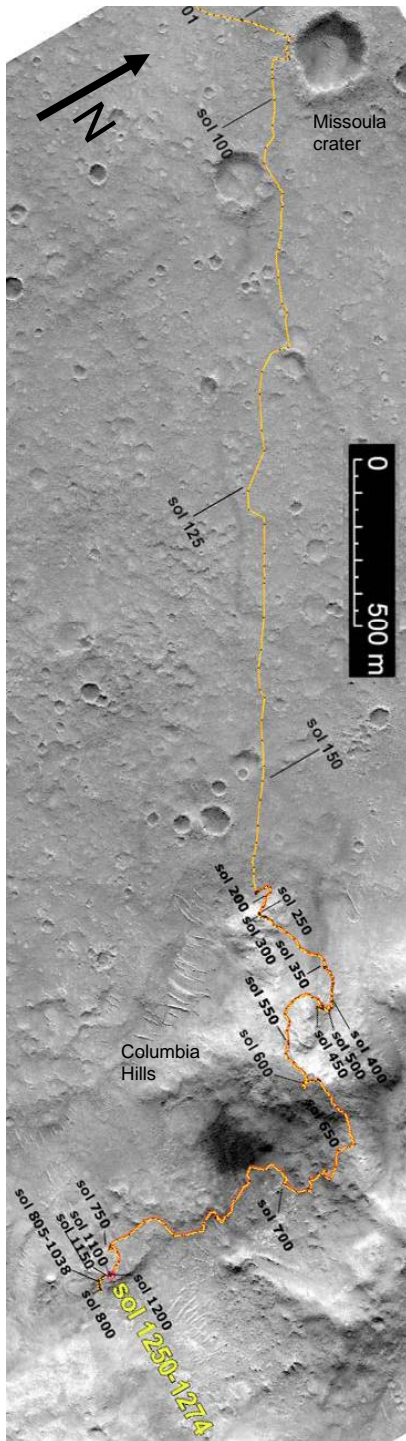


NASA/JPL-Caltech/Cornell

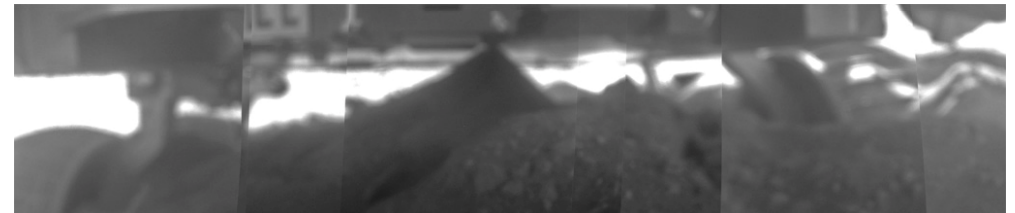


## MER Mars Rover Update – *Spirit*

- **Mission:** Prime mission was 90 days and 600m, but... now at 2158 sols and 7.7 km, but stuck
- **Plans:** Continued study of geology near “homeplate” feature.
- **System:** Mobility system is not functioning – 2 wheel drives are dead (leading to science discoveries and nightmares).
- **Terrain:** Rough and rocky, more craters, hills. Locally soft.
- **Status:** Winter on Mars, rover is “hibernating” with low power levels, and it’s mobility system is stuck in soft terrain. No communication since March 22. Winter solstice is in 10 days.

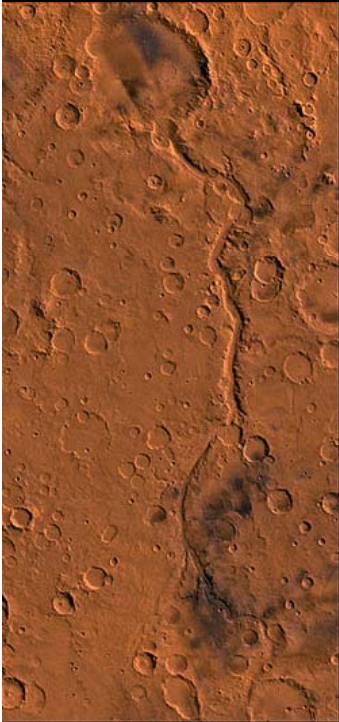


Rover and tracks viewed from orbit

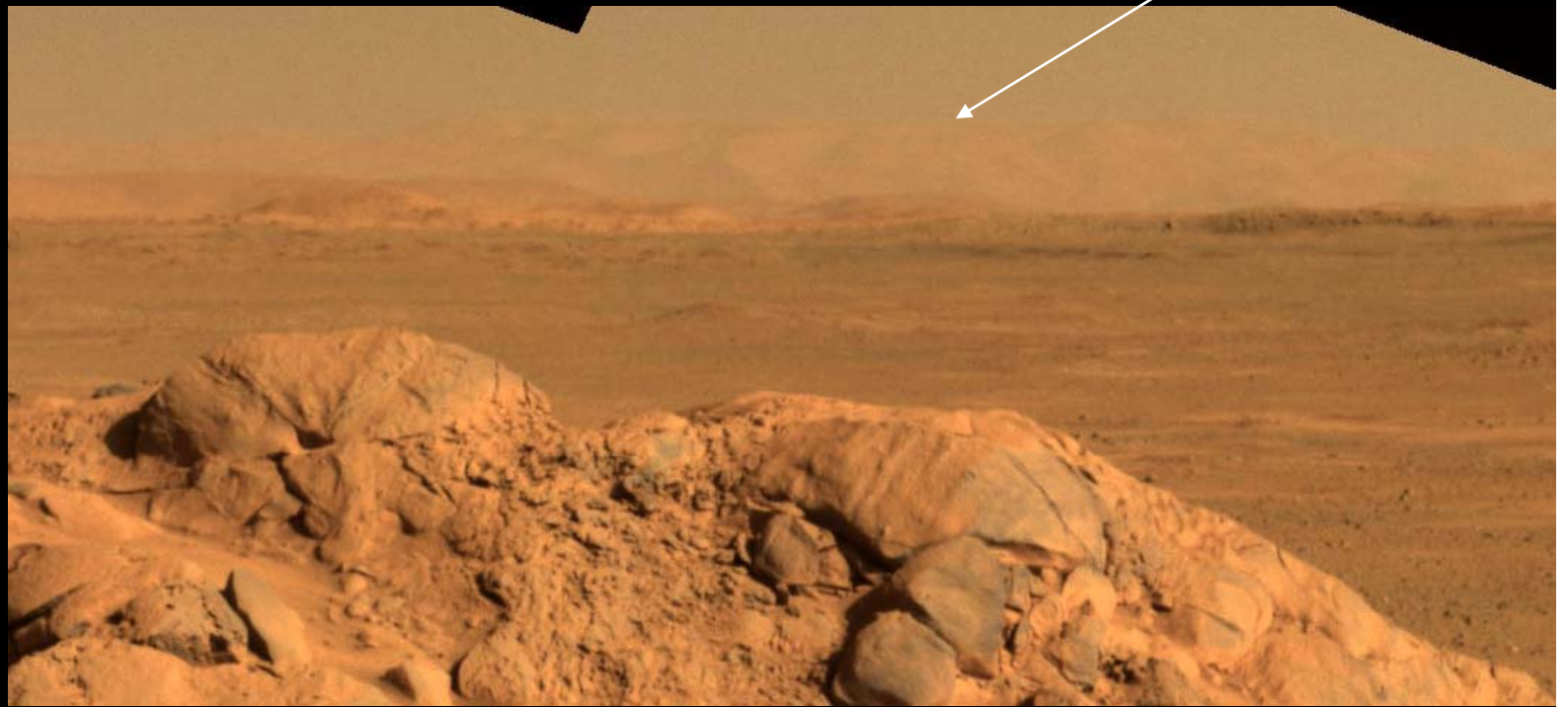


# View from Columbia Hills Gusev Crater

Crater Wall  
(50 miles)



View from  
orbit





## Spirit Finds Salts by dragging wheel

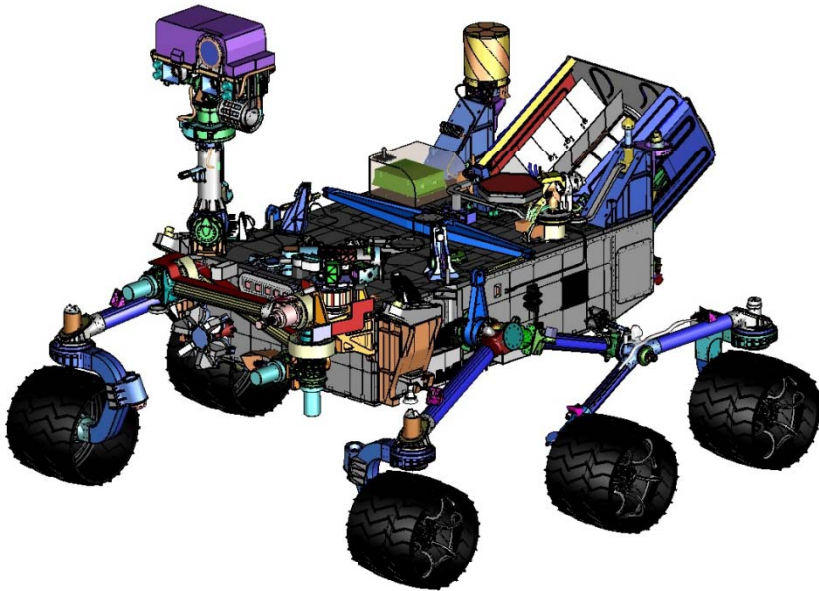


NASA/JPL/Cornell

# MSL Overview

## Science

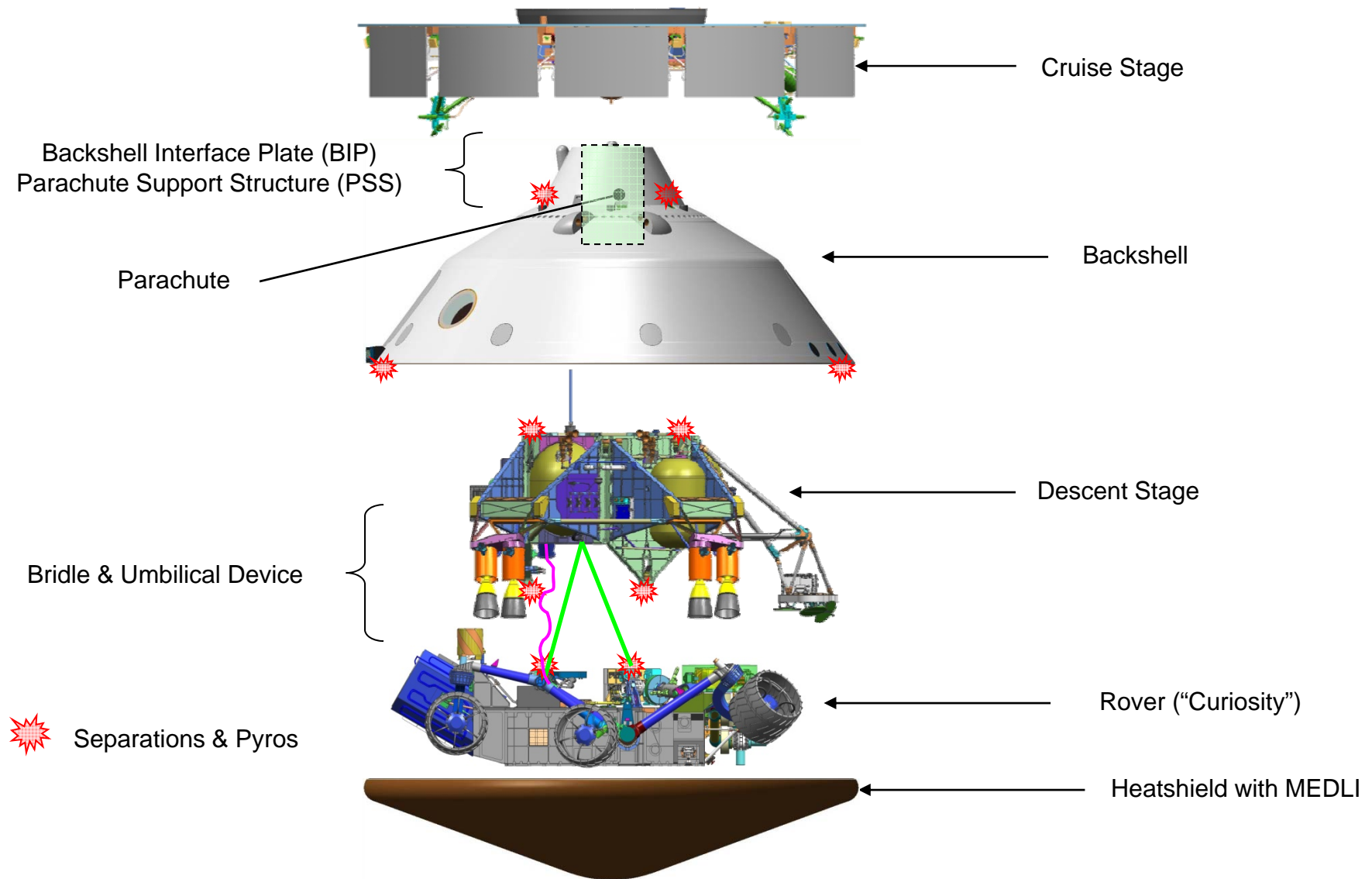
- Focus on Past & Present Habitability of Mars
- Highly Capable Analytical Laboratory
- Next Generation Remote Sensing & Contact Investigations



## Technical Capabilities

- One Mars Year surface operational lifetime (669 sols/687 days)
- Precision Landing via Guided Entry and Skycrane Propulsive Landing
- Long Distance Traverse Capability (20 km)
- Flexible & Robust Sample Acquisition & Processing

# MSL Spacecraft Major Elements





# *MSL Flight System Development*

scheduled for launch in Oct 2011





## *2011 Mars Science Laboratory* JPL Robotics contributions

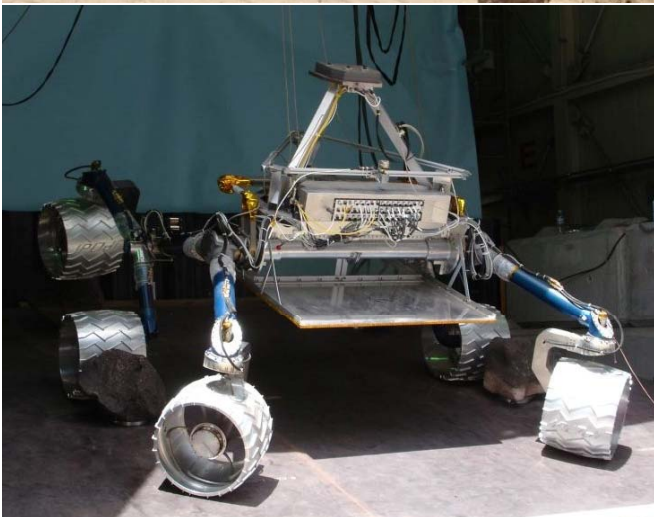


*MSL EM  
Arm*

1. All MER technology
2. Improvements on MER baseline in all areas.
3. Simulation for Entry, Descent, and Landing (EDL) mission analysis.
4. Design, development, and operations staff.



*MSL  
'Scarecrow'  
Mobility Test*



*MSL  
'Scarecrow'  
Drop Test*

*MSL 'Sky Crane' Testing*



## MSL: Capabilities and Status

- Faster CPU (up to 200 MHz vs 20 MHz) and larger nonvolatile flash storage (4 Gbytes vs 0.25 Gbytes) should enable more operational use of autonomy
- Vehicle twice as big in all dimensions, 2X larger wheels will reduce number of rocks perceived as obstacles
- Max possible driving speed similar to MER (6 cm/s vs 5 cm/s)
- Many more sensors on SA/SpAH instrument arm (arm weighs as much as MER).
- STATUS: in development and test
- Launch planned for late 2011
- ATLO activities underway, first mobility tests planned later this year
- Initial FSW tests showed multiple-times speedup, but no hard numbers until we get the complete system in place

Questions?

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