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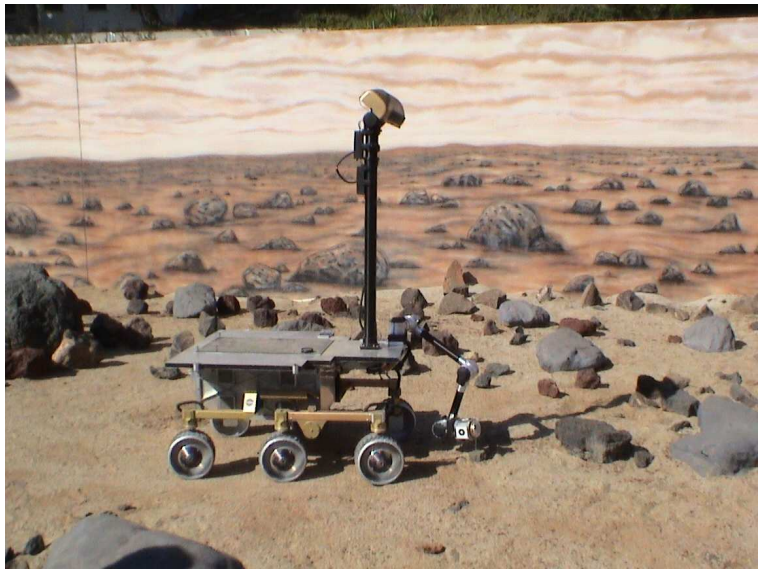
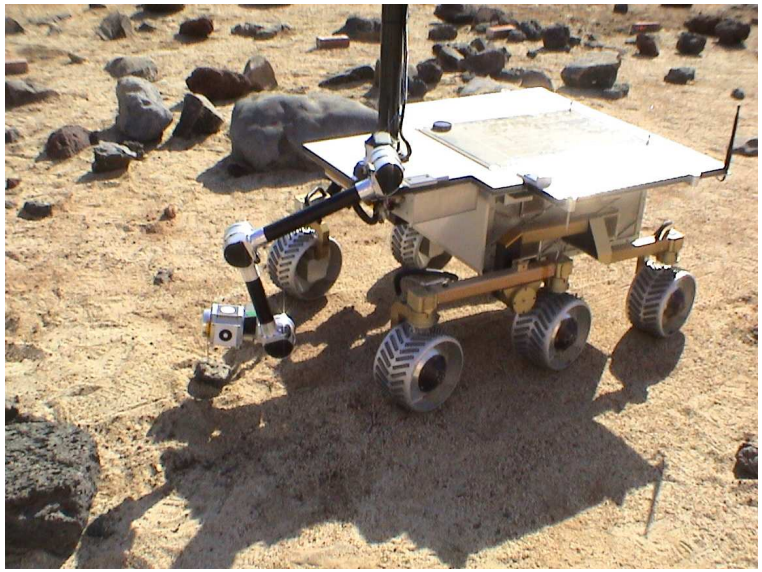
Target Tracking, Approach, and Camera Handoff for Automated Instrument Placement

Max Bajracharya, Antonio Diaz-Calderon,
Matthew Robinson, Mark Powell
maxb@robotics.jpl.nasa.gov
Jet Propulsion Laboratory

Goal

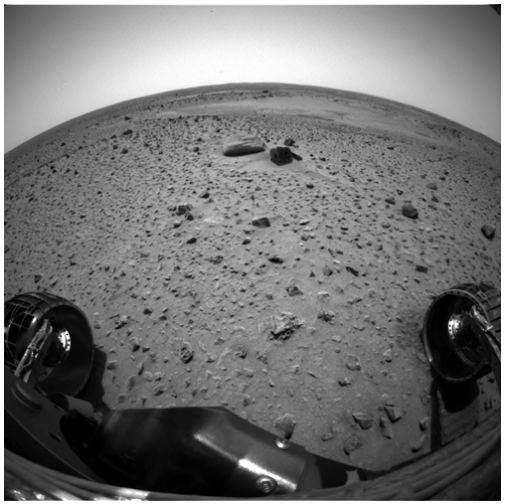
- **Target designation (from 10m)**
  - Using a mast camera panorama
  - Select a rock, outcropping, etc.
- **Approach (10m-2m)**
  - Navigate to the target, avoiding obstacles
  - Track the target from the mast cameras
- **Camera Handoff (2m)**
  - Project from mast camera to body camera
- **Instrument Placement (2m-contact)**
  - Refine the rover position so the target is in the arm workspace
  - Place the instrument on the target

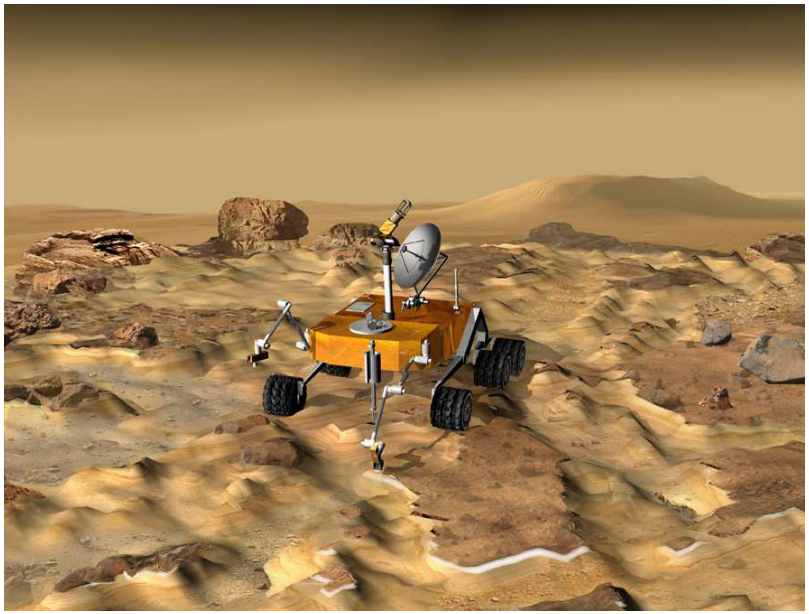




Motivation

- **Mars Exploration Rover (MER) (2003)**
  - Requires at least 3 communication cycles to approach a target
- **Mars Science Laboratory (MSL) (2009/2011)**
  - Increased science return
- **Mars Sample Return (MSR) (2013/2016)**
  - Decreased time on the surface
  - Selection and investigation of multiple targets before sampling





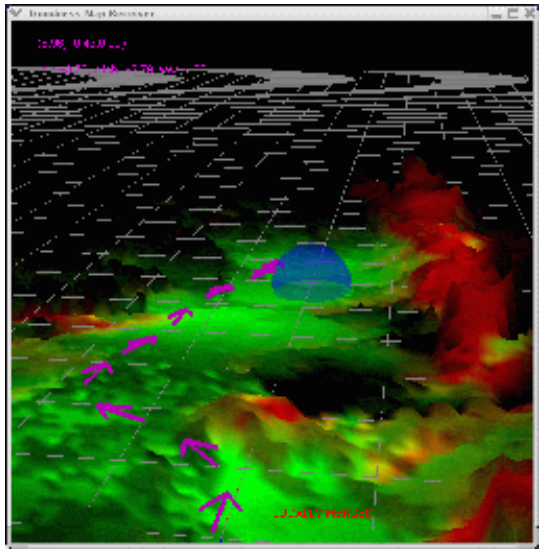
Target Designation

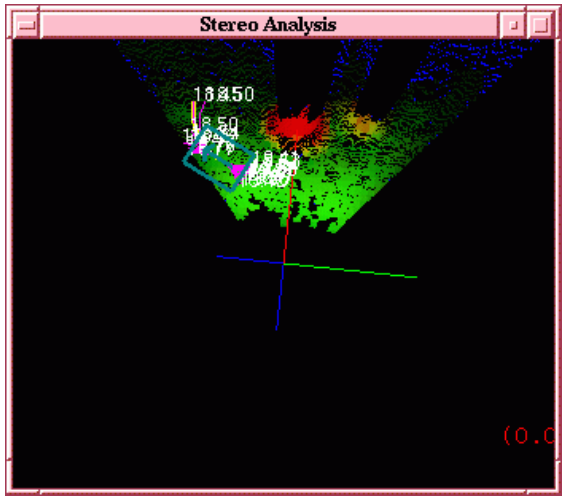
- **Rover panorama**
- **Downlink**
- **Target selection**
  - In Maestro
- **Uplink**

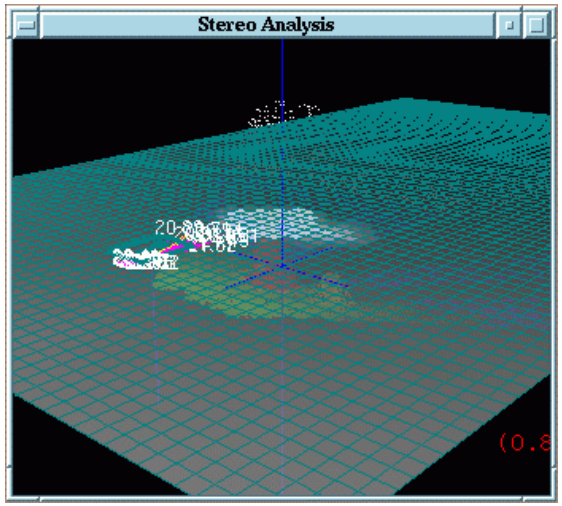
- **Maestro**
  - Science analysis and activity specification tool
  - Used on MER

Navigation

- **Use front and rear stereo images**
- **Create a cell-based traversabilty map**
  - Consider slope, roughness, and step height
- **Evaluate potential arc motions**
  - Local cost based on arc traversability
  - Global cost based on D* cost from arc endpoint





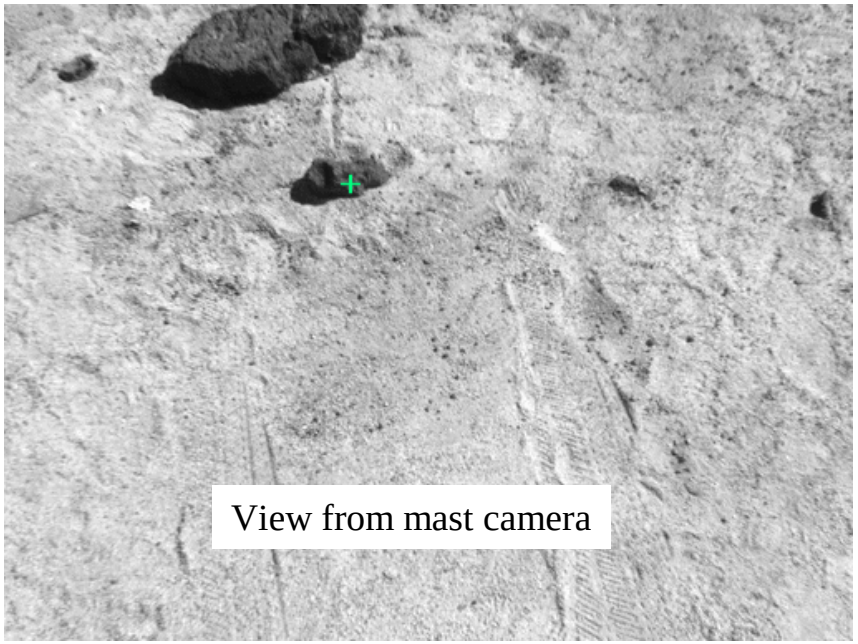


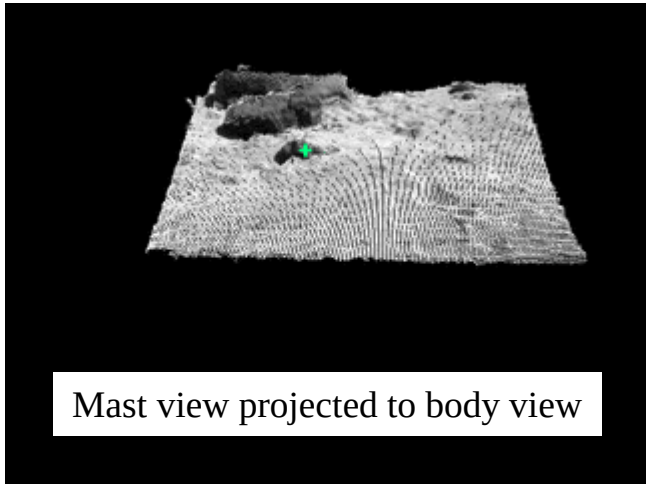
Tracking

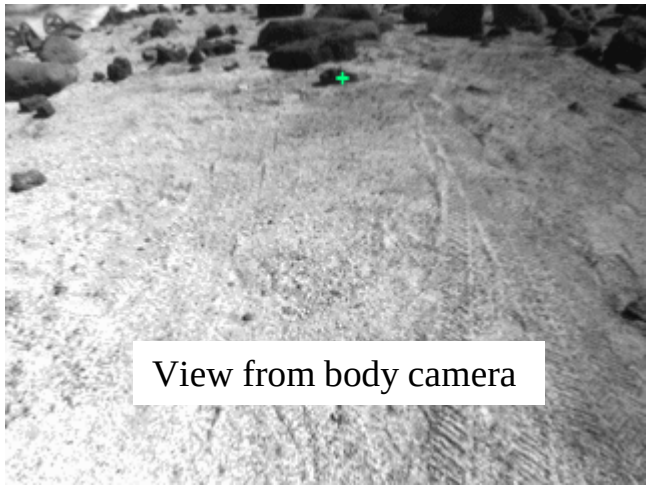
- **Move**
- **Estimate motion**
- **Point camera**
- **Coarse match**
  - Normalized cross correlation
  - On subsampled image
  - Template updated every cycle
- **Fine match**
  - Solve for affine parameters
  - At multiple pyramid levels
  - Template updated periodically
- **Triangulate target**
  - Use for pointing and error detection

Camera Handoff

- **Kinematic projection**
  - Requires well calibrated cameras and small pointing error
- **Stereo Image Based**
  - Project target template to body cameras
  - Match using correlation







Results/Conclusion

- **Tracking accurate to several pixels over 10m run**
  - 0.25m-0.5m steps
- **Handoff is currently largest source of error**
- **System performance is currently being evaluated and validated**
- **Currently working on handling approach and sampling on sloped terrain**

End-to-End Video