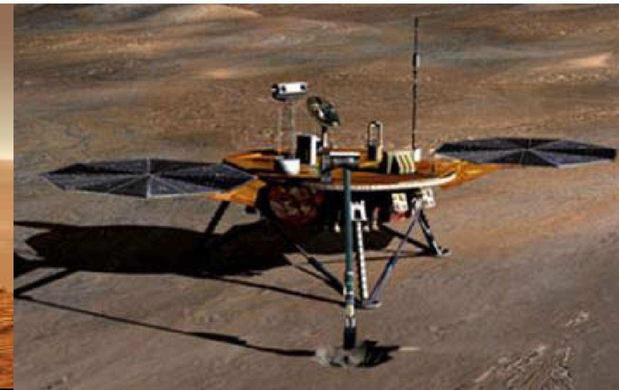
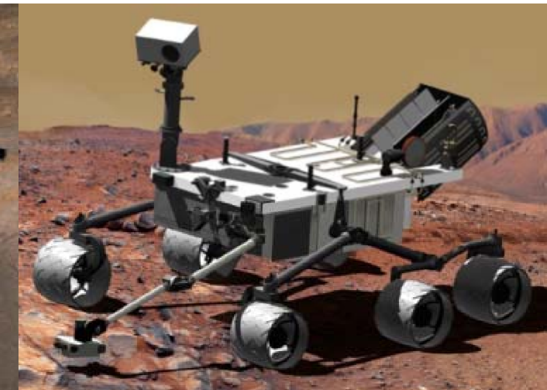



IEEE ICRA 2011

Space Robotics Workshop

Introduction and JPL Robotics Activities Summary

Organized by

Richard Volpe

Manager , Mobility & Robotic Systems Section

Jet Propulsion Laboratory

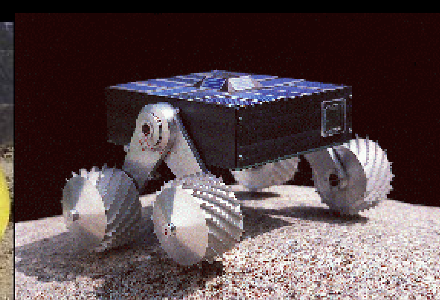
California Institute of Technology

May 2011










Today's Agenda

	Presenter	Org	Country	Topic	start	end	length
1	Richard Volpe	NASA-JPL	USA	Introduction & JPL Robotics	9:00	9:30	0:30
2	Rob Ambrose	NASA-JSC	USA	Robonaut 2	9:30	10:00	0:30
3	Rainer Krenn	DLR	Germany	Satellite Docking	10:00	10:30	0:30
				coffee	10:30	10:45	0:15
4	Maxime Chalon	DLR	Germany	DLR Manipulation	10:45	11:15	0:30
5	Hiroshi Ueno	JAXA	Japan	JEMRMS	11:15	11:45	0:30
6	Takashi Kubota	JAXA	Japan	Advanced Probes	11:45	12:15	0:30
				lunch	12:15	13:45	1:30
7	Glen Henshaw	NRL	USA	Hybrid AI/Control Systems	13:45	14:15	0:30
8	Kazuya Yoshida	Tohoku Univ	Japan	Dynamics and Control	14:15	14:45	0:30
9	Brent Tweddle	MIT	USA	SPHERES	14:45	15:15	0:30
				coffee	15:15	15:30	0:15
10	Sarmad Aziz	ESA	Canada	European Robot Arm	15:30	16:00	0:30
11	Yu Liu	Harbin Inst. of Tech.	China	Arm Parameter Identification	16:00	16:30	0:30
				discussion	16:30	17:00	0:30

Outline:

1. ***Intro to Workshop***
2. ***Workshop Logistics***
3. ***Space Robotics Technical Committee***
4. ***Overview of Selected JPL Robotics Topics***

Related Past Workshops

- Planetary Rovers Workshop, IEEE International Conference on Robotics and Automation (ICRA), Anchorage AK USA, 3 May 2010
- Planetary Rovers 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 Rovers 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 Rovers 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/2011/workshops/SpaceRobotics/

- *Or follow the link from the ICRA 2011 workshops webpage.*

- Please put your presentation and supporting material (e.g. movies) on the memory stick after each talk.

Making the day go smoothly…

- 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 Proposal

South Beauty
Super Brand Mall
10th Floor, West Zone
Phone: 5047 1817

俏江南 SOUTH BEAUTY

Menu: http://en.southbeautygroup.com/comcontent_detail_cp.html

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 applications?

IEEE RAS Technical Committee – Space Robotics
Status Report

Web info:
- IEEE site: http://tab.ieee-ras.org/committeeinfo.php?tcid=28
- Wagner site: http://rjwagner49.com/Robotics/SpaceRobotics/SpaceRoboticsTC.html

New, Spring 2011 Chairs:
- Richard Volpe (JPL)
- Kazuya Yoshida (Tohoku Univ.)
- Dimi Apostolopoulos (CMU)

Membership
- List available online: http://rjwagner49.com/Robotics/SpaceRobotics/Membership.html

Affiliation
- AIAA SARTC: http://www.aiaa.org/content.cfm?pageid=234&id=88 *(several people here today)*

News and Reporting
- send comments, news, announcements to volpe@jpl.nasa.gov
- planned new website
- possible new wiki
- suggestions?

Upcoming Conferences
- Aerospace Conference 2012 (USA)
- I-SAIRAS 2012 (Italy)
- other?

Related Conference

If you can't attend ICRA12 in Minnesota, consider Montana…

2012 IEEE Aerospace Conference
AIAA, Technical Co-Sponsor
March 3-10, 2012
Big Sky, Montana (near Yellowstone NP)

http://www.aeroconf.org/

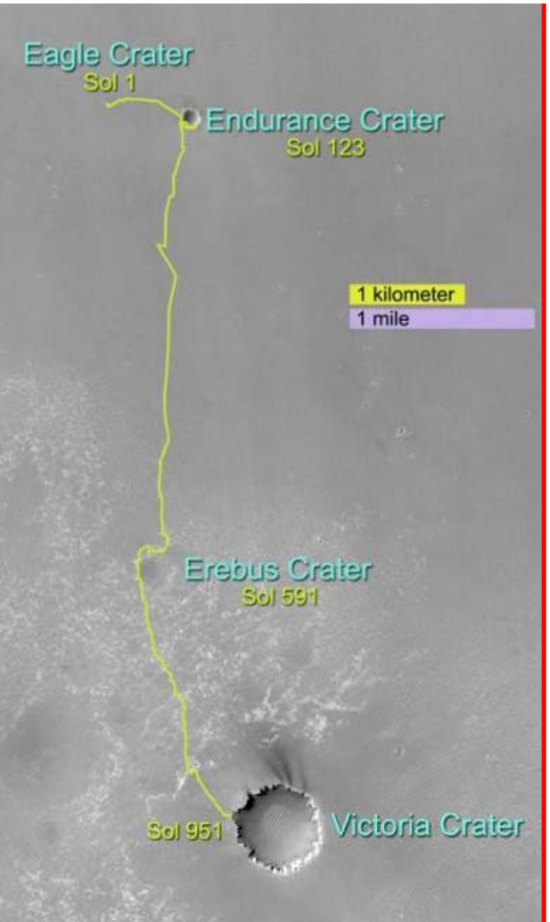
Track 2: Space Missions, Systems, and Architecture
Session 2.09:
Mobility and Robotics Systems for In Situ Exploration
Chairs: R. Volpe & W. Zimmerman

Abstract (300–500 words) due:	*July 1, 2011*
Draft paper (6–20 pages) deadline:	*November 3, 2011*
Final paper deadline:	January 4, 2012

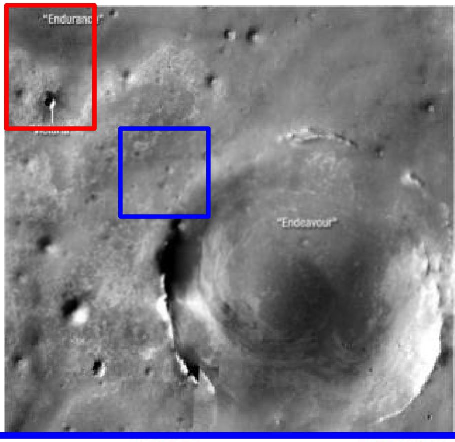
JPL Space Robotics Overview

Flight Projects, MER & MSL

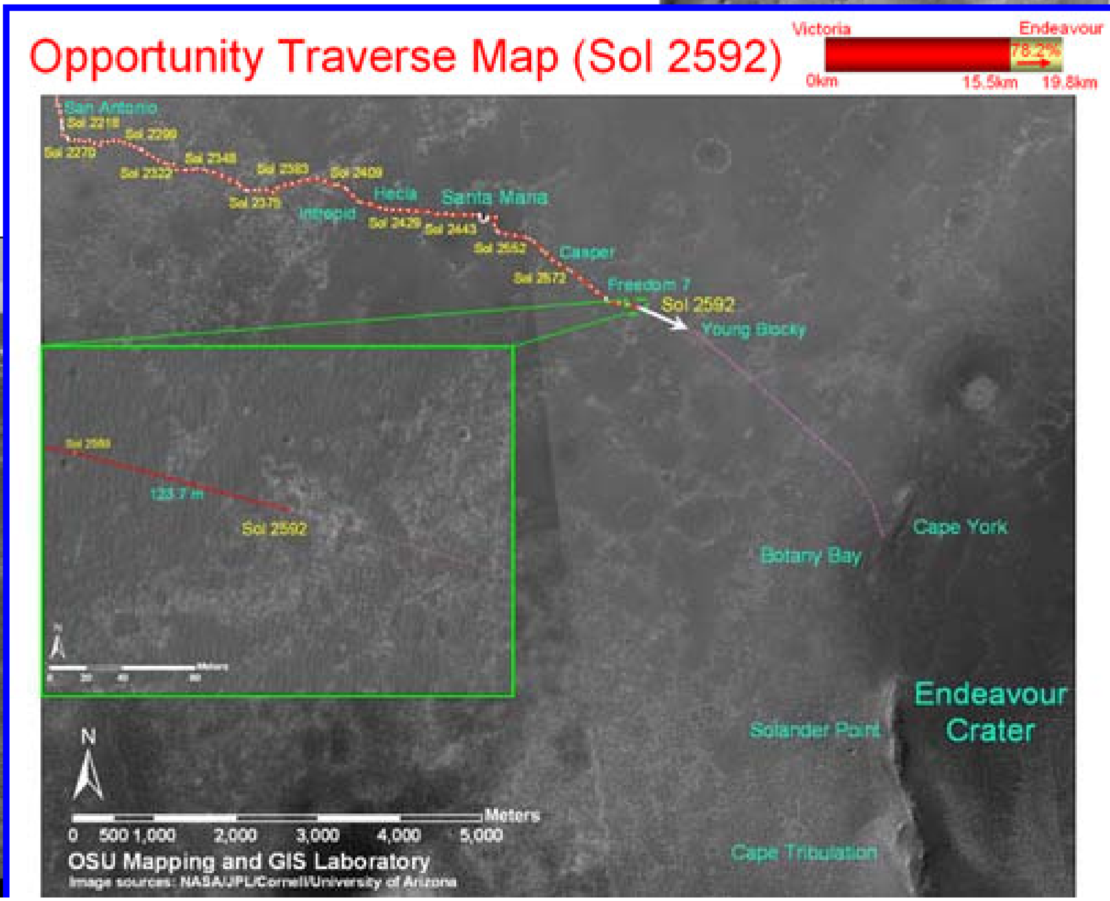
MER Mars Rover Update – Opportunity

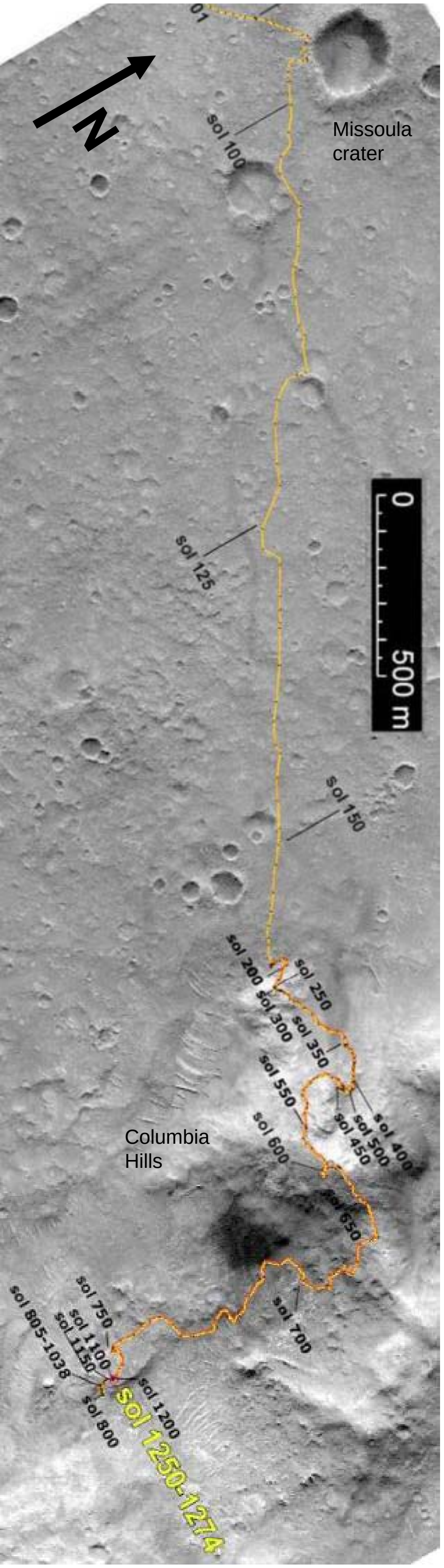


- ***Mission:*** Prime mission was 90 days and 600m, but… now at 2587 sols and 29 km.
- ***Plans:*** Next objective is entrance to Endeavor crater which is ~5 km away.
- ***System:*** One dead steering joint, and problems with one manipulator shoulder joint and one wheel drive
- ***Terrain:*** Relatively flat in general, but large dune fields are a proven obstacle.



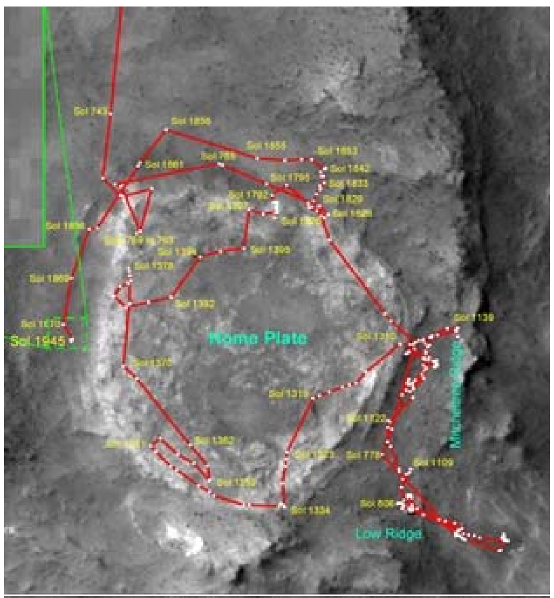
Latest view of the surface



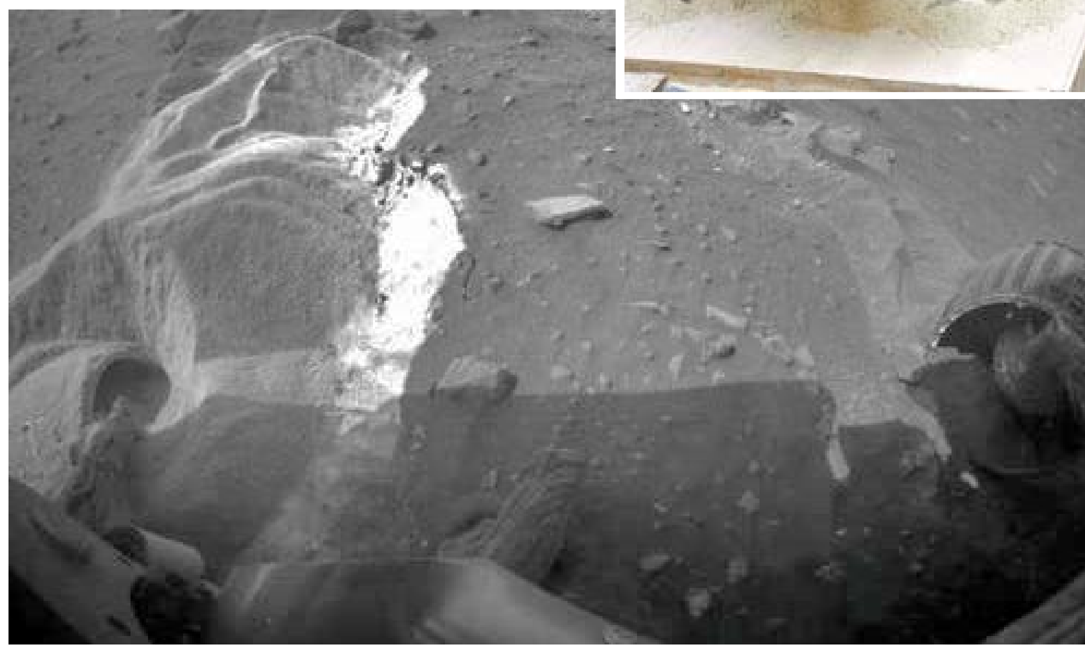


MER Mars Rover Update – Spirit

- ***Mission:*** Prime mission was 90 days and 600m, but achieved at least 2210 Sols and 7.7km. Now at Sol 2555 with no further communication since 22Mar2010, despite regular attempts.
- ***Plans:*** Stationary monitoring station. Possible further attempts to get free from soft soil trap.
- ***System:*** Mobility system is showing its age – one wheel drive is dead, leading to science discoveries and nightmares.
- ***Terrain:*** Rough and rocky, more craters, hills. Locally soft.
- ***Status:*** Increasing solar insolation improve chances of possible rover recovery. Press conference in early June.



Rover and tracks viewed from orbit



MSL Flight System Development

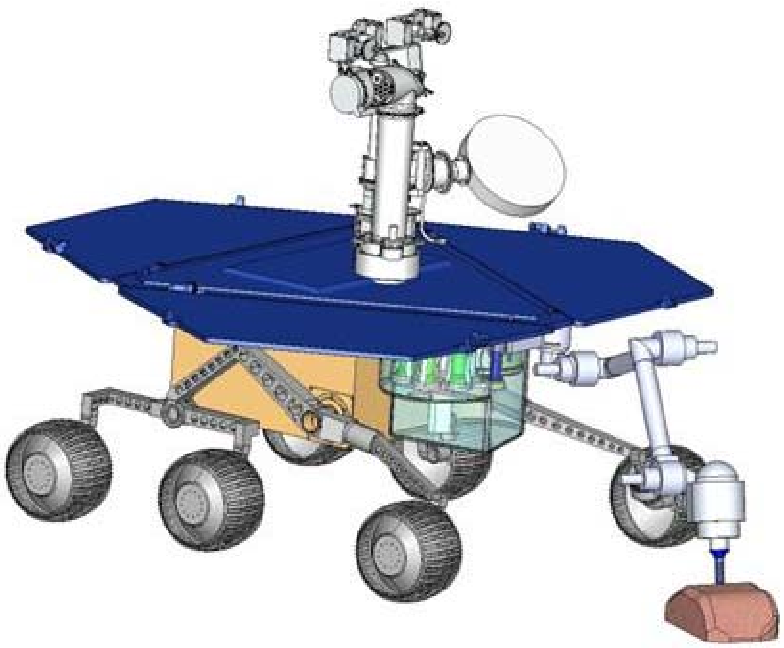
Launch Nov/Dec 2011 – Land Aug 2012

Drive movie
Arm movie
Mission animation

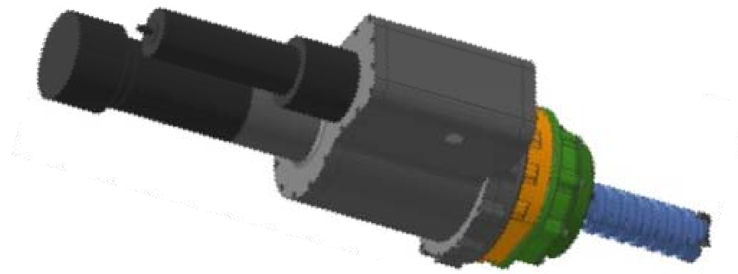
Research for Future Missions

Mars Sample Return* Technology Development

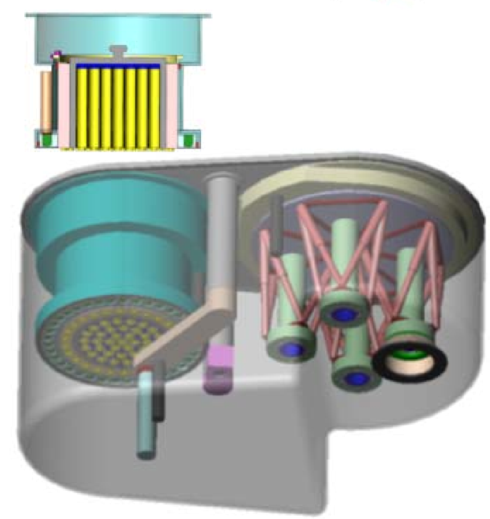
[PI: Paul Backes]



- **Tool Deployment Device:** 5 DOF Arm
- **Coring Tool:** Rotary Percussive

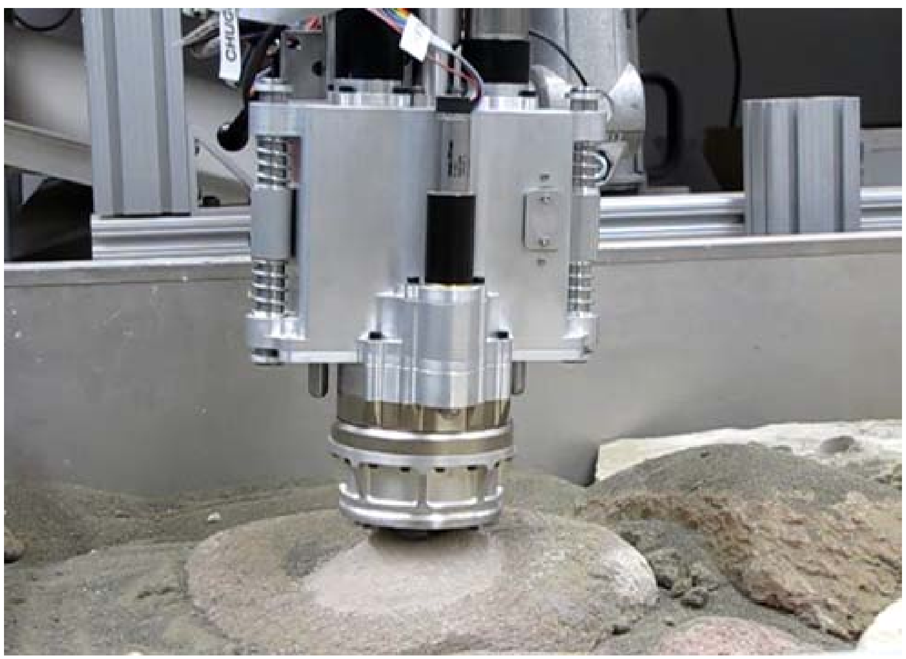


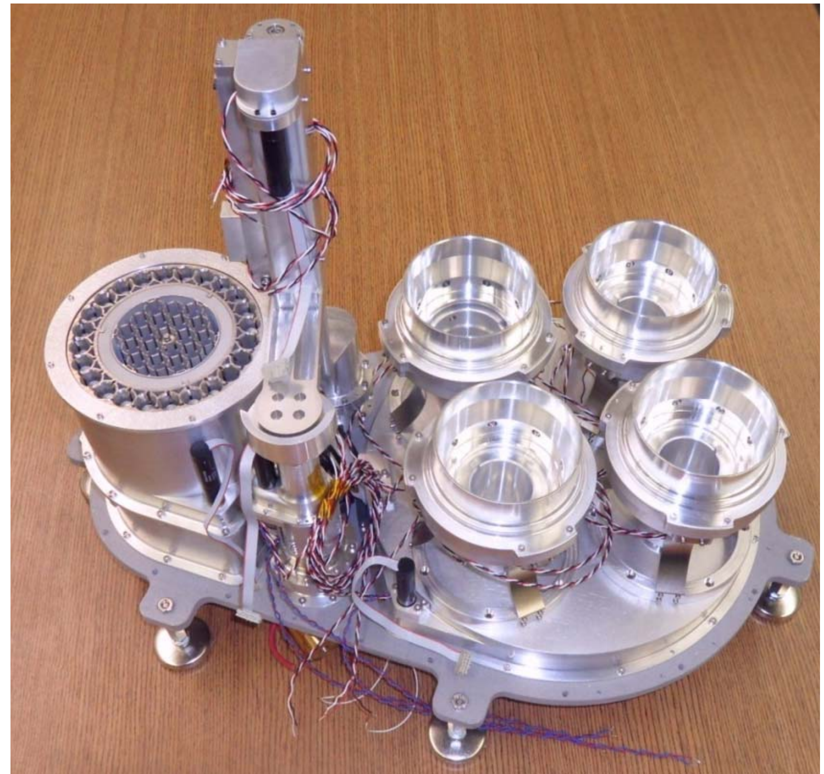
- **Caching Subsystem:**
  - Use bit changeout to transfer sample to caching subsystem in tube in bit;
  - Seal tubes, store tubes in canister;

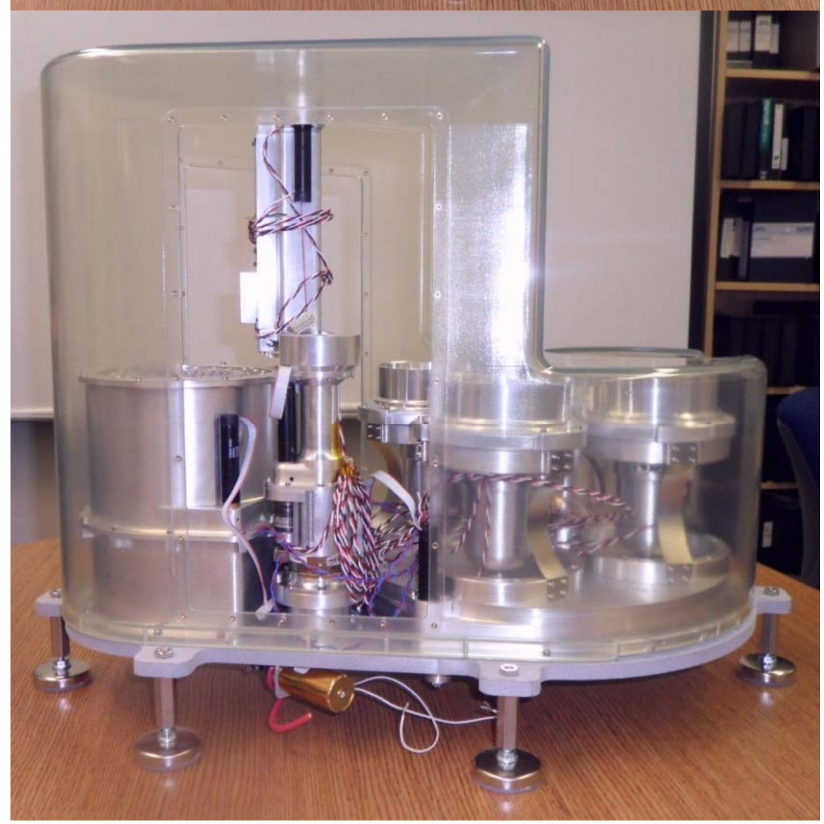


- **Operation Sequence:**
  1. Caching puts tube in bit and rotates bit to bit port;
  2. Arm puts tool at bit port and tool engages bit;
  3. Arm deploys tool to rock;
  4. Tool acquires, breaks off, and retains a core directly into a sample tube in the bit;
  5. Arm puts tool at bit port and tool releases bit;
  6. Tube is removed from bit, sealed, and stored in the canister.

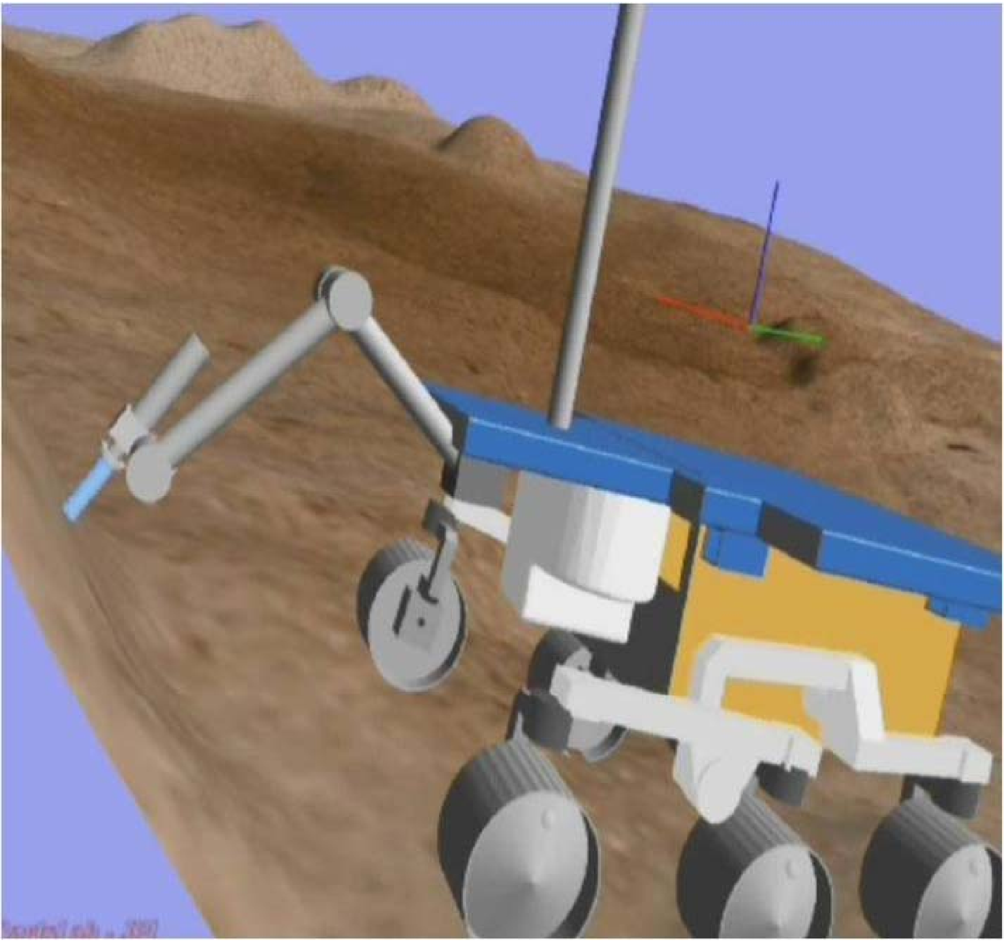
Coring and Caching Prototypes







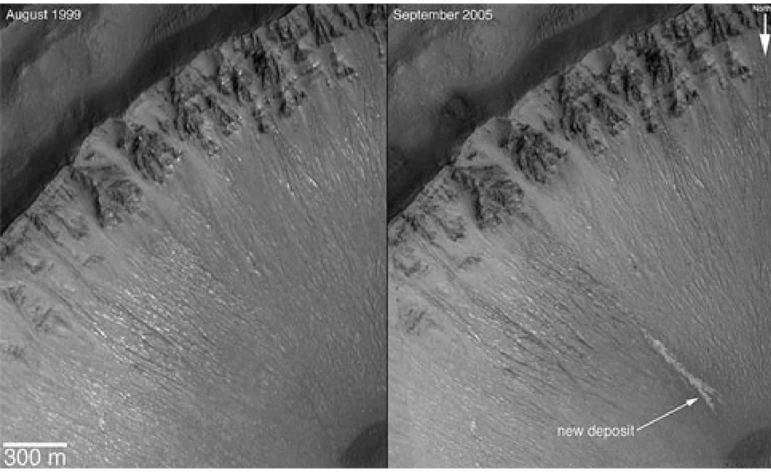
Integrated Mars Sample Acquisition and Handling (IMSAH) System Movies



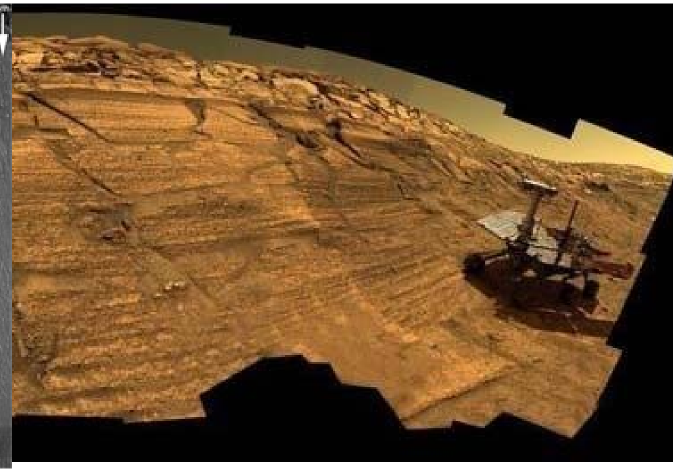
Operational Sequence Animation

Coring Autonomy Field Test
Mono Lake, CA – October, 2010

Autonomous Coring in the lab at JPL



Centauri Montes Region crater seepage



Opportunity rendered in Endurance Crater

Victoria Crater Cliff and Layers

Steep Terrain Access Systems

- water seepage and rock layering are science drivers.
- current ‘rocker-bogey’ systems limited to ~30 deg slopes.
- new system concepts are being explored. Typically tethered for access down steep terrain.

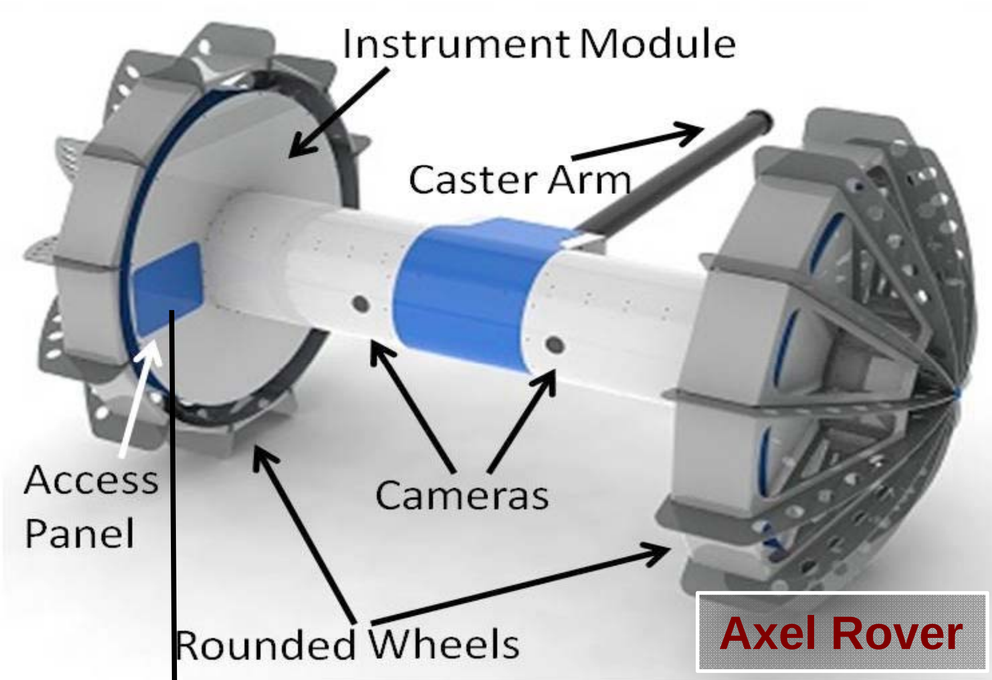
Axel 2-wheeled in Marsyard

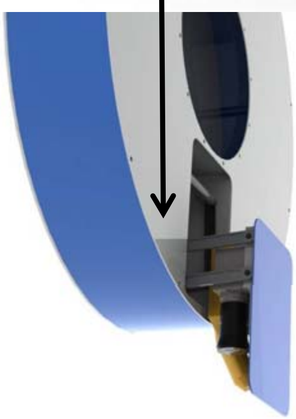
Cliffbot 4-wheeled in Norway

ATHLETE 6-wheeled New Mexico

Lemur 4-limbed in lab

Technology: Axel Robots

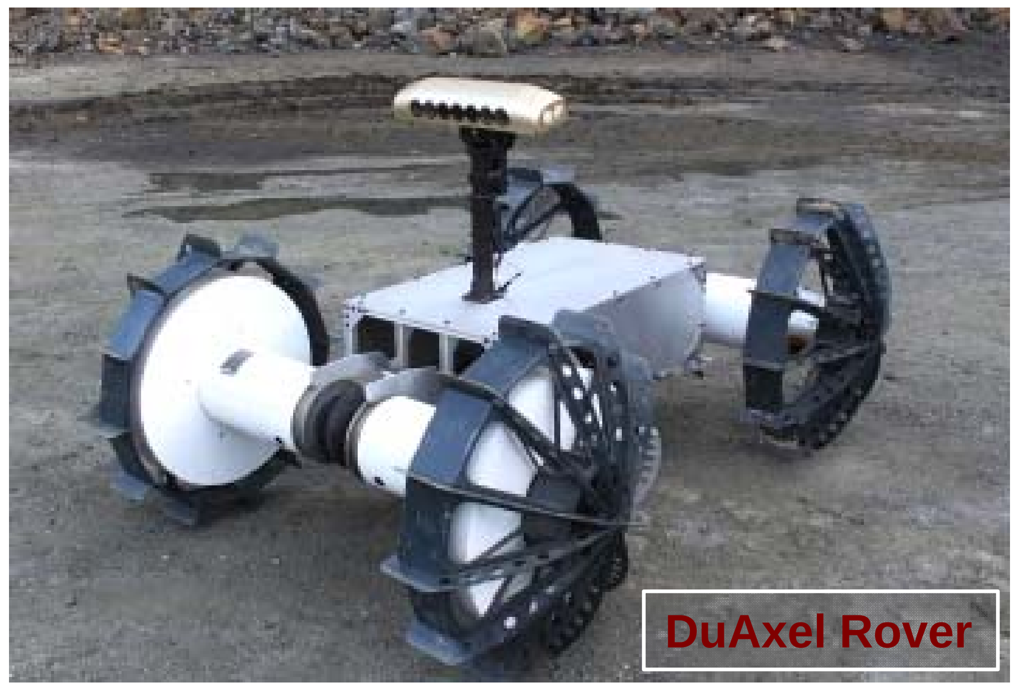




Instrument deployment

Works like a YoYo

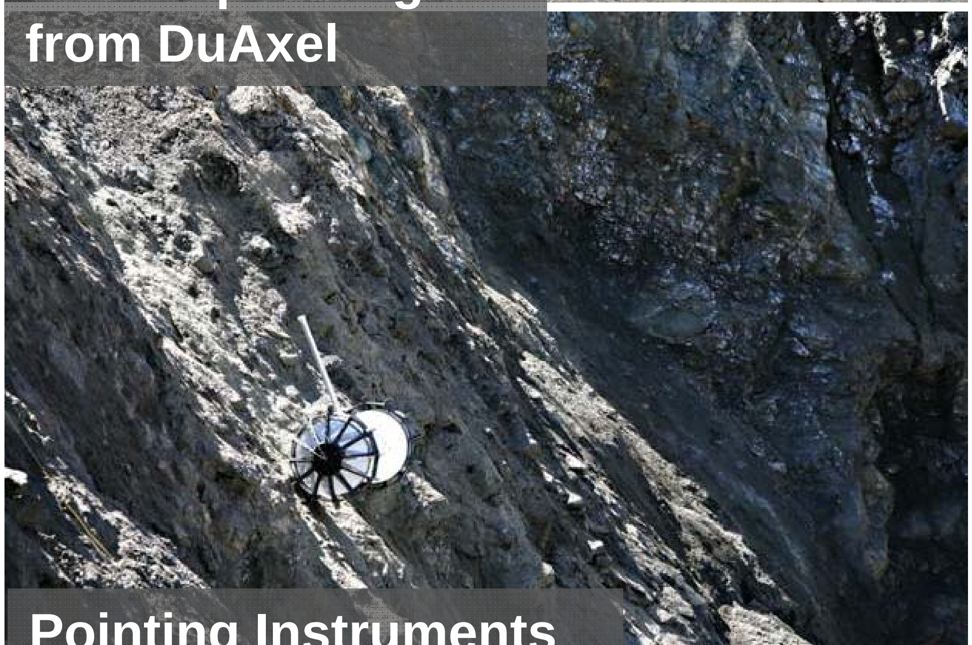
- **Versatile Mobility**
  - **Operates with and without a tether**
  - **Traverses extreme terrain**
  - **Robust: operates upside down**
  - **Simple: minimally actuated**
- **Science Capability**
  - **Acquires multiple measurements**
  - **Acquires samples**
  - **Favorable payload mass to system ratio**



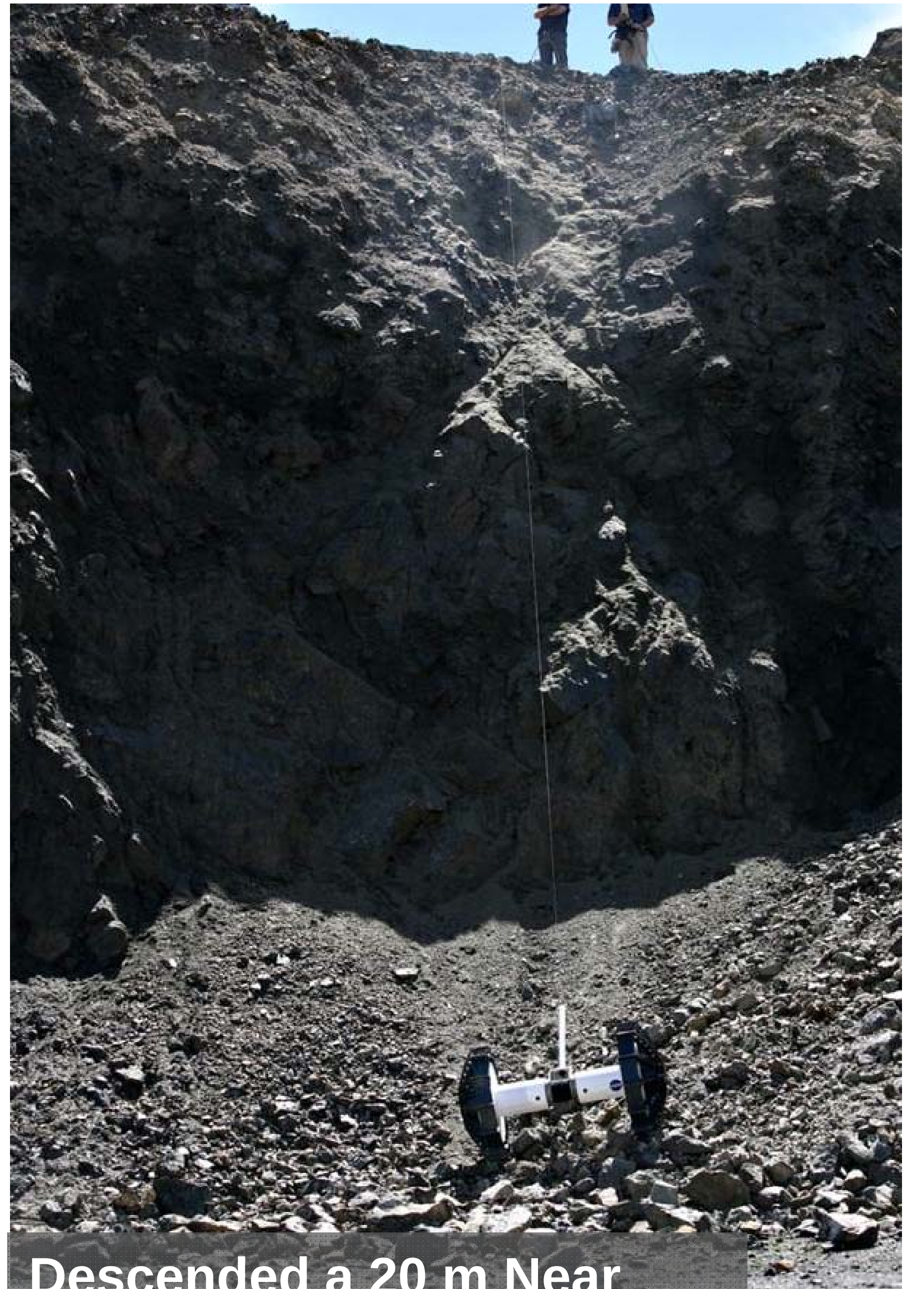
Axel/DuAxel Field Testing - Lancaster, CA

(video to be shown on National Geographic 6/11)

Axel Separating from DuAxel



Pointing Instruments on Cliff face



Descended a 20 m Near Vertical Cliff Face

Robotic Exploration of Primitive Bodies

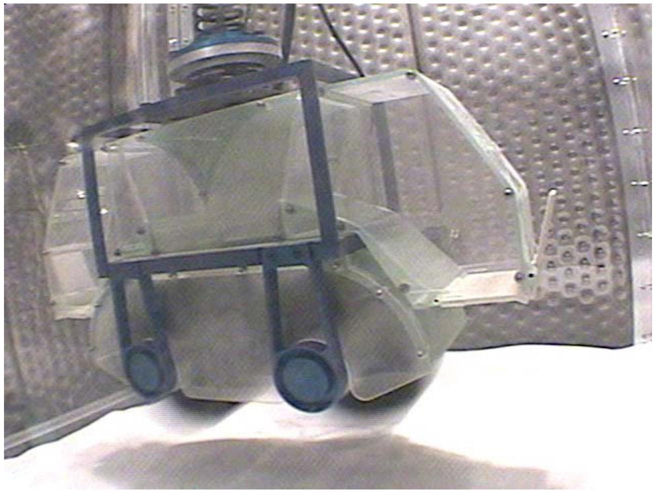
Primitive Bodies Touch-and-Go (TAG) Sampling Technology

JPL TAG Sampling Tool – Brush Wheel Sampler

video

Sample Acquisition
- Flight-like shaped canister
- 60° off alignment to 30° slope
- 50-80 kPa mixed pumice
- 0.5 kg/s collection rate

Sample Acquisition
- Flight-like shaped canister
- 30° slope
- 6 cm/sec horizontal velocity
- Glass bead simulant
- 0.22 kg/sec collection rate



Sample Acquisition
- Vaccum Chamber
- Glass bead simulant
- 0.22 kg/sec collection rate

Robotic Exploration of Venus

Venus Cloud-Level Balloon Concept

[PI: Jeff Hall]

- **Objective:** Develop a balloon for Venus that could float in the clouds at ~55 km altitude for a 1 month flight mission with a 100 kg payload.
- **Challenges:**
  - Clouds are made of sulfuric acid aerosols.
  - Balloon must maintain altitude despite turbulence and changing solar heating conditions (expect 5-6 circumnavigations in 1 month).
  - Balloon must be deployed from a folded/stored configuration and inflated upon arrival at Venus.
- **Solutions:**
  - Spherical helium superpressure balloon design to maintain altitude despite environment changes.
  - Laminate balloon material:
    - Aclar film for gas barrier and acid resistance (Aclar is a close chemical cousin of Teflon)
    - Vectran fabric for high strength to take pressure loads
  - Aerial deployment and inflation of the balloon during initial parachute-assisted descent
    - Would avoid the need to land first on the hot (460 °C) surface.

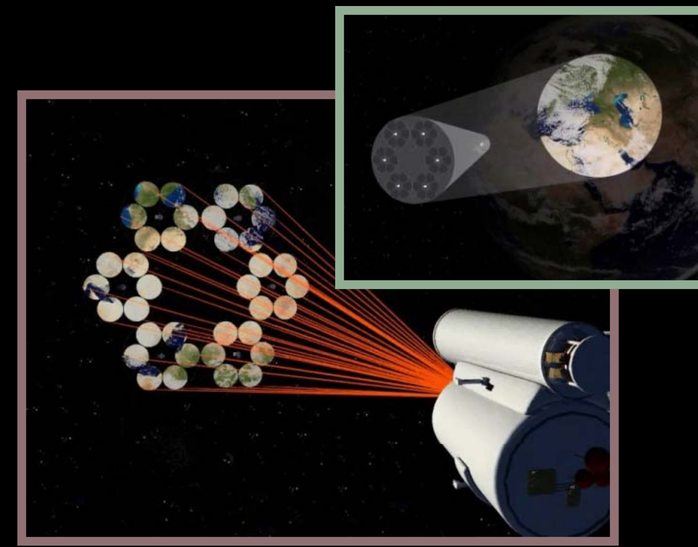
Prototype 5.5 m diameter Venus balloon

Prototype Venus balloon during aerial deployment and inflation test

Spacecraft Formation Flying

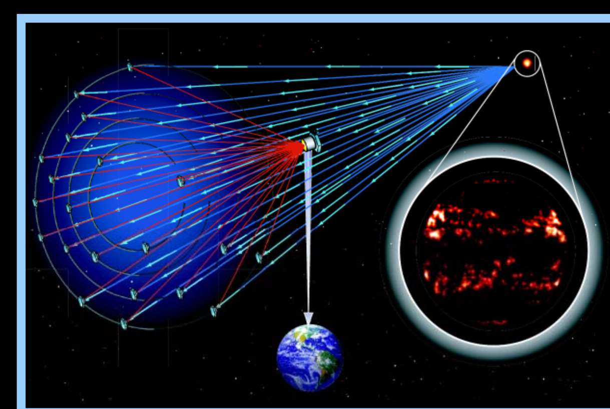
[PI: Fred Hadaegh]

- Formation: S/C coupled by feedback control with direct or Indirect coupling between all S/C
- Tightest requirements for synthetic apertures
- GEO Sparse Aperture: DARPA LASSO
  - Control requirements derived from stroke limitations of adaptive optics and deformable mirror
  - Millimeter-level error box
  - Arc second-level attitude control



- Deep Space Nulling Interferometer: TPF-I
  - Control requirements derived from stroke limitations of adaptive optics
  - Half-centimeter to several centimeter error box
  - Sub-arcminute to arc second level attitude control

- Deep Space Fizeau Synthetic Aperture: Stellar Imager
  - Sub-Centimeter-level error box
  - 32 S/C – Large formation control
  - Sub-arcminute to arc second level attitude control



Movie: JPL RoboDome Testbed

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