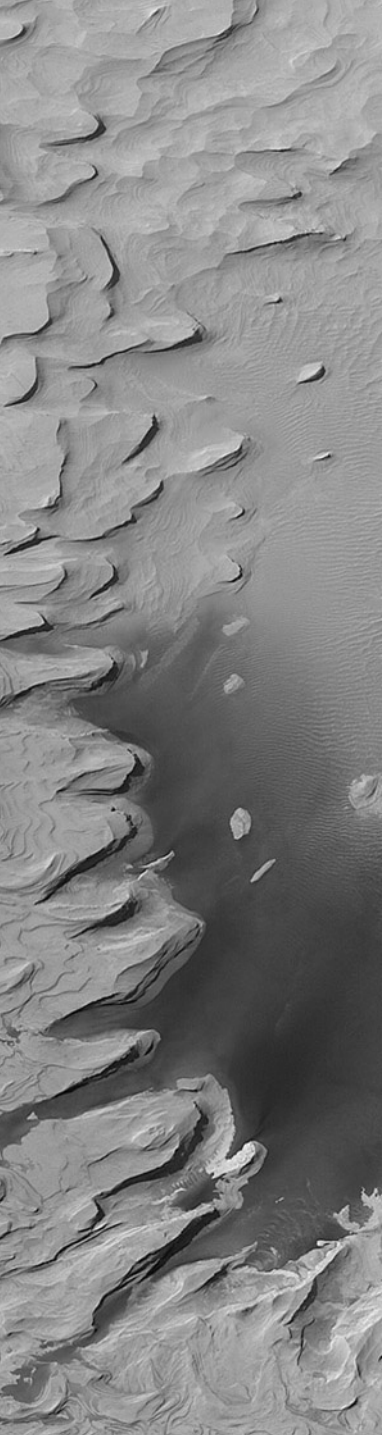


Approach and Instrument Placement Validation

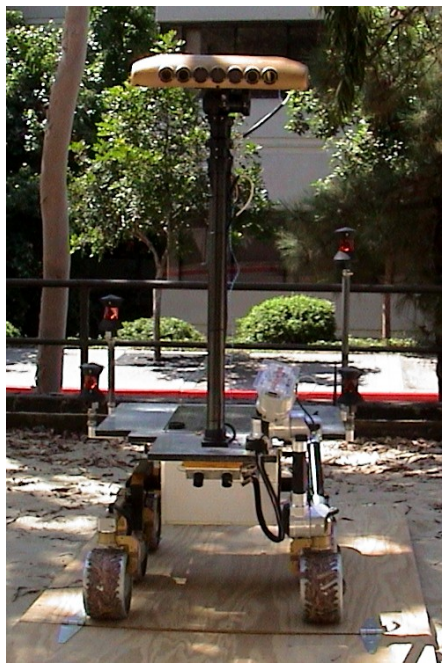
Shawn Catron
New Mexico State

Danielle Ator
University of Idaho

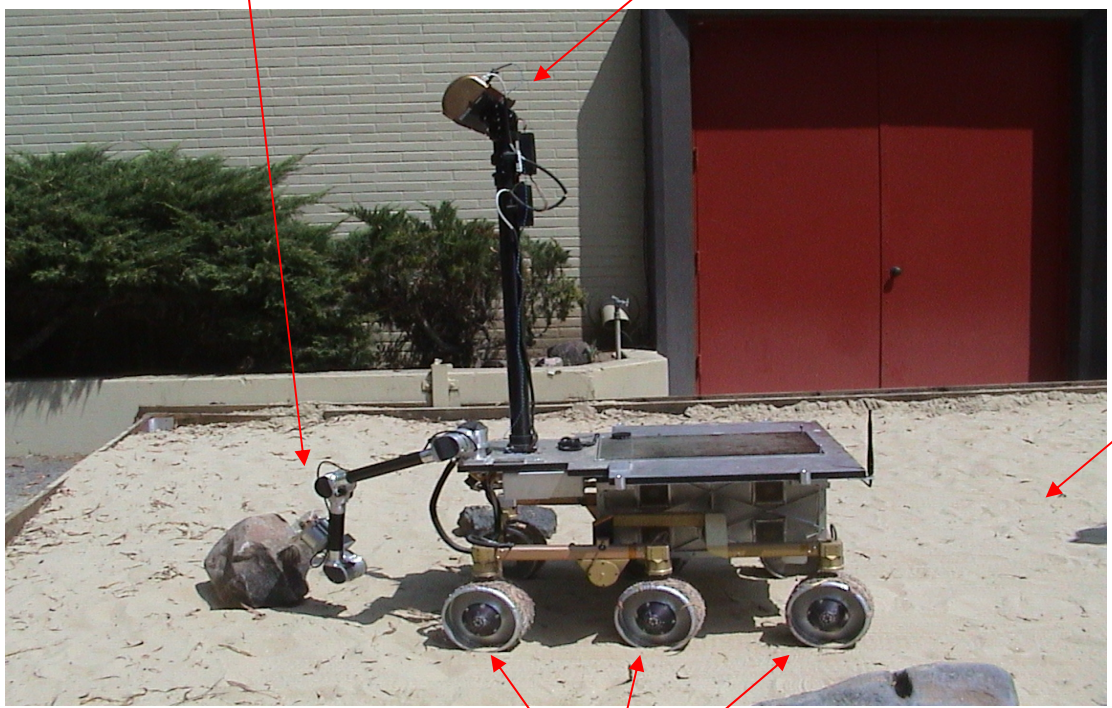
Section 347
August 18, 2005

Objective

- "To provide an experimentally validated single-sol instrument placement capability to future Mars missions where the science target is up to 10 m away."
- Give early feedback to technology providers for improvements



Rocky8 Research Rover



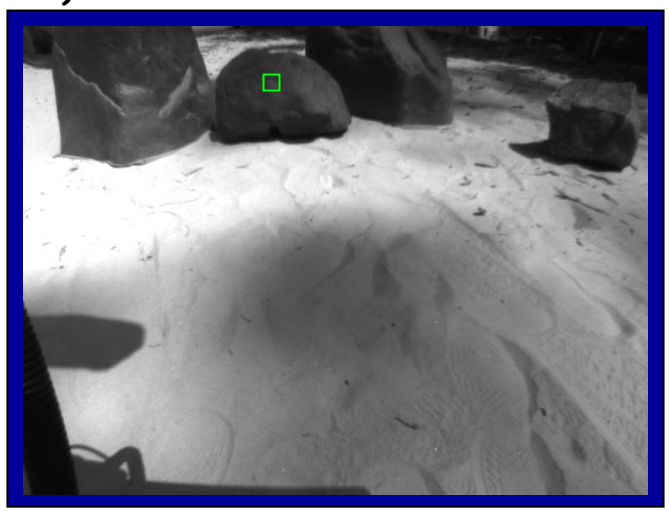
Single Cycle Instrument Placement

- Target selection
- Tracking
- Hazard avoidance
- Camera handoff
- Turn in place
- Base placement
- Instrument placement

Tracking

Pancam tracking (10 m)

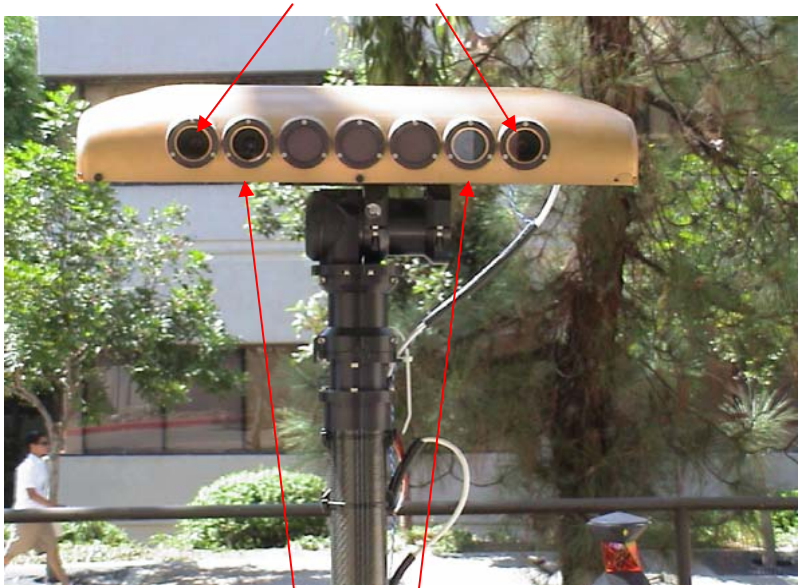
Navcam tracking (4 m)



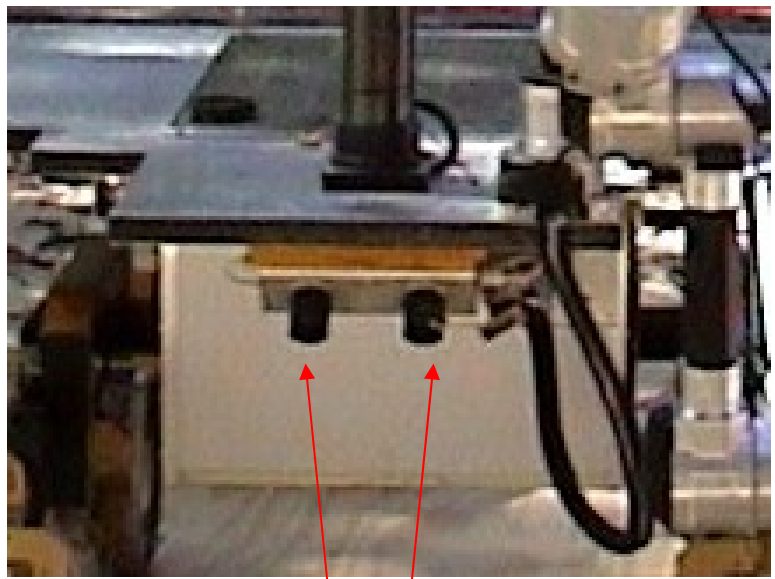
Hazcam tracking (2 m)

Camera Handoff

Pancams

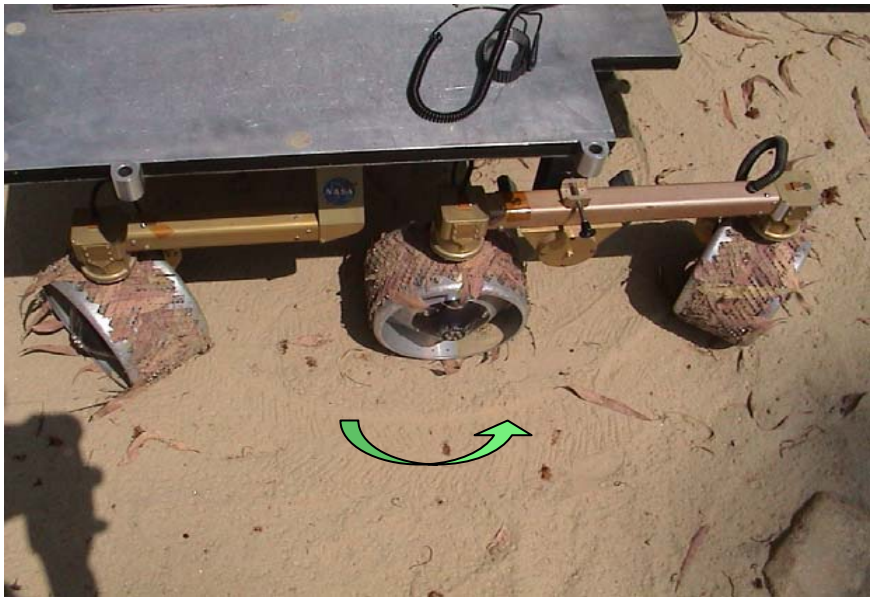


Navcams



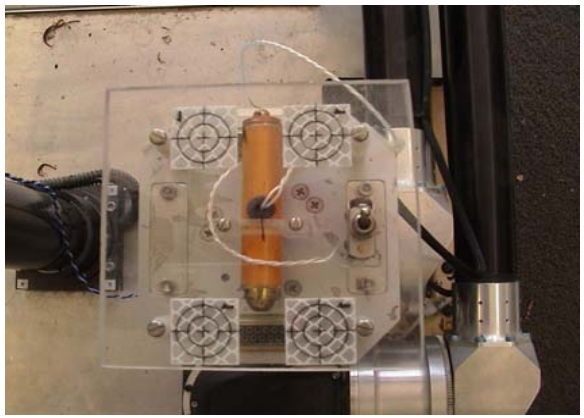
Hazcams

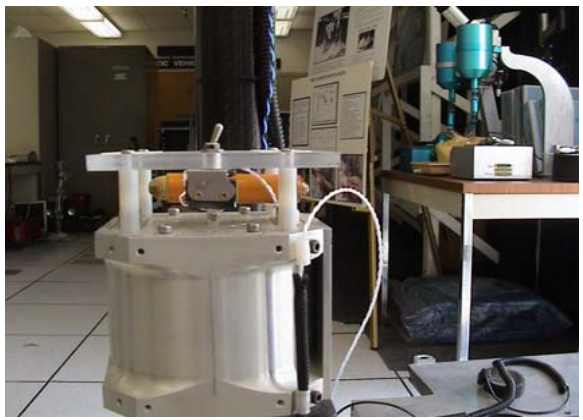
Turn in Place



Used to align hazcams with target

Laser Pointer





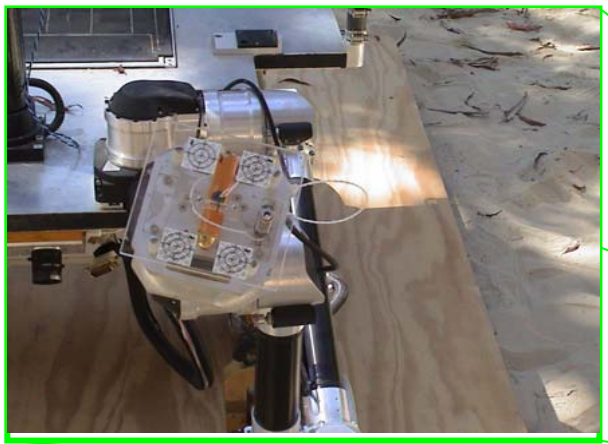
- Added to pinpoint the location where the instrument would be placed and for aesthetic purposes

Arm Calibration

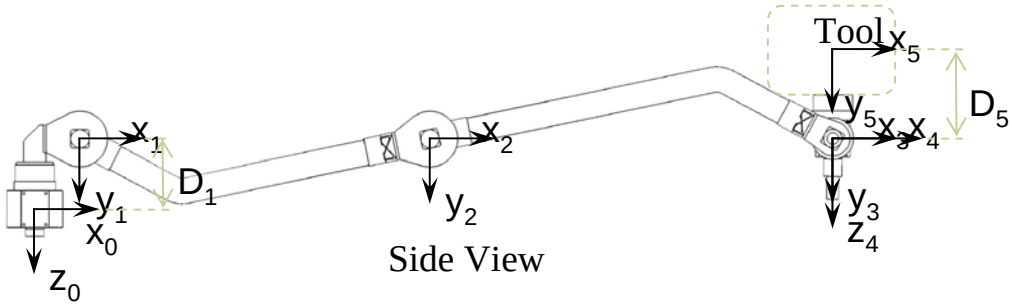
- Current method requires arm to be initialized in stow position visually
- Optimal method would allow arm to stow itself from any starting position

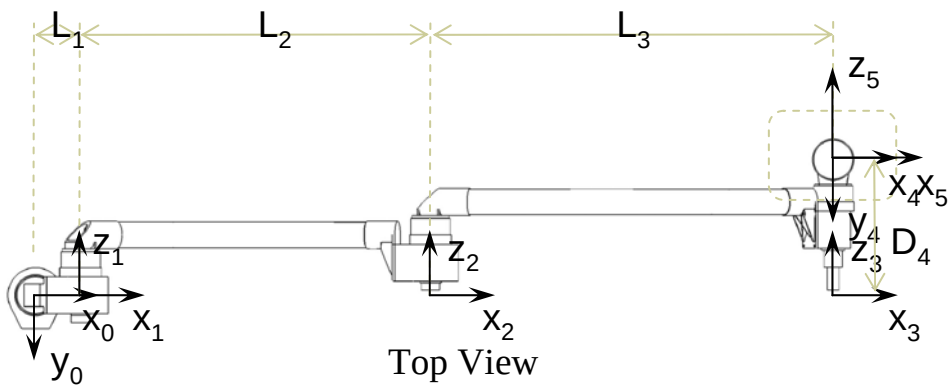
Arm Calibration (cont.)

- Used total station to measure the Cartesian position relative to the rover frame



Arm Calibration (cont.)



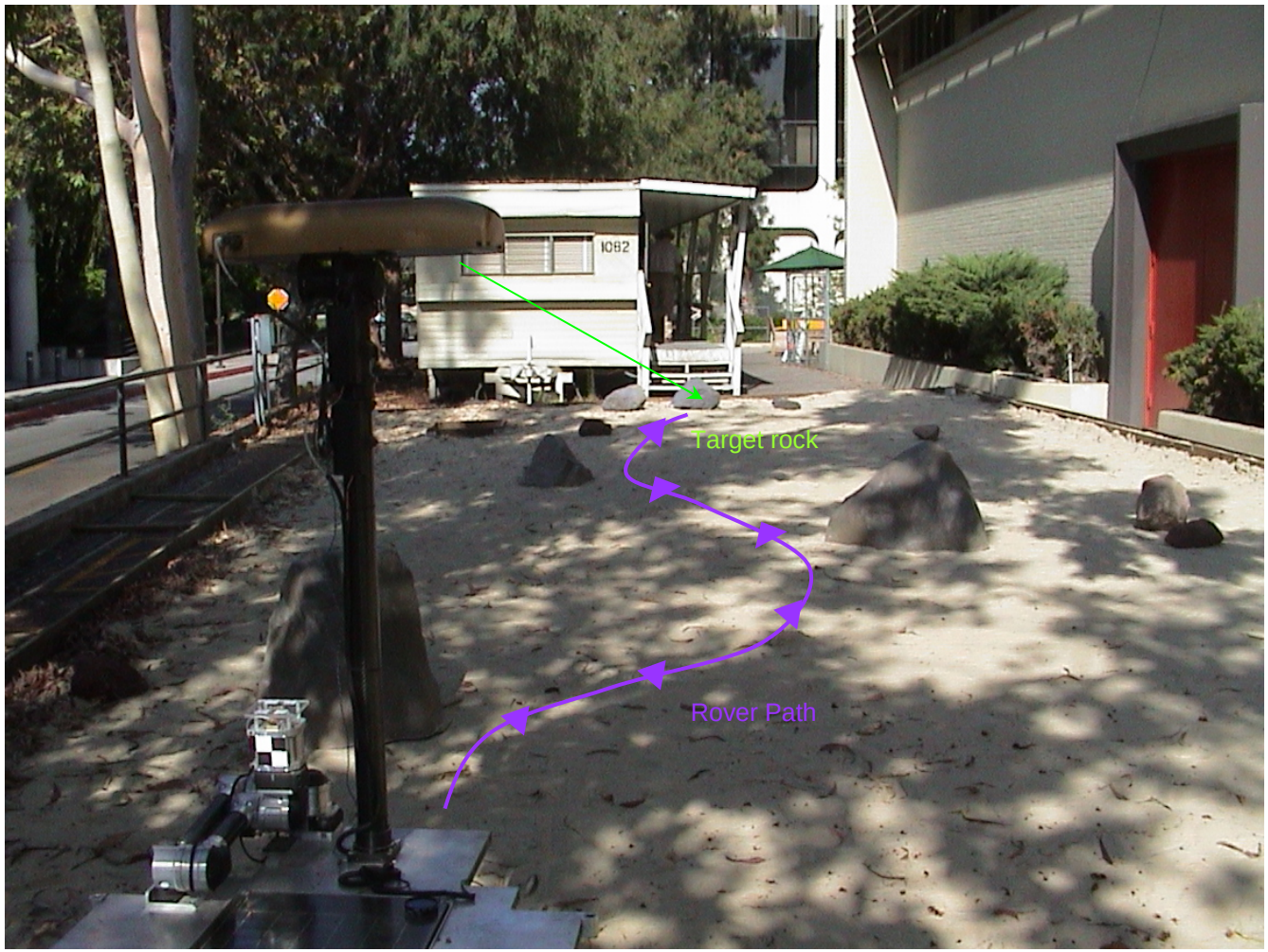


- Used non linear least squares method to optimize the D-H parameters

$$
{}^{0}_{5}T = \begin{bmatrix}
c_1c_{234}c_5 - s_1s_5 & -c_1s_{234} & c_1c_{234}s_5 + s_1c_5 & L_1c_1 + L_2c_1c_2 + L_3c_1c_{23} + D_4s_1 - D_5c_1s_{234} \\
s_1c_{234}c_5 + c_1s_5 & -s_1s_{234} & s_1c_{234}s_5 - c_1c_5 & L_1s_1 + L_2s_1c_2 + L_3s_1c_{23} - D_4c_1 - D_5s_1s_{234} \\
s_{234}c_5 & c_{234} & s_{234}s_5 & D_1 + L_2s_2 + L_3s_{23} + D_5c_{234} \\
0 & 0 & 0 & 1
\end{bmatrix}
$$

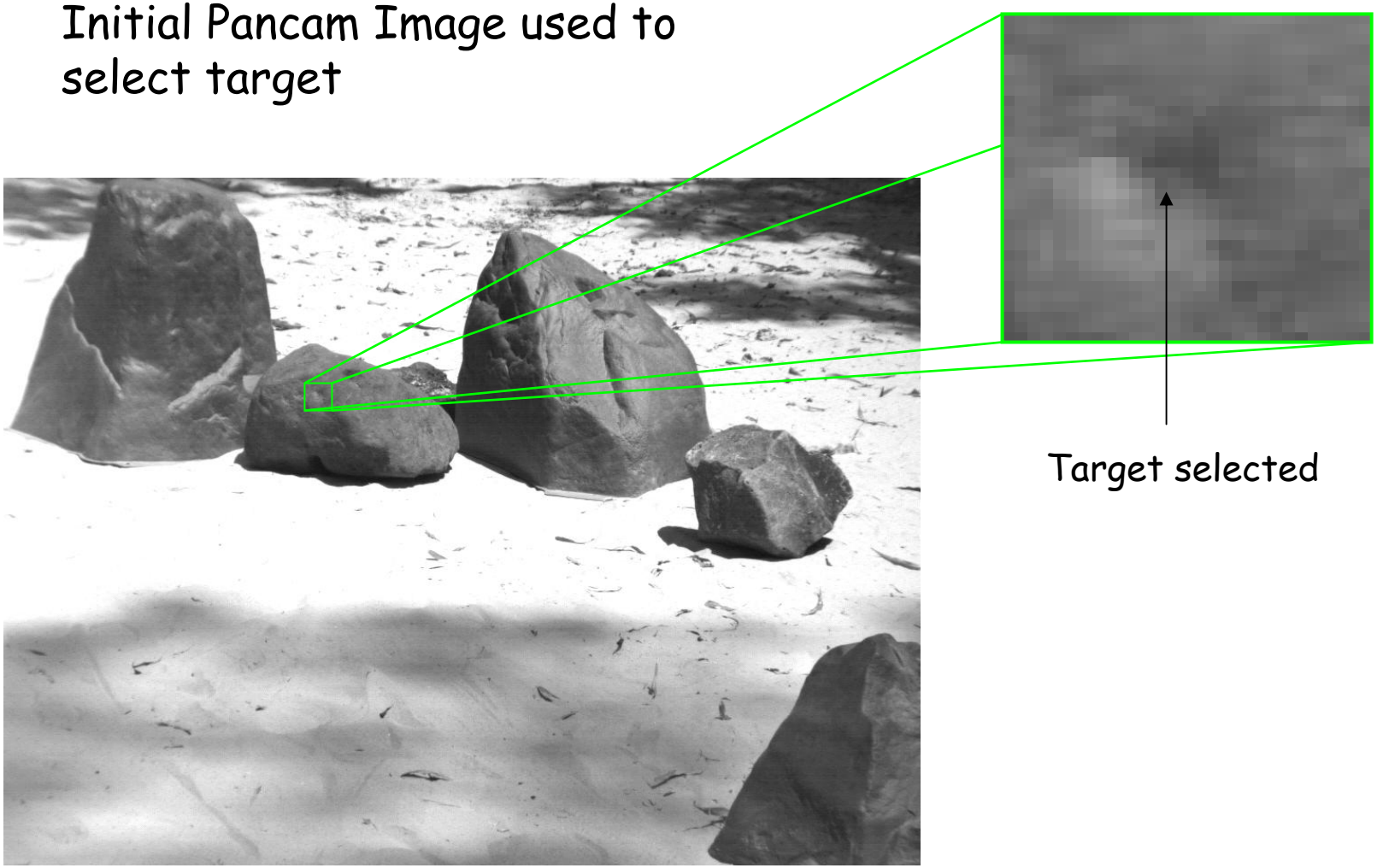
How Does SCIP Work?

The Course



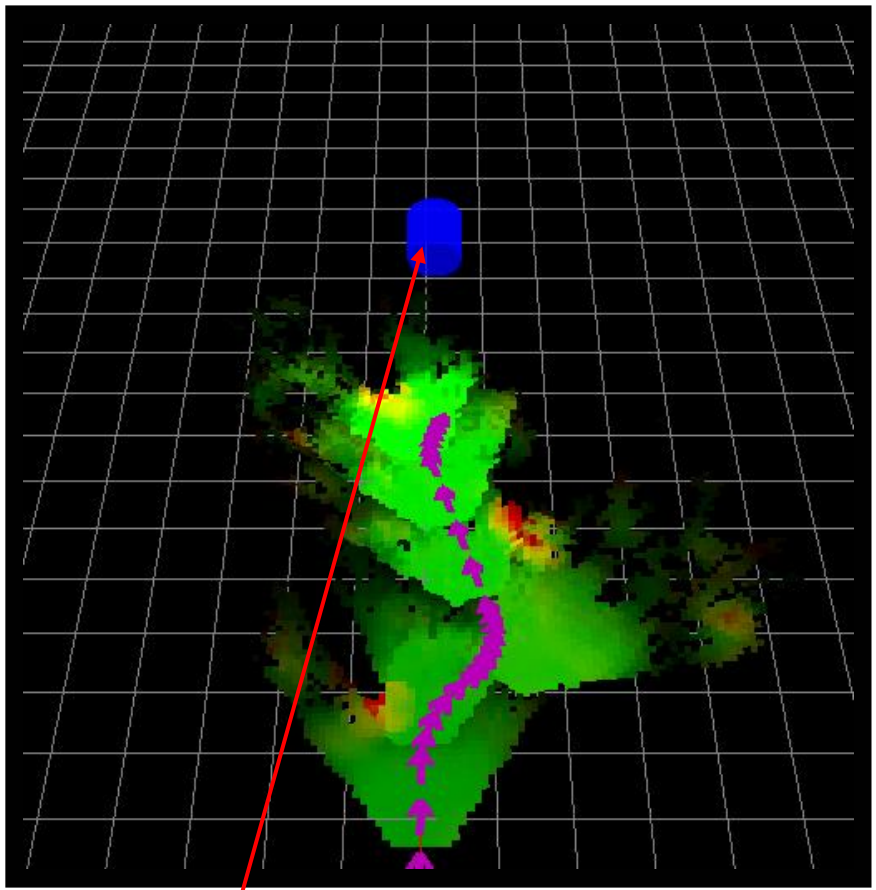
Selecting the Target

Initial Pancam Image used to select target



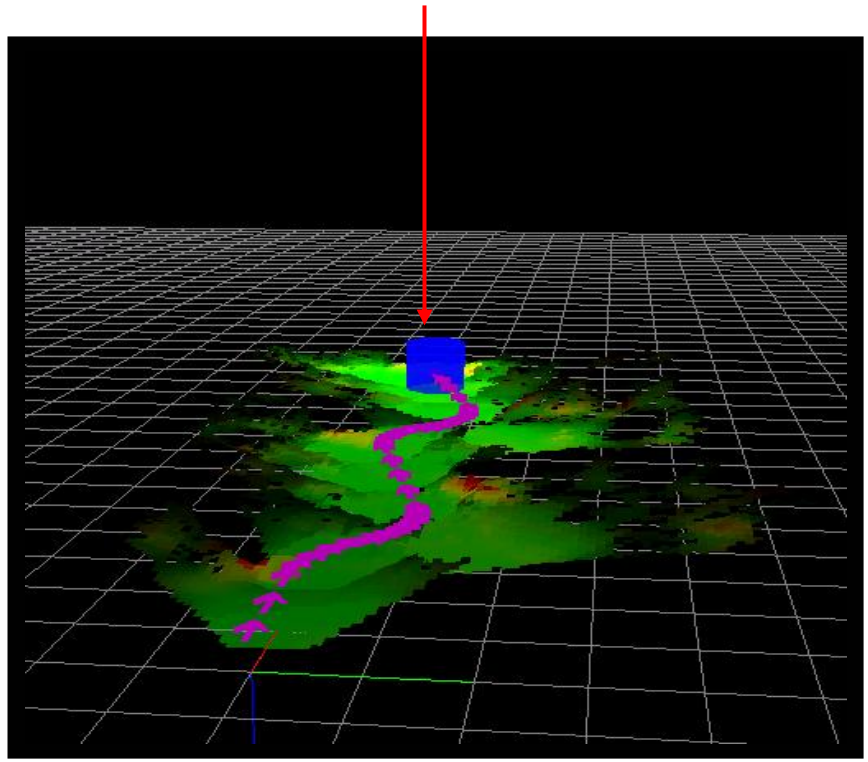
Target selected

Morphin Navigator Viewer Display



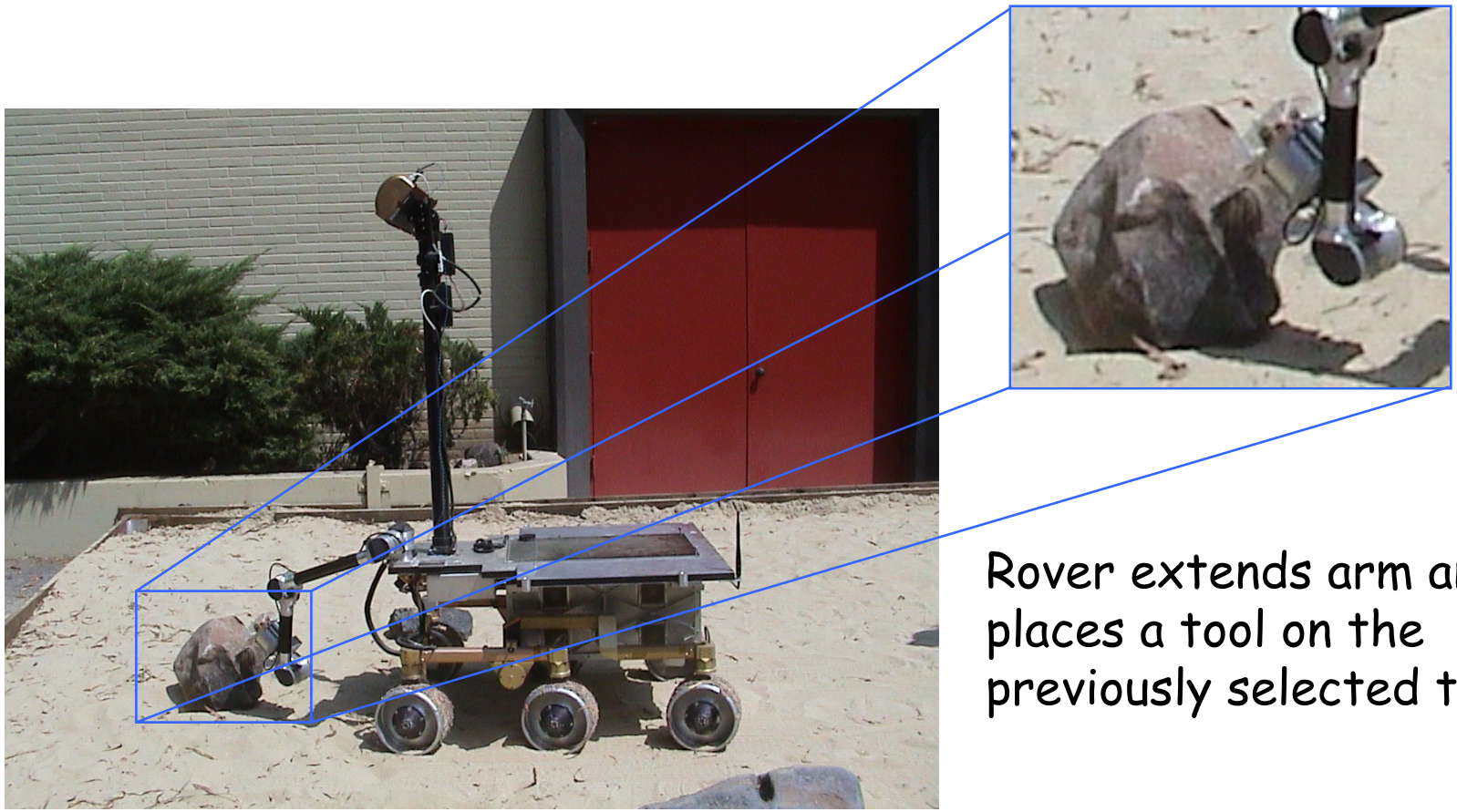
Position for rover base placement

Actual target approximately 2 meters behind base placement location



Purple arrows show rover path

Arm Placement



Rover extends arm and places a tool on the previously selected target

Initial Tests of Single Cycle Instrument Placement

Test Conditions	Statistics	Problems Found	Fixes	Results
Initial test of "new run_scip delivery" with addition of pancam tracking & handoff refinement	3/8 tracked within 7 cm	• Lost target during navcam & hazcam tracking • Lost target during handoff	• Reduced search windows: Pancam – 400x400 pixels Navcam – 150x150 pixels Handoff & Hazcam – 50x50 • Turned off refinement	• Size reduction of search window not sufficient • Had to turn off refinement
Vary the base place threshold parameter	3/7 tracked within 7 cm	• Rover base placement tends to be too far	• Set rover base placement threshold to 1.5 m as the best value	• 1.5 m is OK but problems if a lower value is tried
Test continually including hot afternoons	9/18 tracked within 8 cm 2/5 tracked within 13 cm	• Wireless disconnection and corrupted images during hot days • Memory corruption problem.	• Added code fixes to remove the memory corruption	• Still occasional problems during hot days
Tracking with hazard avoidance	4/7 tracked within 13 cm	• Frequent failures during turn-in-place	• Handoff pyramid level changed from 1 to 0 to improve accuracy. • Change turn in place from many small steps to one step	• A fix is found in the next step
Tracking with hazard avoidance	4/5 runs tracked within 2 cm	• Rover pose estimator data for rover turn-in-place were changing	• Added "wait until done" line after turn in place	• Frequent failures during turn-in-place disappeared

Stress Testing Conditions

- Target distances of greater than 10 m
- The effects of lighting conditions and the position of the sun
- Tracking reliability of featureless targets
- Tracking reliability while avoiding multiple hazard rocks

Initial Conclusions

Stress Test Conditions	Statistics	Problems Found	Results/Fixes
Long traverse (> 12 m)	4/7 tracked within 6 cm	• Morphin navigator sometimes caused too wide turns or failed • Mast shadow also caused tracking failures	• Tracking over 10 to 20 m traverse appears to be fine by starting with pancam tracking
Sun lighting	3/8 tracked within 7 cm (sun in front) 4/6 tracked within 5 cm (sun behind) 2/2 tracked within 5 cm (sun straight above)	• When the sun was behind the target rock, the rock image was very dark • When the sun is in front of the target rock, the background bright white sand still made the rock image very dark	• Tracking performed best when the sun is directly overhead. • Dark image of the target rock caused tracking failure (for hazcam tracking) • Needs to look at exposure adjustment
Featureless targets	3/8 tracked within 5 cm	• Featureless targets were trouble during hazcam tracking when dark	• Fine with pancam/navcam tracking • Needs to look at hazcam tracking
Multiple hazard rocks	8/15 tracked within 11 cm (5 within 3 cm)	• Morphin navigator sometimes caused too wide turns or failed	• Morphin navigator appear to avoid rocks well if not too tightly located • Needs to improve Morphin navigator to avoid tightly located rocks

Overall stress test performance = 23/42 = 54% tracking success rate

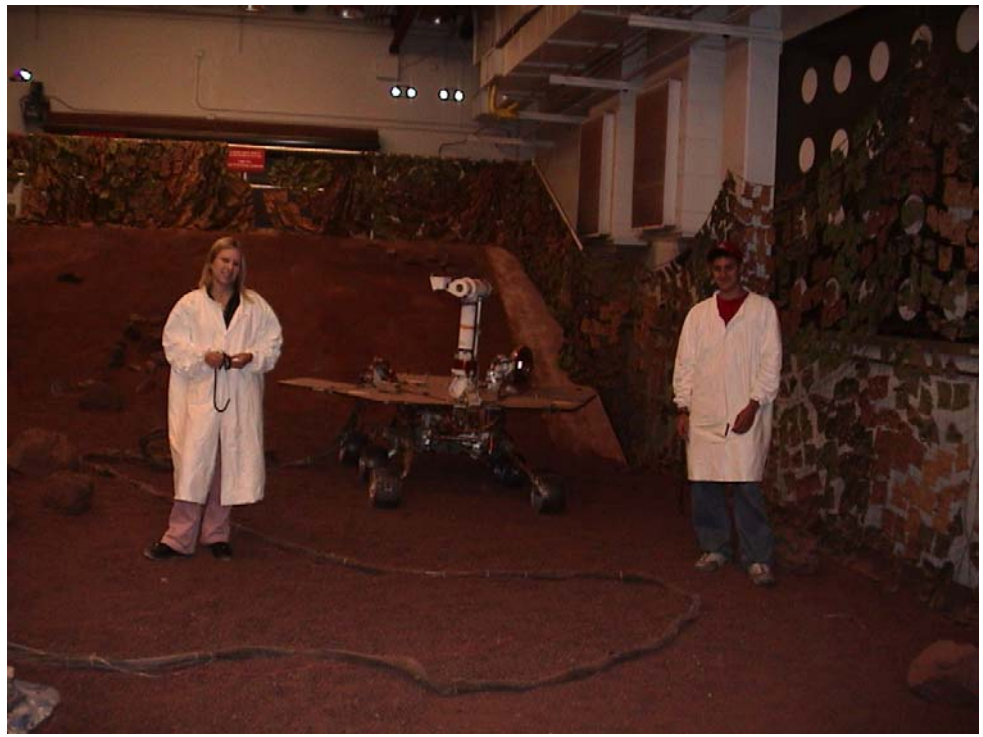
Causes of failure: dark image/featureless=6; shadow=4; navigator failure=3; base placement too far=2; mast out of range=2;inverse kinematic error=2; turn-in-place on rock=1; handoff too early=1

Offline Tracking

Pan Cam Images

Surface System Test Bed (SSTB)

- Participated in the MER flight testing of the visual tracking flight software using the SSTB (Surface System Test Bed) sandbox as a second operator.
- If this algorithm ever does become flight ready, it will be implemented and tested in the SSTB



Acknowledgements

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  - Won Kim
  - Rob Steele
  - Max Bajracharya
  - Antonio Diaz-Calderon
  - Ed Barlow

Also, special thanks to Idaho and New Mexico Space Grant for funding our way

Any Questions?

References

- [1] Kim W. S., Ansar A. I., Steele R.D., "Rover Mast Calibration, Exact Camera Pointing, and Camera Handoff for Visual Target Tracking," IEEE 12th Int. Conf. on Advanced Robotics (ICAR'05), Jul. 2005.
- [2] Bajracharya M., Diaz-Calderon A., Robinson M., Powell M., “Target Tracking, Approach, and Camera Handoff for Automated Instrument Placement,” IEEE Aerospace Conference, 2004