Example of Robotic Technology for Accessing and Sampling High-Risk Terrain

Prof. Joel Burdick
California Institute of Technology

Issa A.D. Nesnas
Jet Propulsion Laboratory

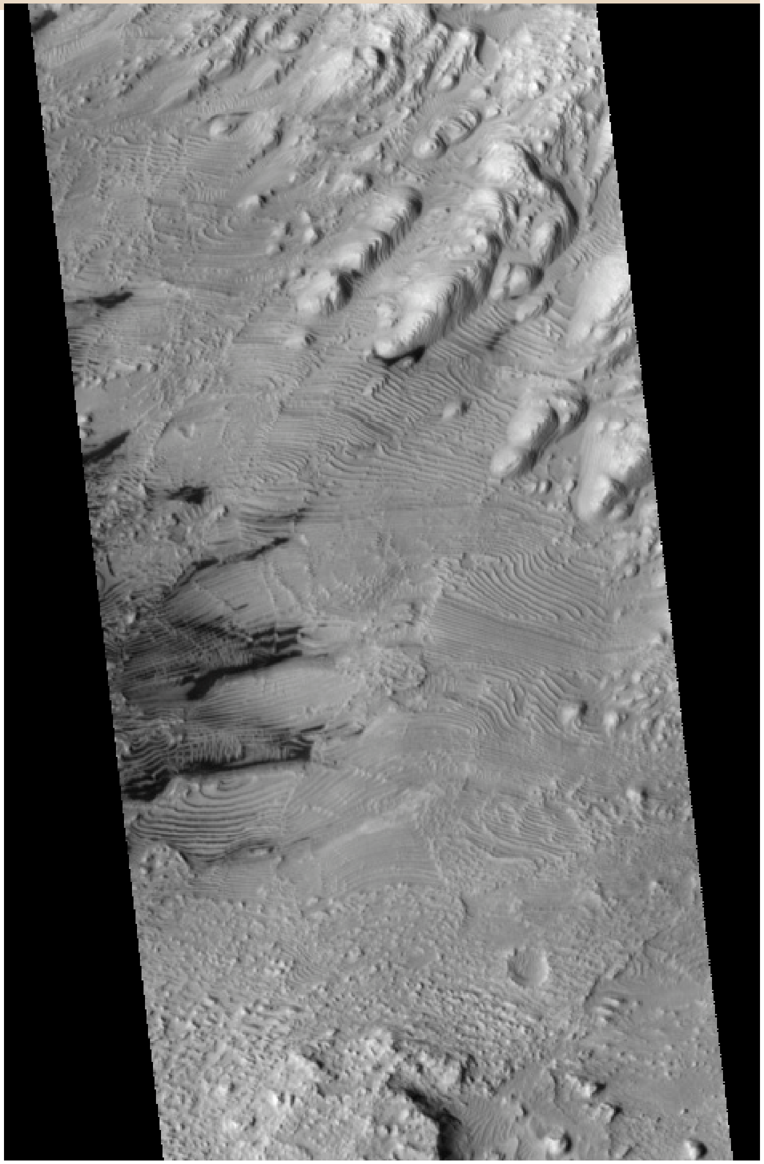
Thanks to:
Pan G. Conrad, Pablo Abad-Manterola, Jeffrey Edlund, Srikanth Saripalli, Kevin Noertker, Tom Oliver, Daniel Helmick, Raymond Christian

Keck Institute for Space Studies workshop on
2009 Mission Concepts for Accessing and Sampling High Risk Terrains

March 30th – 31st, 2009

Minimalist Robotic Platform to Deliver Instruments and/or Acquire Samples on High-Risk Terrains

- Objective:
  - Provide a **low-cost low-mass** platforms to deliver science instruments to terrains that would otherwise be inaccessible to state-of-the-art mobility platforms
  - Provide capability to collect samples and return to a host platform for in-depth analysis
  - Confine risk for accessing high-risk terrain to delivery platform

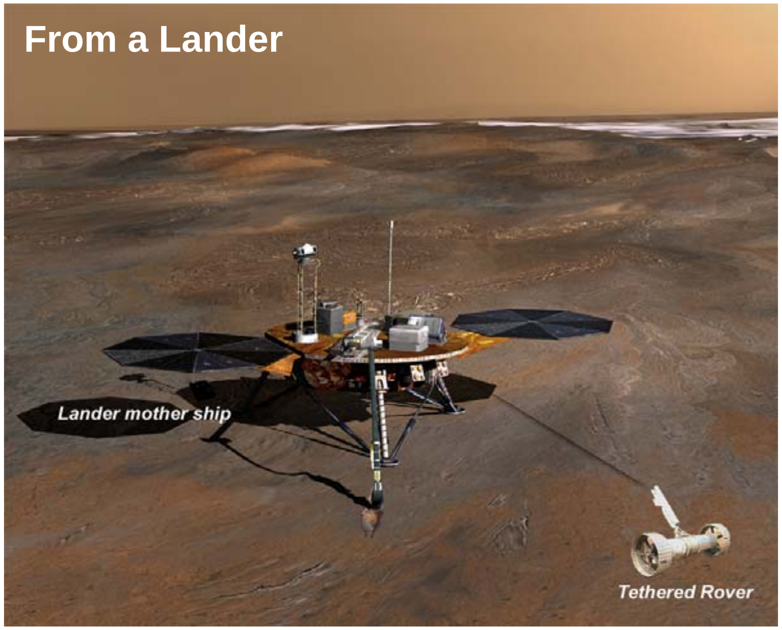


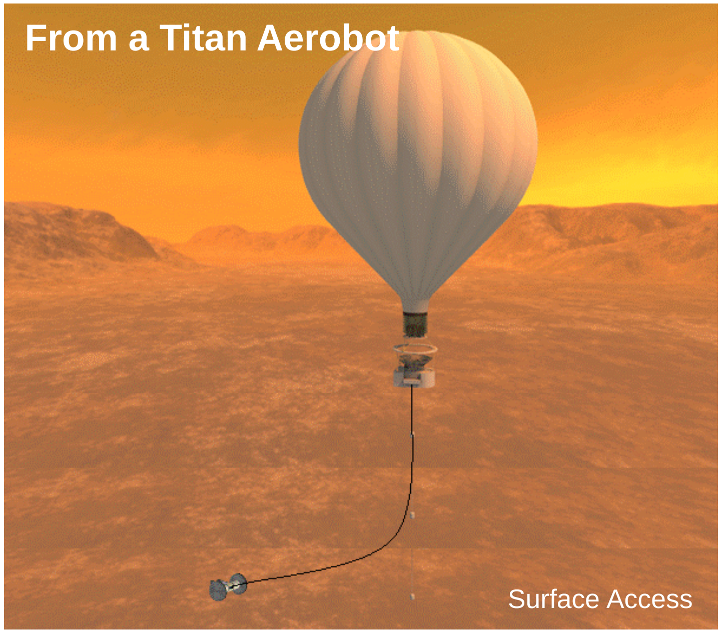
Supports mission concepts that may include multiple such assets

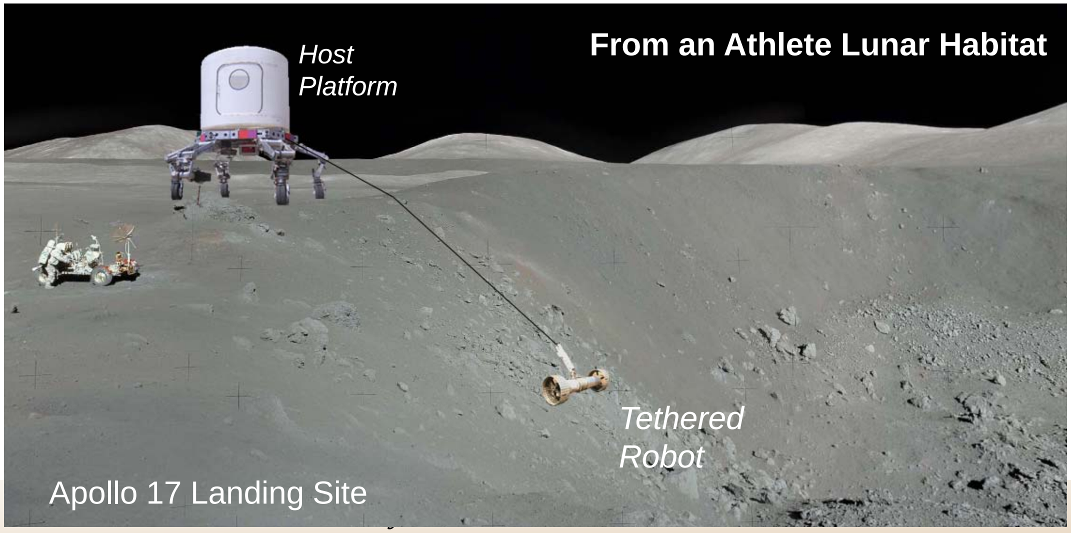
One Possible Mission Concept for Mars:
Mobile Science Payload Tethered to a Larger Rover

Cape Saint Vincent, Victoria Crater, Mars
False Color, Graphics not to scale

Other Mission Concepts for Terrain Access and Sampling

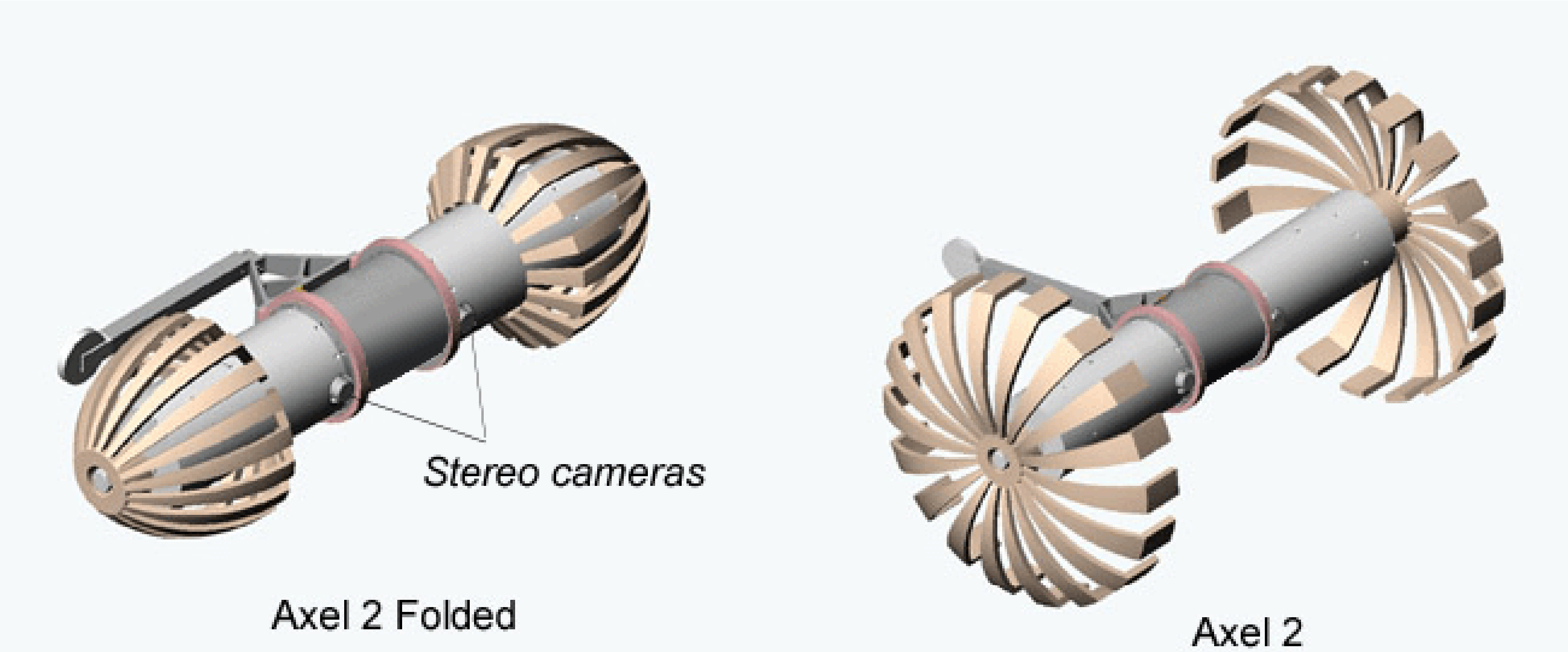






[redacted]

Mobility Platform Example: Axel



A yoyo-like rover

- **Simple**
- **Low mass** and **low cost**
- Can carry and **point multiple science instruments**
- Operable from any state using **symmetric design**
- **Robust** to sudden drops and hazardous terrain
- **Scalable** design
- **Compact** for flight packaging

Handles large obstacles

Inside the Robot

Science Payload

Rechargeable Battery

Inertial Measurement Unit

Avionics stack with flash storage

Color Stereo cameras

Capabilities

- **Mission Capabilities**
  - Can be hosted on larger rover, lander, or possibly self-anchor
  - Potential accommodations of multiple science instruments
  - Confines risk of steep terrain excursions to mobile payload
  - Multiple such mobility platforms in a single mission can reduce mission risk
- **System Capabilities**
  - Mobility, pointing and sampling using only three motors
    - Full motion range on moderately sloped terrain, vertical on higher slopes
    - Points its instruments using wheels and boom on moderately sloped terrain
    - Uses a tether to pull itself out of sand traps
  - Host requirements minimized (e.g. fixed mount, power, communication)
  - Light tether carried and managed by rover (e.g. polyethylene fiber)
  - On-board computing with data storage and autonomy capabilities
  - Stereo vision sensing and inertial sensing
  - Wireless communication

Next Steps

- Integration of three instrument payload and field-test
- Power management
- Tether management
- Various levels of autonomy for operations
- Optimize science operational scenarios

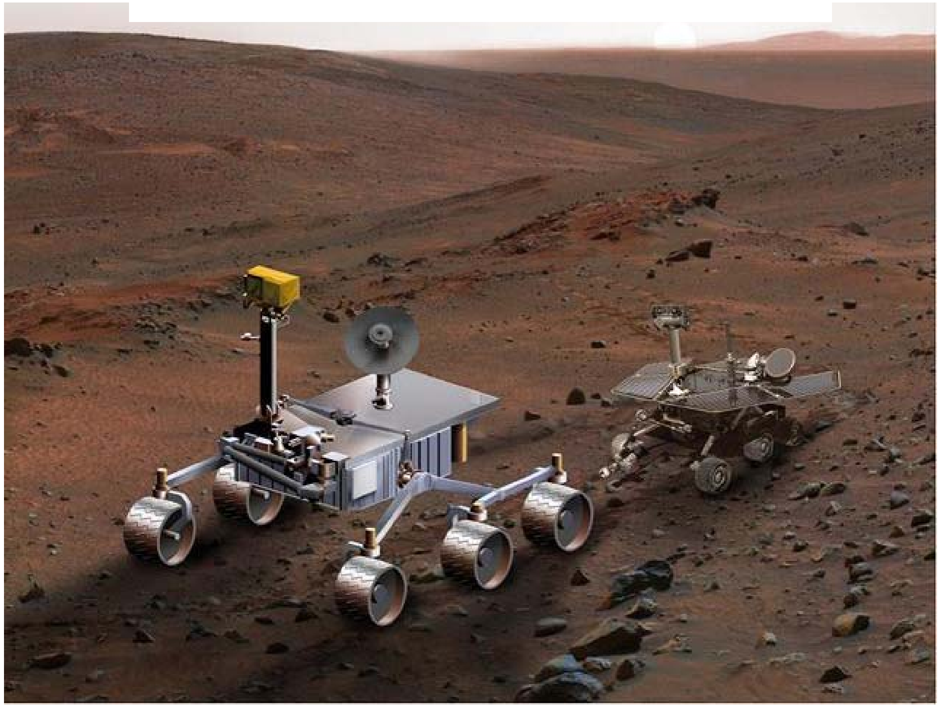
Summary

- Low-mass and low-cost mobility platform that delivers science payload to high-risk terrains
- Can extend access to previously inaccessibly terrains
- Preliminary investigations demonstrate potential for accessing, measuring and sampling highly sloped terrain
- Potential to host multiple science instruments for assessing geochronology and chemostratigraphy

Backup Slides

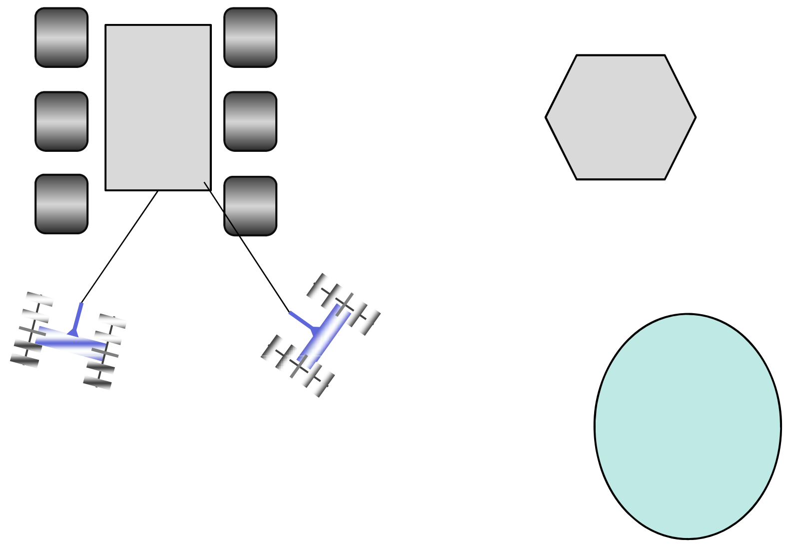
Surface Explorers: Today's vs. Tomorrow's

State-of-the-art



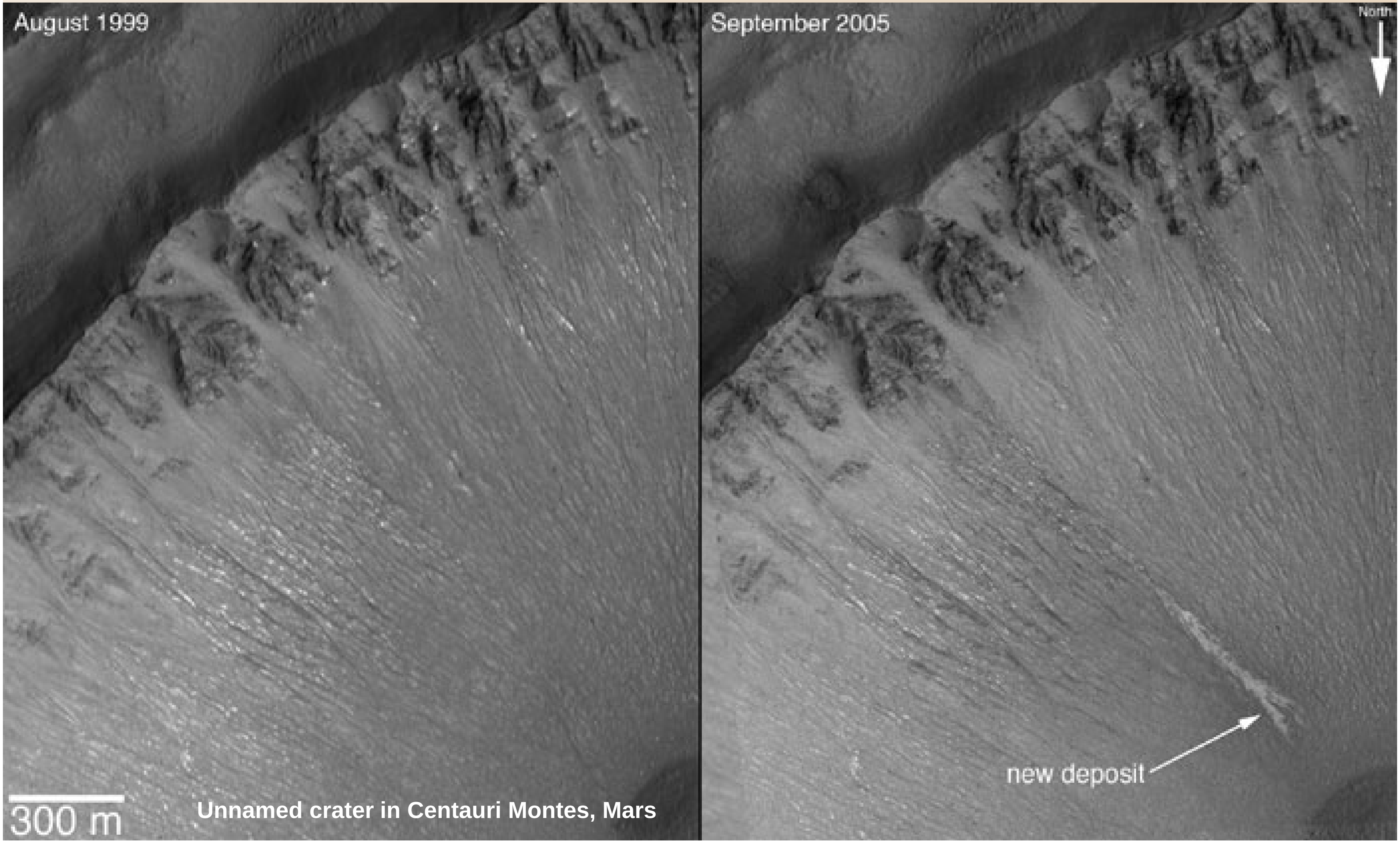
Architecture: single rover
Terrain: low-risk
moderately sloped (0 – 30º)
Range: 15- 20 km
Risk: single level

Future Possibilities

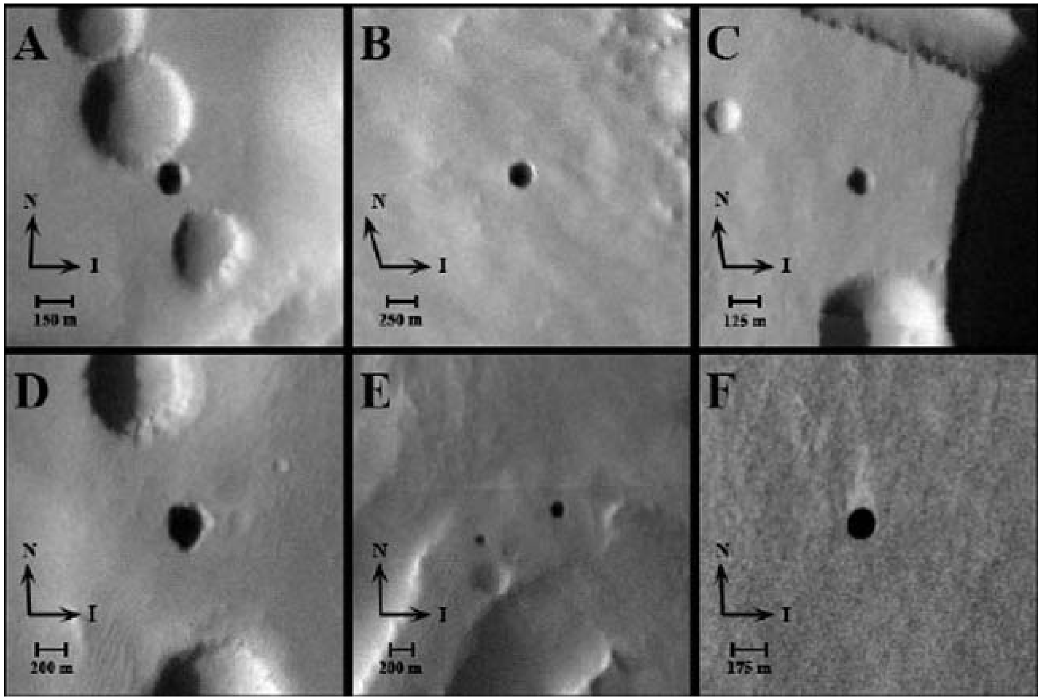


Architecture(s): marsupial
lander + tethered rover(s)
rover + tethered rover(s)
Terrain: high-risk for tethered robots
vertical strata (90º slopes)
Range: 100 m – possibly kms
Risk: multi-level

Technology Relevant to Other Challenging Terrains



Including possible caves



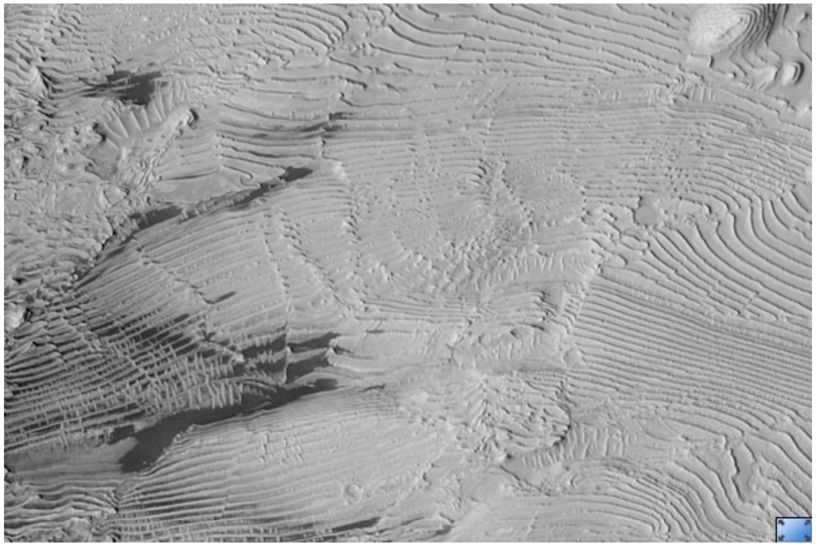
Dark spots believed to be caves observed by the Thermal Emission Imaging System (THEMIS) on the Mars Odyssey spacecraft

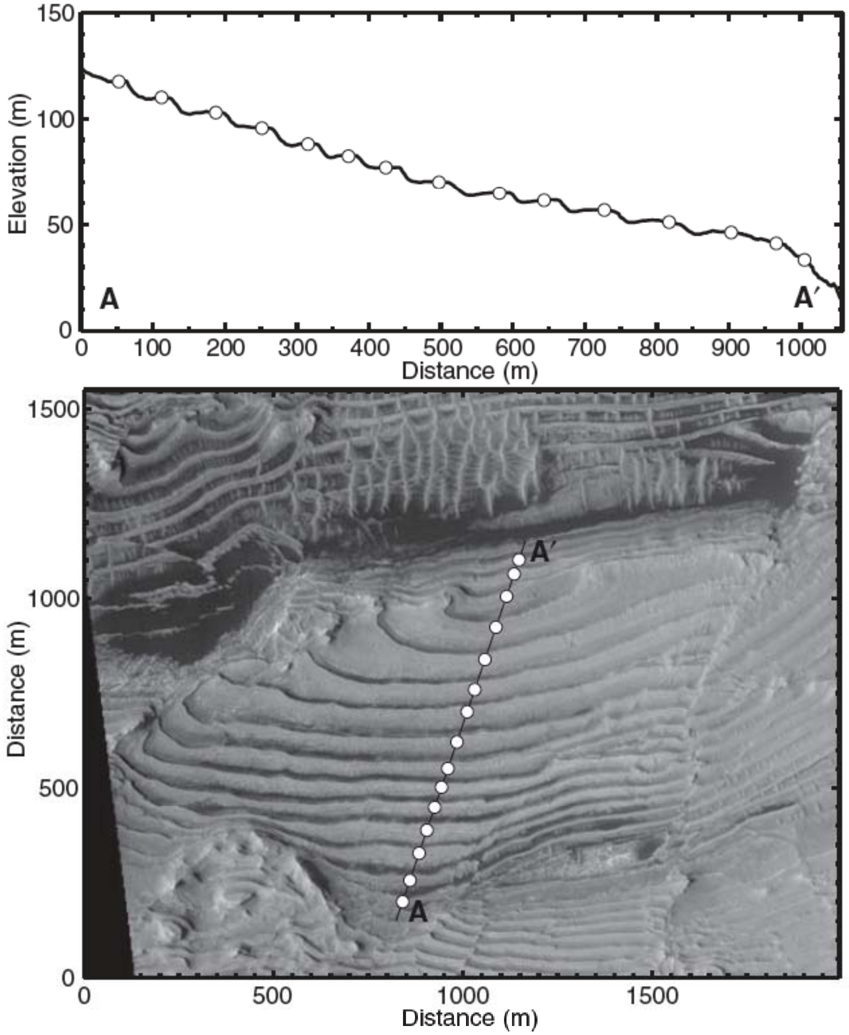
Credit: Cushing, G. E., T. N. Titus, J. J. Wynne, and P. R. Christensen (2007), THEMIS observes possible cave skylights on Mars, Geophys. Res. Lett., 34, L17201, doi:10.1029/2007GL030709.

Challenges of Terrain Topography for Mobility Platforms

Credit: Kevin W. Lewis, Oded Aharonson, John P. Grotzinger, Randolph L. Kirk, Alfred S. McEwen, Terry-Ann Suer, "Quasi-Periodic Bedding in the Sedimentary Rock Record of Mars," Science 5 December 2008

Crater	Location	Number of beds measured	Mean thickness ± SD (m)
Becquerel (beds)	22°N, 352°E	66	3.6 ± 1.0
Becquerel (bundles)	22°N, 352°E	10	35.5 ± 9.2
Crommelin	5°N, 350°E	8	19.6 ± 4.0
Unnamed	8°N, 353°E	14	9.7 ± 1.5
Unnamed	9°N, 359°E	10	12.6 ± 2.6





Faulted Layers in Impact Crater in Meridiani Planum of HiRISE image PSP_002733_1880