Imaging Services Flight Software on the Mars Exploration Rovers

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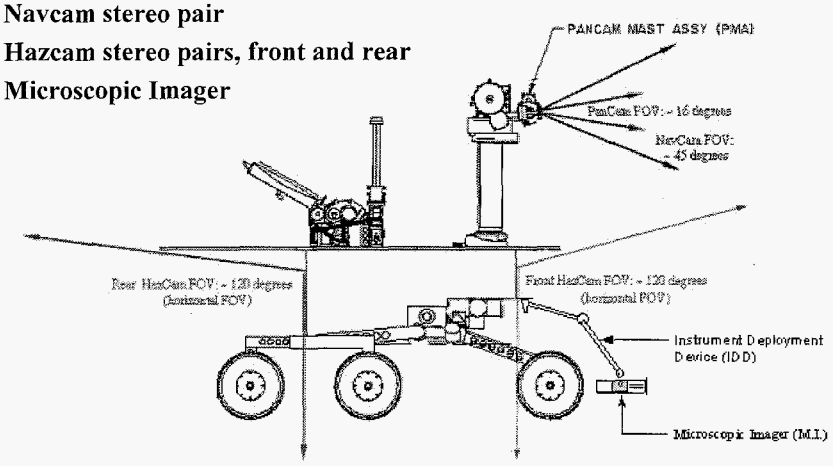
Imaging Instruments

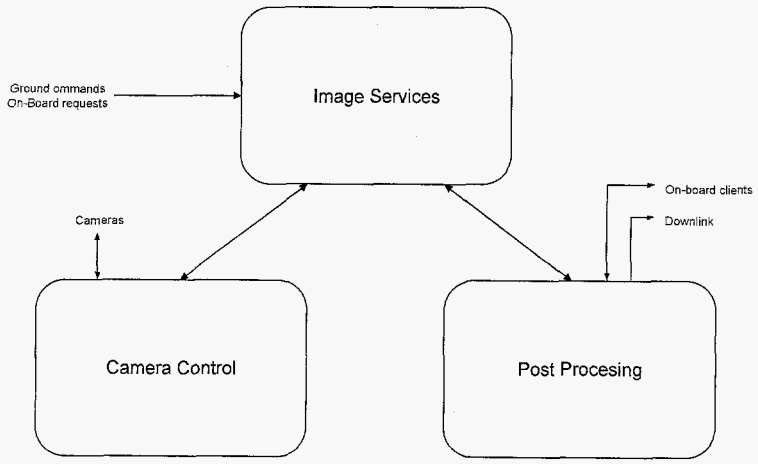
- Descent Imager
- Pancam stereo pair
- Navcam stereo pair
- Hazcam stereo pairs, front and rear
- Microscopic Imager



Goals

- Acquire images by ground command and by request from on-board systems
- Give the ground controllers maximum control over imaging behavior
- Keep the cameras as busy as possible

Task Structure



Requesting Image Acquisition

- How to get an image:
  - Initialize with a named set of parameters defined by ground command
  - Optionally override some parameters autonomously
  - Make the request
  - Wait for the results

Web Interface

- Needed to start interacting with cameras within days of starting implementation
- There was not yet any way to downlink or process image data
- IMG will respond to any client making requests
- Wrote a non-flight client module presenting a web server interface over a diagnostic network connection
- Viewed web page on any browser (we used Netscape)
- Selections on the web page resulted in imaging requests
- Returned images were displayed in the browser
- Used to discover early errors, such as understanding the bit format for pixel data

Web Interface

MER/IMG Test Server

file:///Users/telitwin/Desktop/Backup/litwin/projects/flight/mer/img/images

MER/IMG Test Server

Select one of the following:

- Front Hazcam: left, right, stereo
- Rear Hazcam: left, right, stereo
- Navcam: left, right, stereo
- Pancam: left, right, stereo
- EDL imager
- Microscopic imager

Settings:

Exposure time = 100 counts = 0.5100 seconds
Auto exposure = no
Voff = 0xfff
Flush = 2
Shutter subtraction = no
Flat-field correction = no
Subframe = no, Row0=0, Col0=0, Rows=1024, Cols=1024
Downsample = no
Test image = no
Pixel size = 12
Left pancam filter = none
Right pancam filter = none
PMA pointing = no, Azimuth=0°, Elevation=0°
Image data = early

Web Interface

MER/IMG Test Server

file:///Users/telitwin/Desktop/Backup/litwin/projects/flight/mer/img/imag

Change Settings:

Exposure counts: 100
Auto exposure: ○ Yes ◉ No
Voff: ff (hex)
Flush: 2
Shutter subtraction: ○ Yes ◉ No
Flat-field correction: ○ Yes ◉ No
Subframe: ○ Yes ◉ No Row0: 0 Col0: 0 Rows: 1024 Cols: 1024
Downsample: ○ Yes ◉ No
Test image: ○ Yes ◉ No
Pixel size: ○ 8 ◉ 12
Left filter: ◉ None ○ L1-empty ○ L2-750 ○ L3-670 ○ L4-600 ○ L5-530 ○ L6-480 ○ L7-450 ○ L8-440-Sun
Right filter: ◉ None ○ R1-450 ○ R2-750 ○ R3-800 ○ R4-860 ○ R5-900 ○ R6-930 ○ R7-985 ○ R8-880-Sun
PMA pointing: ○ Yes ◉ No Azimuth: 0 deg Elevation: 0 deg
Image data: ◉ Early ○ Late ○ Telemetry ○ Reference ○ Thumbnail

Update

Todd Litwin: x4-5028, email, home page.

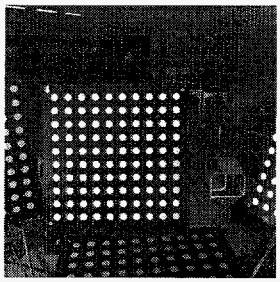
Web Interface

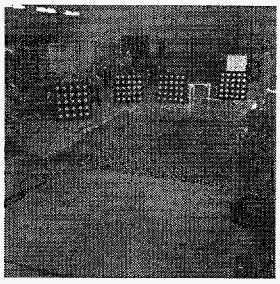
Unit Testing

- Wrote non-flight client module to exercise the interfaces, including:
  - Camera management: power control, hardware identification
  - PMA pointing control
  - Image Acquisition: exposure control, subframing, pixel scaling
  - Post processing: camera-model labelling, bad-pixel replacement, flat-field correction
  - Telemetry generation: images, histograms, row/column sums, spatial downsampling
  - Command support
- Test suite evolved and was used as development progressed:
  - "If it hasn't been tested, it doesn't work."
  - Errors were discovered every step of the way
- Most errors were caught and corrected here

Geometric Camera Calibration

- Took images of dot targets
- Surveyed 3D dot positions
- Fit data to model appropriate to camera geometry (perspective projection, fisheye)
- Created over 80 models during preparation for launch: 2 flight rovers, 2 testbed systems, repeated calibrations





System Testing

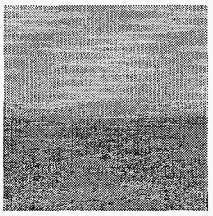
- Planned testing:
  - Command sequences to exercise the interfaces
  - Examined resulting telemetry for expected results
  - Reported problems
- Unplanned:
  - System locked up when flooded by unexpected interrupts
    - Traced to flaky non-flight camera cabling and test setup
    - Replaced cables
    - Modified software to disable interrupts most of the time
  - Speckling seen in images
    - Eventually traced to miswired cable
  - Intermittent timeout while acquiring images
    - Eventually traced to software error

Status

- A few minor bugs have been found after launch
- Intermittent problems commanding Opportunity's MI, possibly due to flex-cable delamination
- Number of images received as of September 19, 2005:
  - Spirit: 63,477
    - 3 EDL
    - 12,139 Navcams
    - 3,900 Front Hazcams
    - 1331 Rear Hazcams
    - 42,850 Pancams
    - 3,254 MI
  - Opportunity: 54,696
    - 3 EDL
    - 8.947 Navcams
    - 3,125 Front Hazcams
    - 1,572 Rear Hazcams
    - 37,971 Pancams
    - 3,078 MI

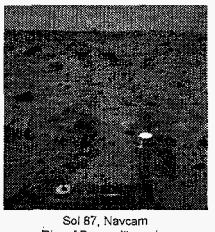
Images: Spirit

Sol 2, Pancam
Columbia memory patch

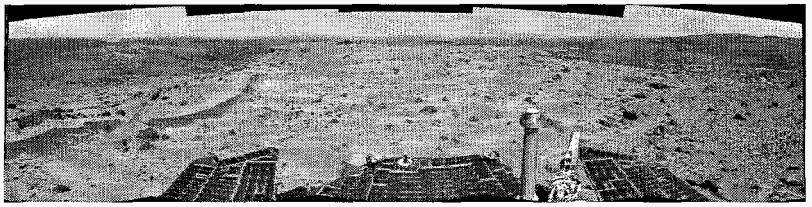


Sol 3, Pancam
Columbia Hills in the distance

Sol 12, Rear Hazcam
View of lander after egress

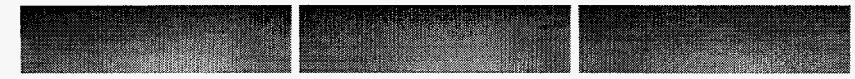


Sol 87, Navcam
Rim of Bonneville crater

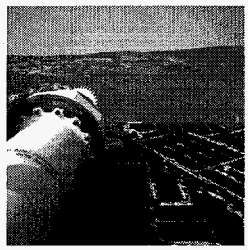


Sol 581, Navcam mosaic, top of Husband Hill in the Columbia Hills; note dust devil in the distance on left

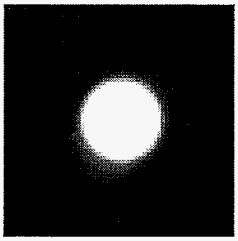
Images: Opportunity



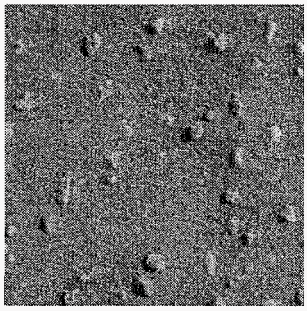
Sol 1, EDL imager
All 3 images during descent



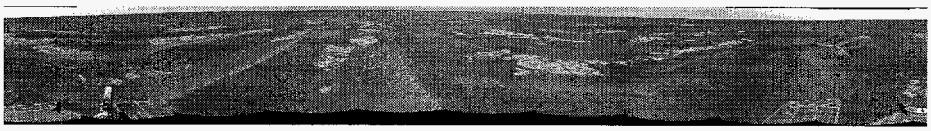
Sol 1, Navcam
View of outcroppings in Eagle crater



Sol 2, Pancam
First sun find, automatically subframed



Sol 9, Microscopic Imager
Granules on ground after egress



Sol 576, Navcam mosaic, sand dunes and exposed bedrock, on the way to Erebus Highway