General 3D Acquisition and Tracking of Dot Targets on a Mars Rover Prototype

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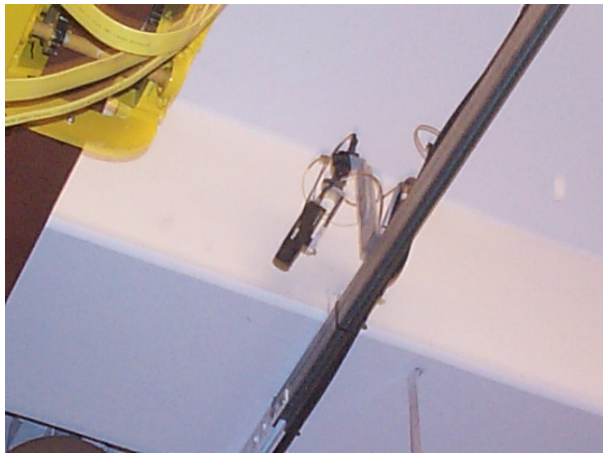
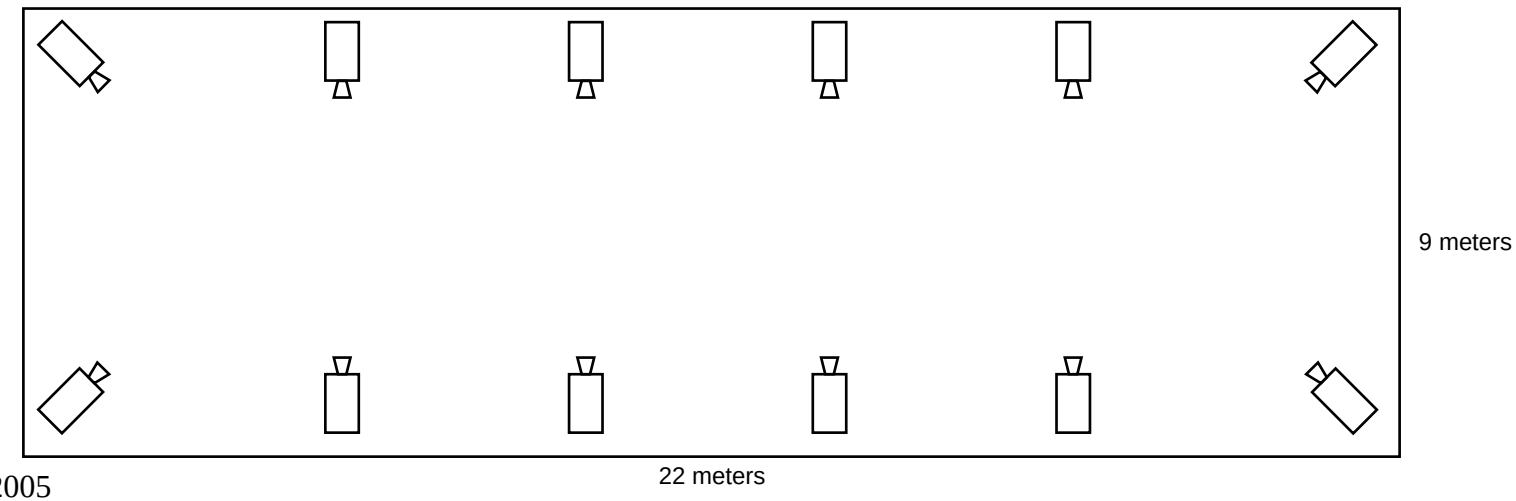
Goals

- **Produce 3D position and orientation; 1cm position accuracy desired**
- **Acquire the target automatically and track 5cm/sec motion in real time**
- **Tolerate clutter and obscuration**

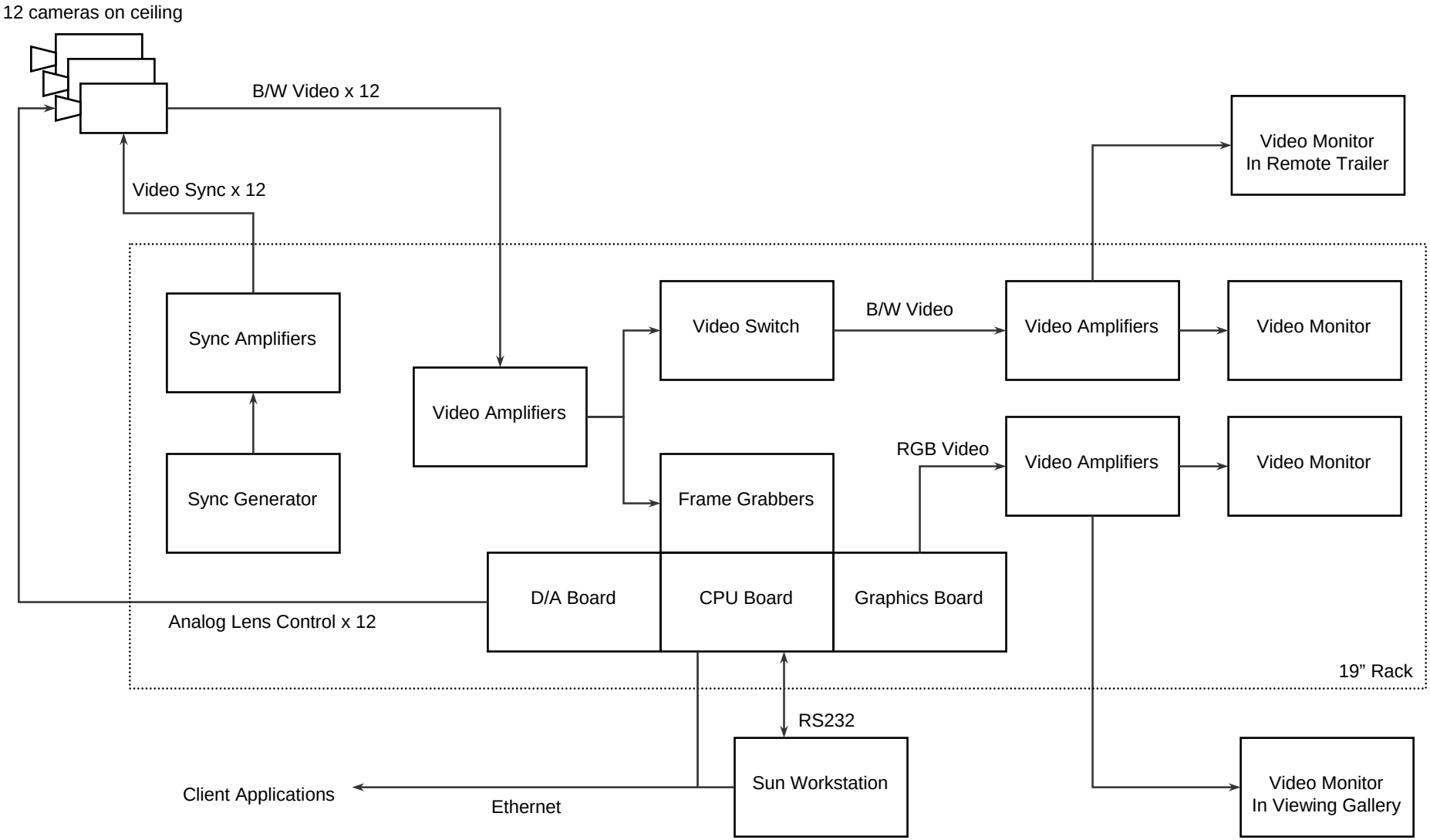
Cameras

- **Cameras on ceiling, with 4-camera overlap to minimize occlusions**
- **Pulnix TM-9701 monochrome progressive-scan camera**





System Block Diagram

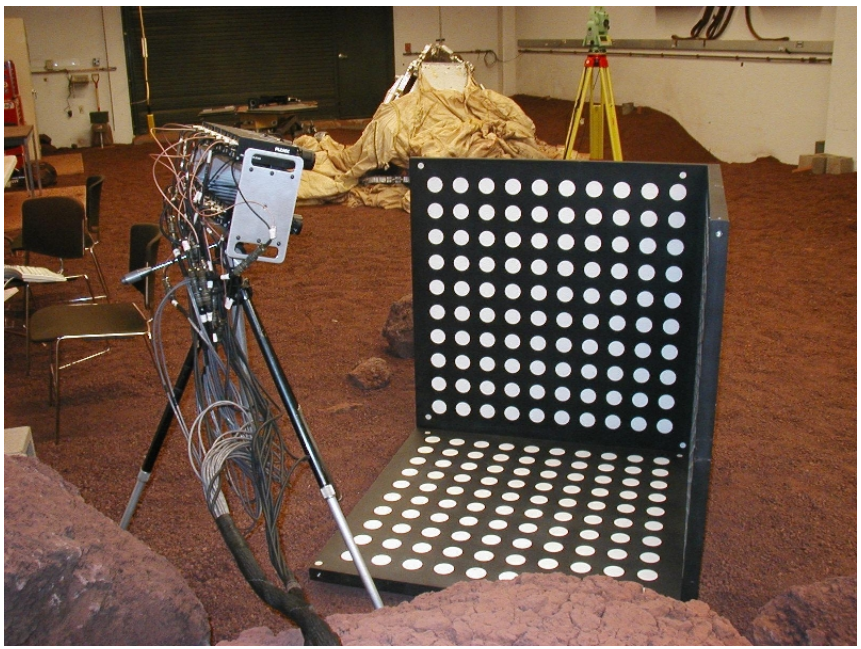


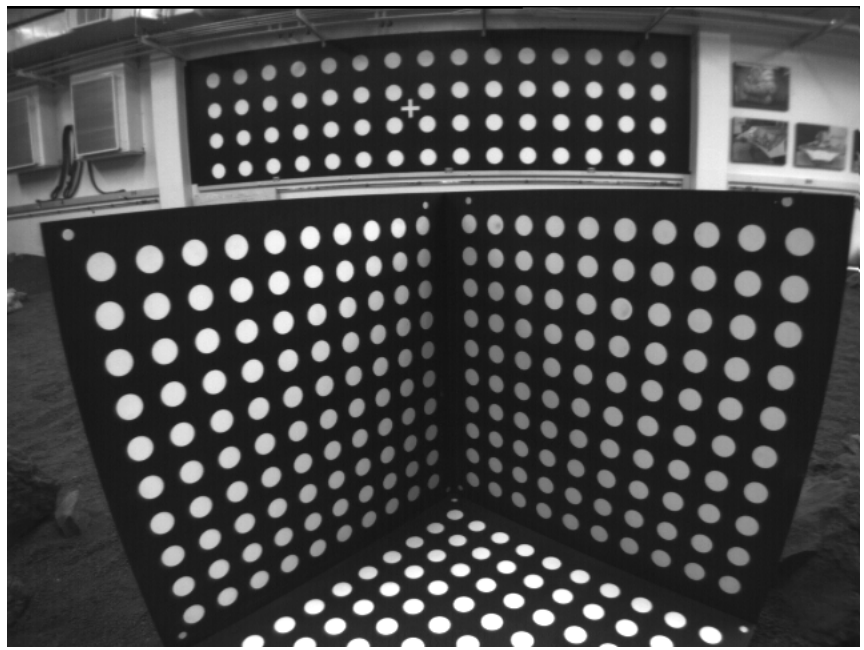
Equipment Rack

- Monitors for live & computer-generated images
- VME chassis
  - CPU board
  - Frame Grabbers
  - Graphics board
  - D/A board
- Video Switch
- Video & Sync Amplifiers
- Sync Generator
- Power supplies

Ground Calibration

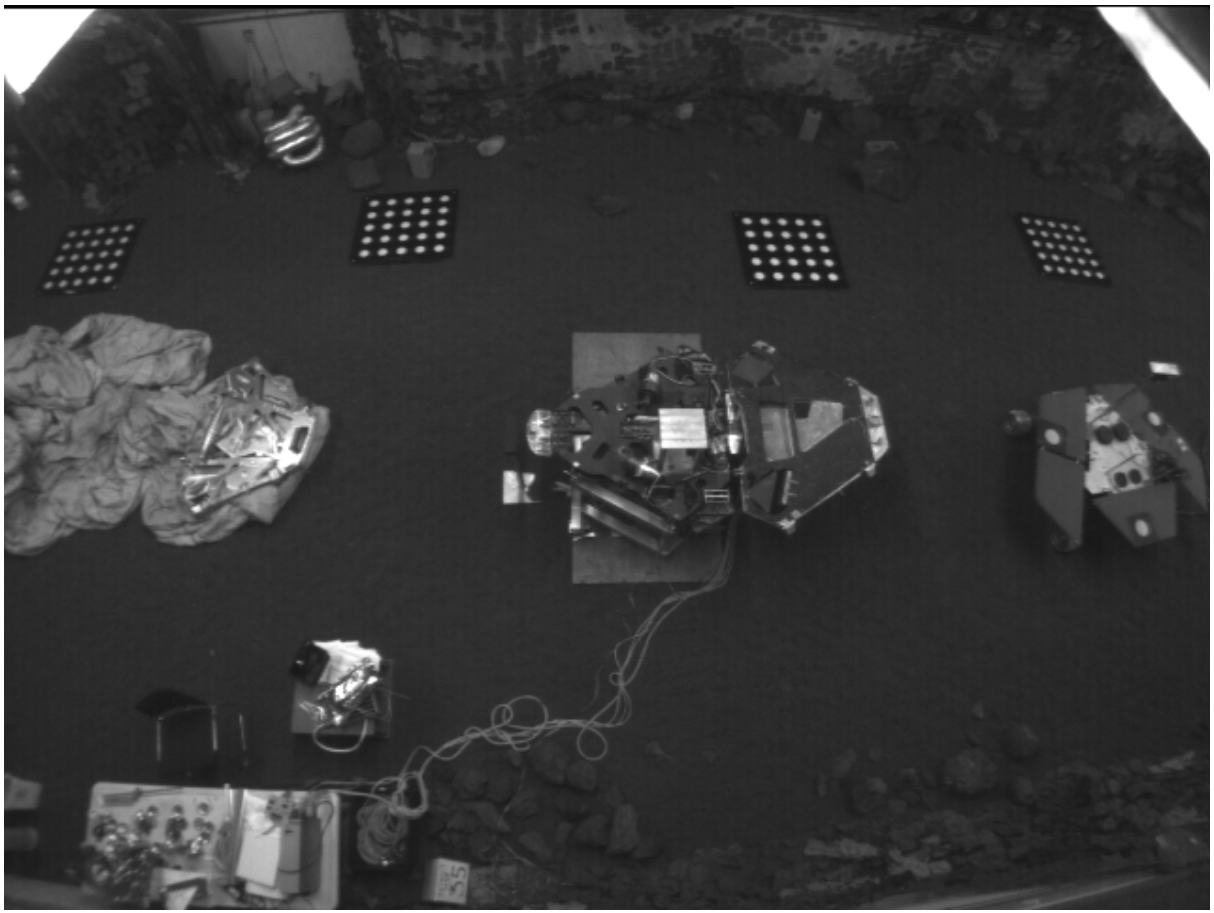
- **Three-dimensional spread of visual targets to characterize cameras**
- **Arbitrary reference coordinate system**





Ceiling Calibration

- **Only two-dimensional spread of data available**
- **Target coordinate system**
- **Combined with ground calibration**



Tracking Software

- **VxWorks real-time operating system**
- **Algorithm:**
  - **Acquisition**
  - **Tracking**
  - **Iris control**
- **Tasks:**
  - **ACQTRACK: implements tracker algorithms**
  - **HTTP: web server to display system status & diagnostic images**
  - **NTP: synchronizes local clock with external clocks**
  - **CMD: services commands from remote clients**

Logged Output Data

- Tracking status
- Time of data acquisition
- Rover Position
- Rover Orientation
- Positions of tracked dots in 3D
- Positions of tracked dots in 2D in all cameras

Web Browser Display

Rover Tracking

file:///Volumes/litwin/projects/flight/mer/track/images/2

Rover Tracking

Rover state:

```
STATUS = TRACKING, 1054442331.18 = 2003-06-01 04:38:51.18
  POSITION = 12.5903 15.4528 1.7444
  ROTATION = 0.8430 0.5373 -0.0247 -0.5378 0.8429 -0.0180 0.0111 0.0285 0.9995
  QUATERNION = 0.9599 0.0121 -0.0093 -0.2800
  FORWARD = 0.8430 -0.5378 0.0111
  ROLL = 1.6324
  PITCH = -0.6383
  HEADING = -32.5346
  TIME = 1054442331.08 = 2003-06-01 04:38:51.08
  3 TARGETS +/= 0.0054
    TARGET 0 = 13.2365 15.8704 1.3677 +/- 0.0044
    TARGET 1 = 12.4858 14.6915 1.3279 +/- 0.0058
    TARGET 2 = 11.9695 15.7217 1.3337 +/- 0.0030
  4 CAMERAS
    CAMERA 0, 3 TARGETS
      CAMERA 0, TARGET 0 = 412.33 295.09
      CAMERA 0, TARGET 1 = 317.79 282.59
      CAMERA 0, TARGET 2 = 334.98 358.45
    CAMERA 1, 2 TARGETS
      CAMERA 1, TARGET 0 = 207.23 47.00
      CAMERA 1, TARGET 1 = 280.19 62.15
    CAMERA 2, 3 TARGETS
      CAMERA 2, TARGET 0 = 516.26 288.28
      CAMERA 2, TARGET 1 = 420.50 283.55
      CAMERA 2, TARGET 2 = 469.08 362.55
    CAMERA 3, 3 TARGETS
      CAMERA 3, TARGET 0 = 138.22 70.44
      CAMERA 3, TARGET 1 = 211.50 62.62
      CAMERA 3, TARGET 2 = 188.92 32.44
```

Select an image:

- Display
- Camera 0
- Camera 1
- Camera 2
- Camera 3
- Camera 4
- Camera 5
- Camera 6
- Camera 7
- Camera 8
- Camera 9
- Camera 10
- Camera 11

Todd Litwin: x4-5028, email, home page

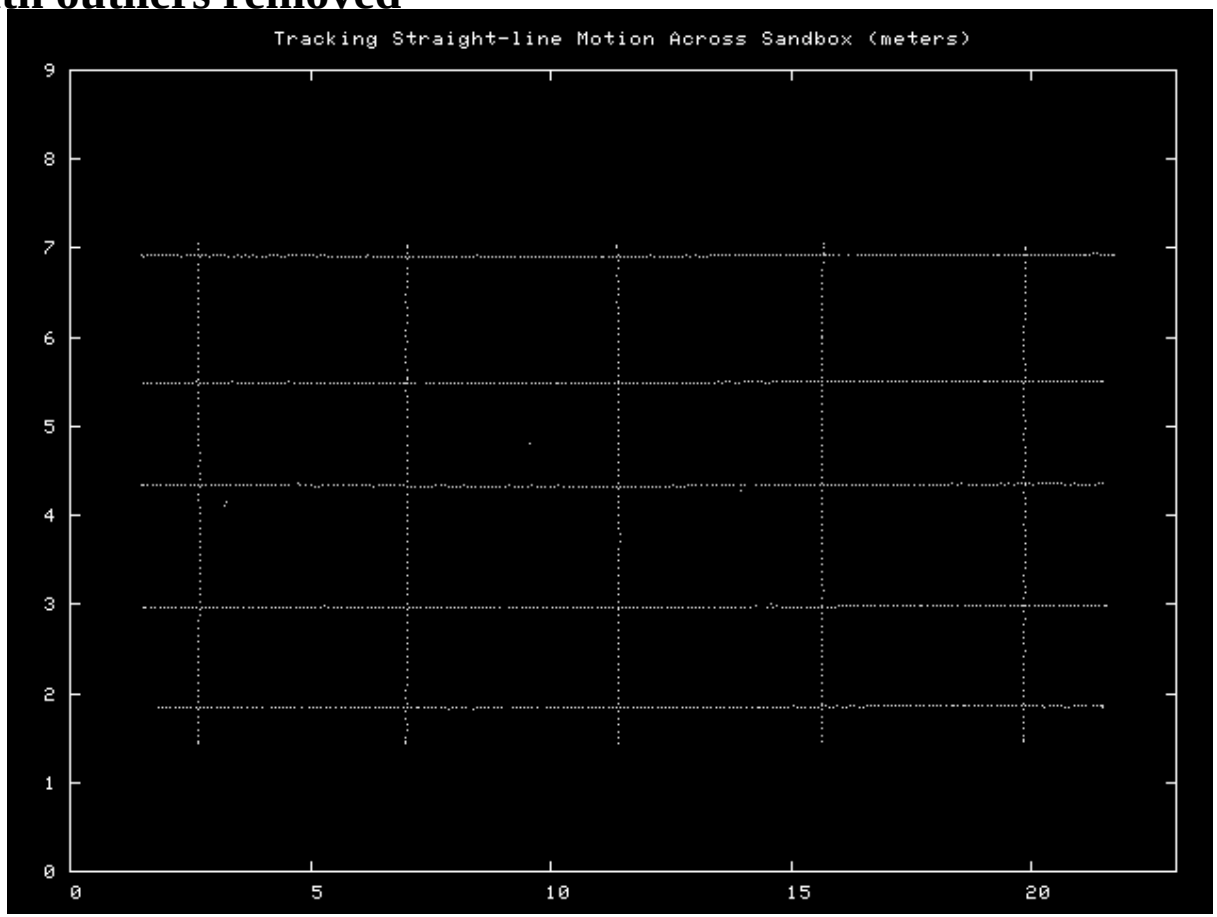
- **State: tracking/lost**
- **Data if tracking**
- **Links to diagnostic and camera images**

Remote Command-Line Tools

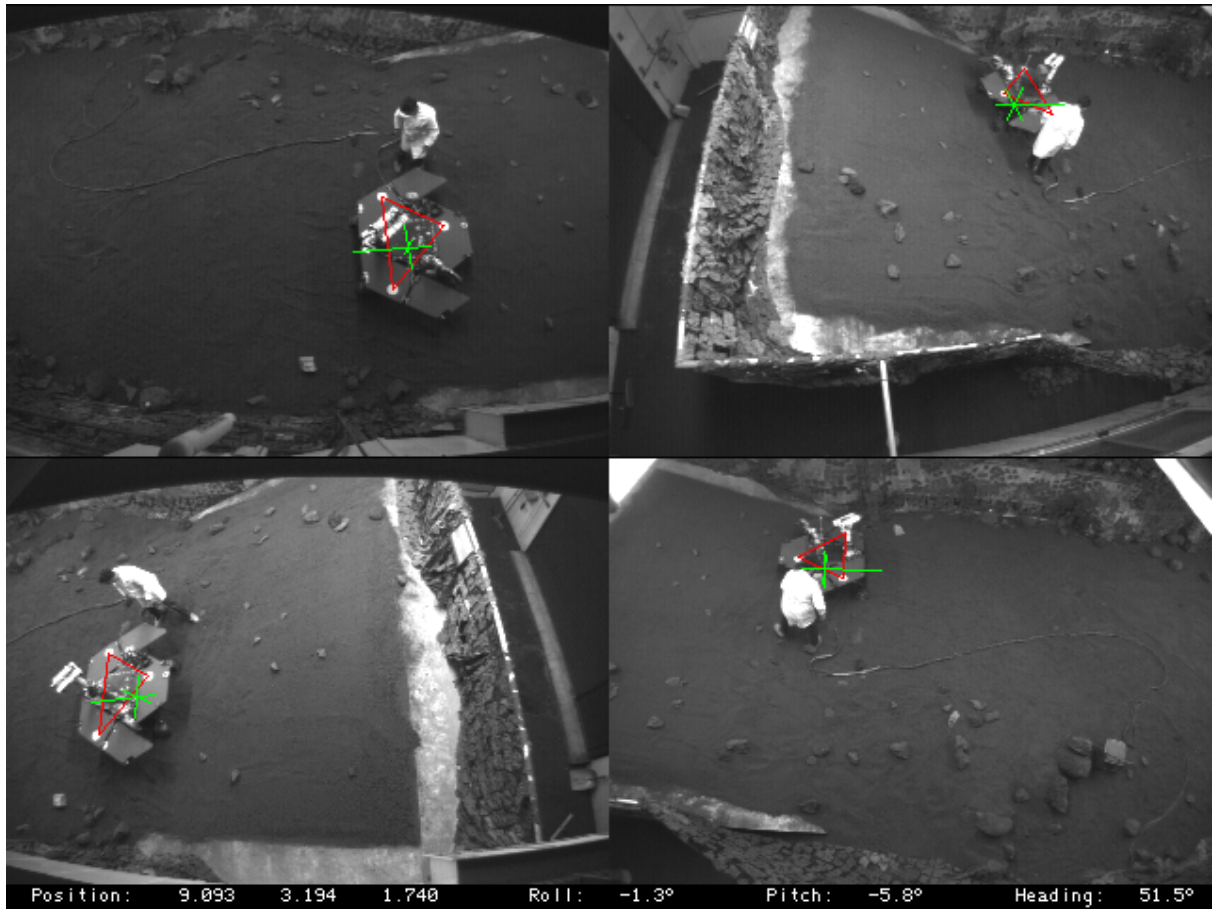
- **dumptrack**
  - connects to tracking system and dumps data to standard output
- **cmdtrack**
  - sends commands to tracking system
- **currtrack**
  - connects to tracking system and displays data in full-screen mode
- **savetrack**
  - grabs images from tracking system and saves to files
- **showtrack**
  - grabs images from tracking system and displays in X windows

Test Runs

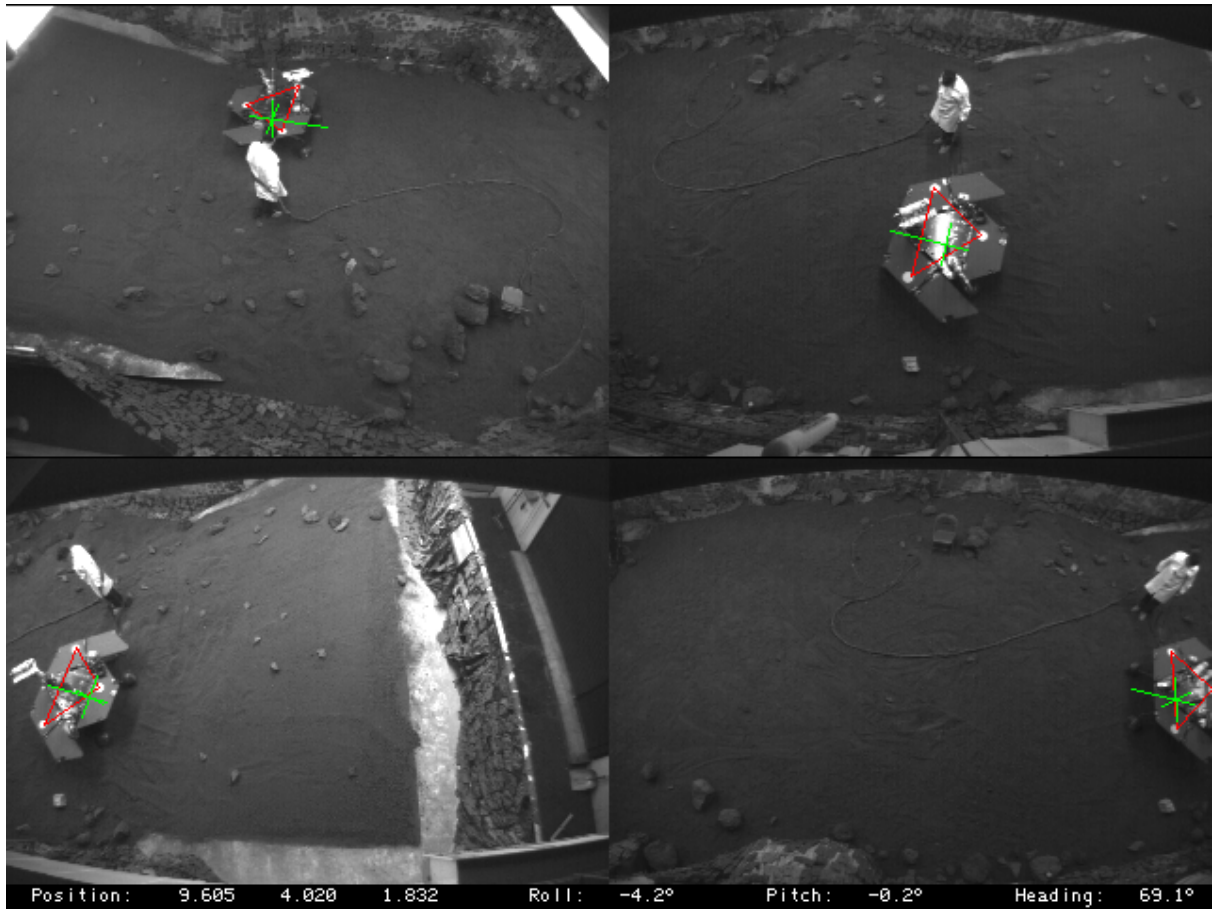
- **Absolute accuracy: Placed tracking target in a few locations on the sand and spot checked with Leica TotalStation – 15.3mm RMS error over 18m**
- **Relative accuracy: Suspended tracking target from ceiling crane and tracked north-south and east-west runs – 7.6mm horizontal and 6.1mm vertical RMS error with outliers removed**



Backing up



Turning in Place



Summary

- Typically operates at 5-6Hz
- Has been in operation since 2003
- Used to initialize IMU state for test runs
- Used to log test runs to analyze results while driving
  - hazard avoidance
  - wheel slippage
  - visual odometry
- Currently in use to support testing of a new version of flight software