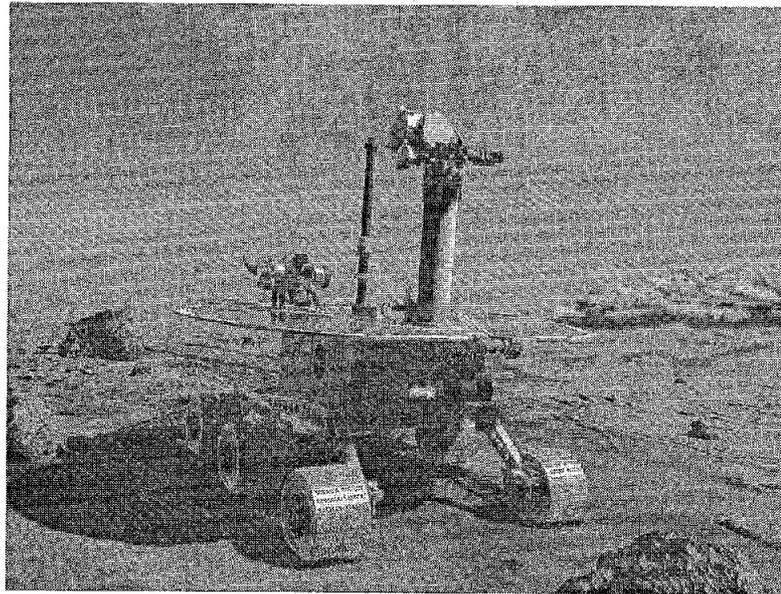




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Mars Exploration Rover

Optomechanical Design of Ten Modular Cameras for the Mars Exploration Rovers



Virginia Ford, Paul Karlmann, Ed Hagerott, Larry Scherr

Jet Propulsion Laboratory, California Institute of Technology

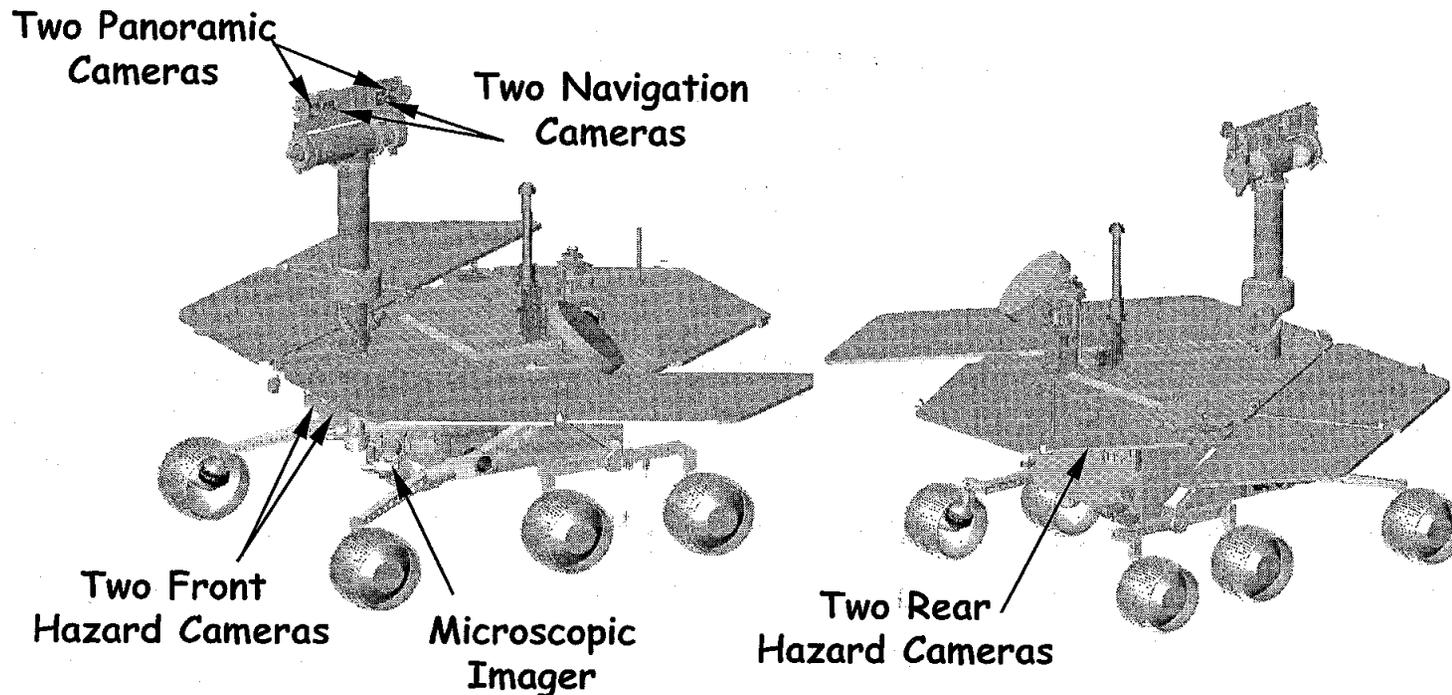


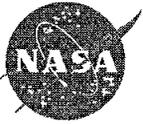
BACKGROUND



Mars Exploration Rover

- 2003 Mission to Mars: 2 Landers and 2 Rovers
- Ten cameras for each lander and rover:
 - Science cameras: two Panoramic Cameras, one Microimager
 - Engineering cameras: four Hazard Cameras, two Navigation Cameras, on Lander Descent Camera



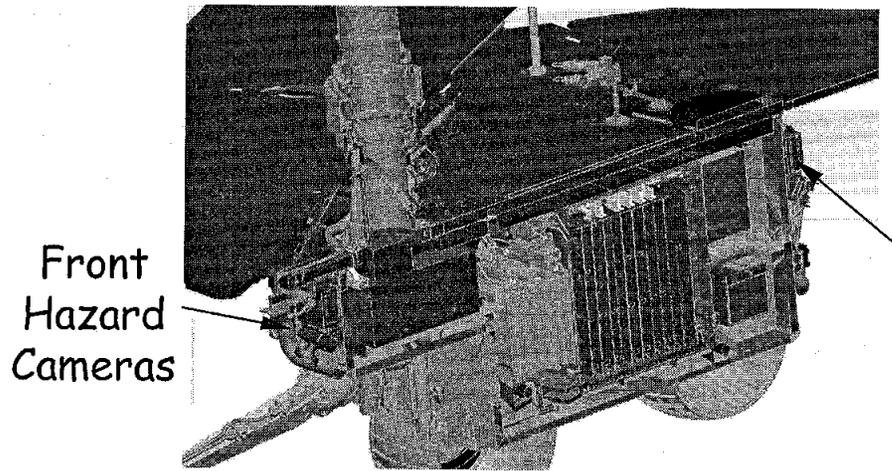
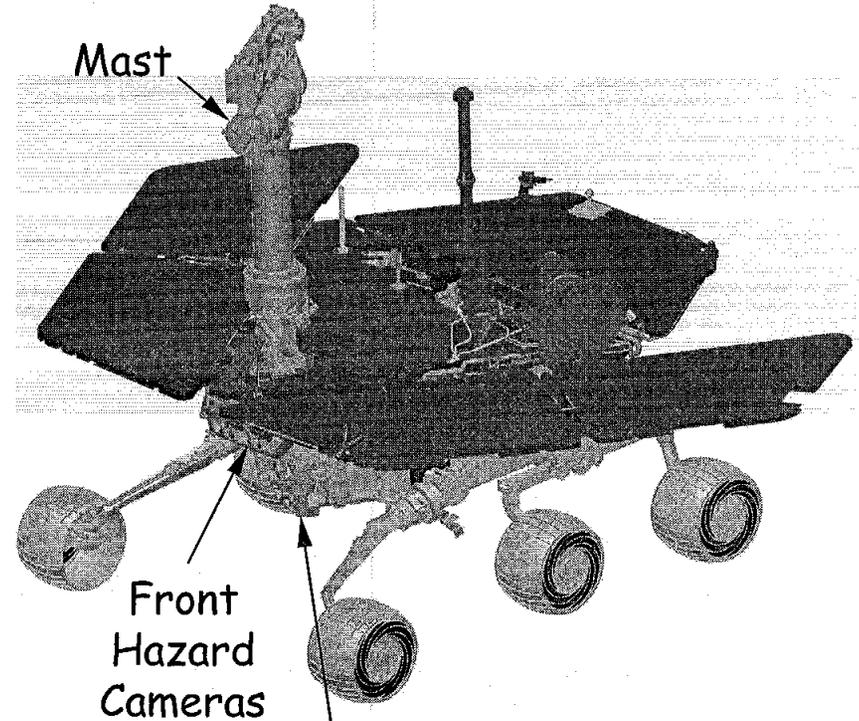


BACKGROUND (CONT)

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- Design drivers:
 - Volume constraints (and mass)
 - budget based on previous design without flight hardened electronics
 - Thermal requirements
 - electronics - similar to Mil Spec requirements
 - detector - cold as possible to decrease noise



Cross Section

Rear Hazard Cameras

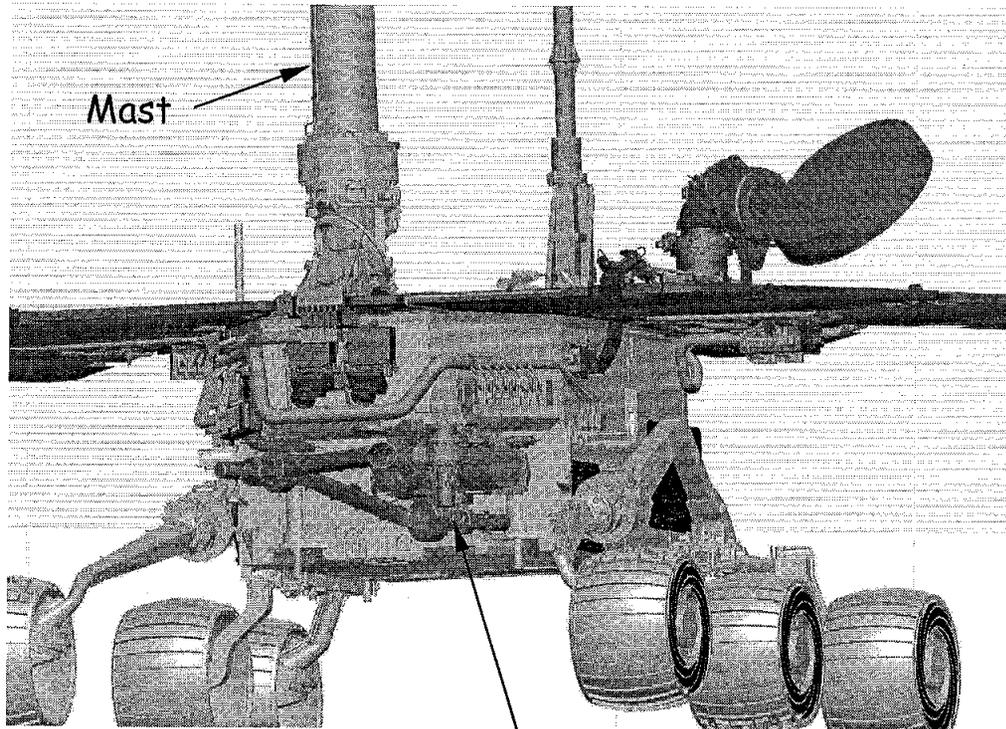


BACKGROUND (CONT)



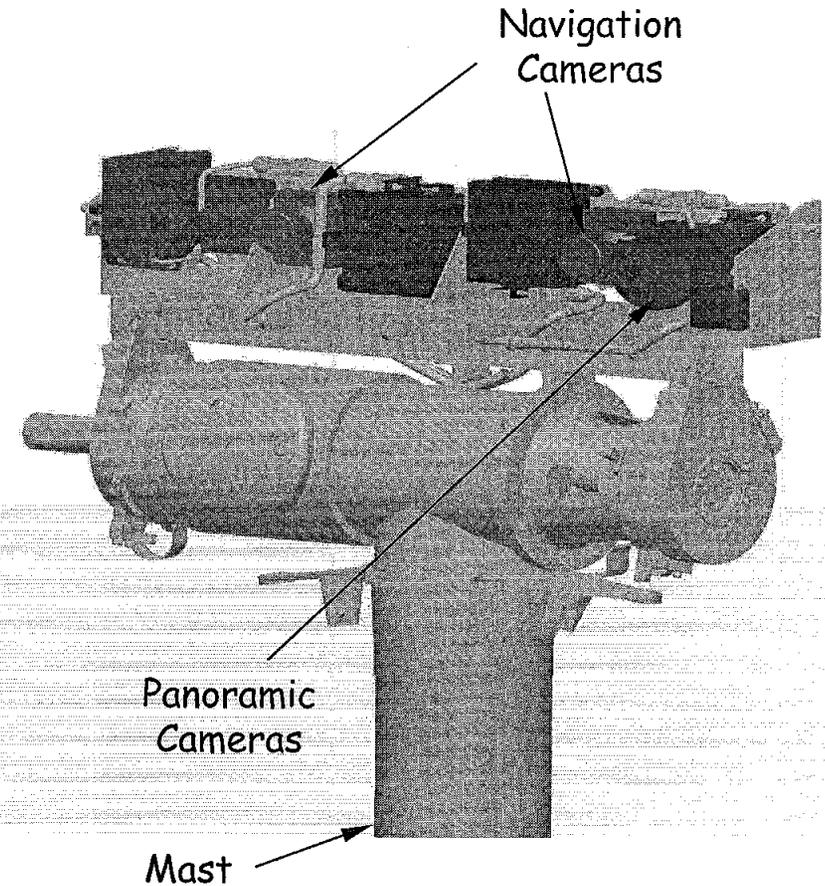
Mars Exploration Rover

- Design drivers (cont):
 - Versatility requirements
 - 10 locations/10 mounting interfaces
 - Need to be flexible to fit



Mast

Instrument Deployment Device (IDD)
(carries microscopic imager)



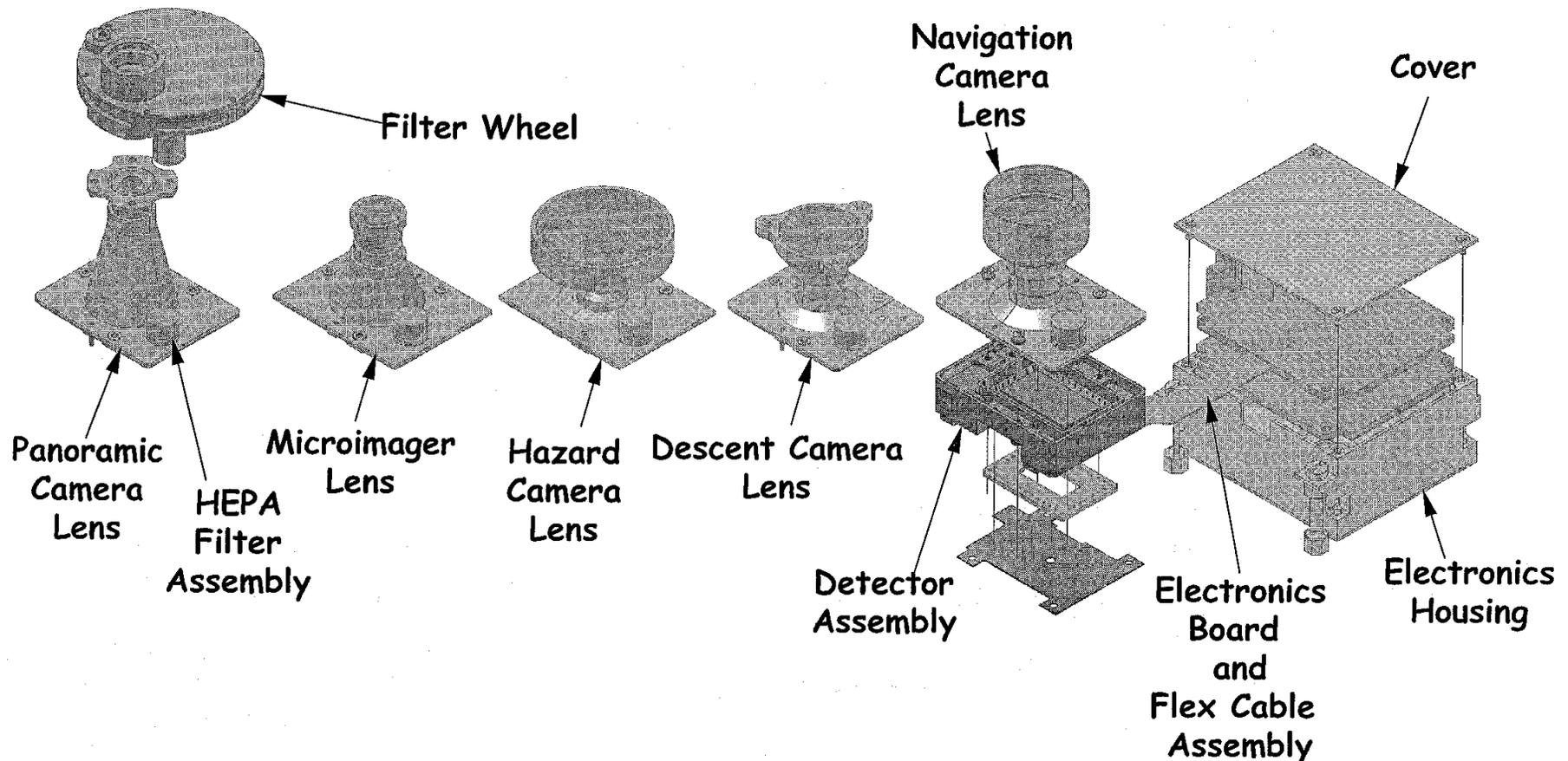


Camera Design Solution



Mars Exploration Rover

- Two sides:
 - lens and detector side
 - electronics side
- Modular
 - Detectors, electronics, HEPA Filters identical/interchangeable
 - Only lens barrels are unique



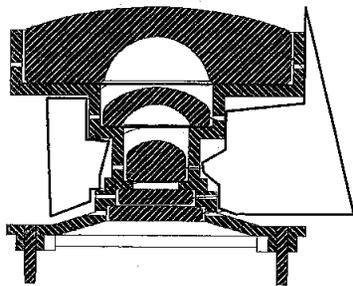


Lens Designs



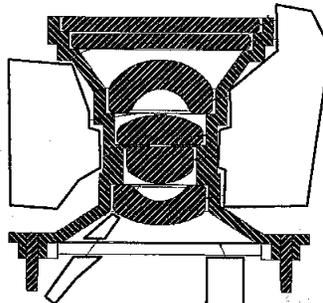
Mars Exploration Rover

- Aluminum lens barrels positions lenses
 - Axially located on precision ledges
 - Precision bores locate lenses radially within tolerances
 - Precision pins fit between lens and housing
 - Gap filled with RTV
- Stray light baffles
- Venting through axial holes
- HEPA filter on lens housing - microbe and dust barrier

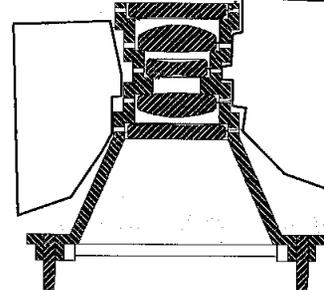


Hazard
Camera
Lens

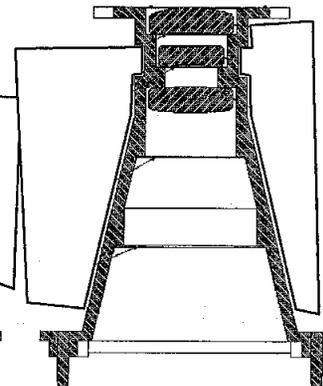
OSSC



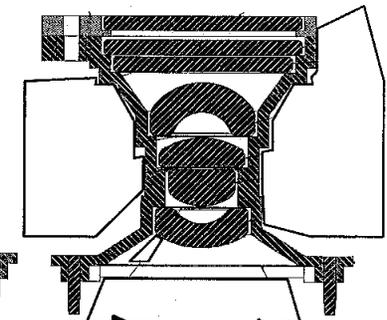
Navigation
Camera
Lens



Microimager
Lens



Panoramic
Camera
Lens



Descent
Camera
Lens

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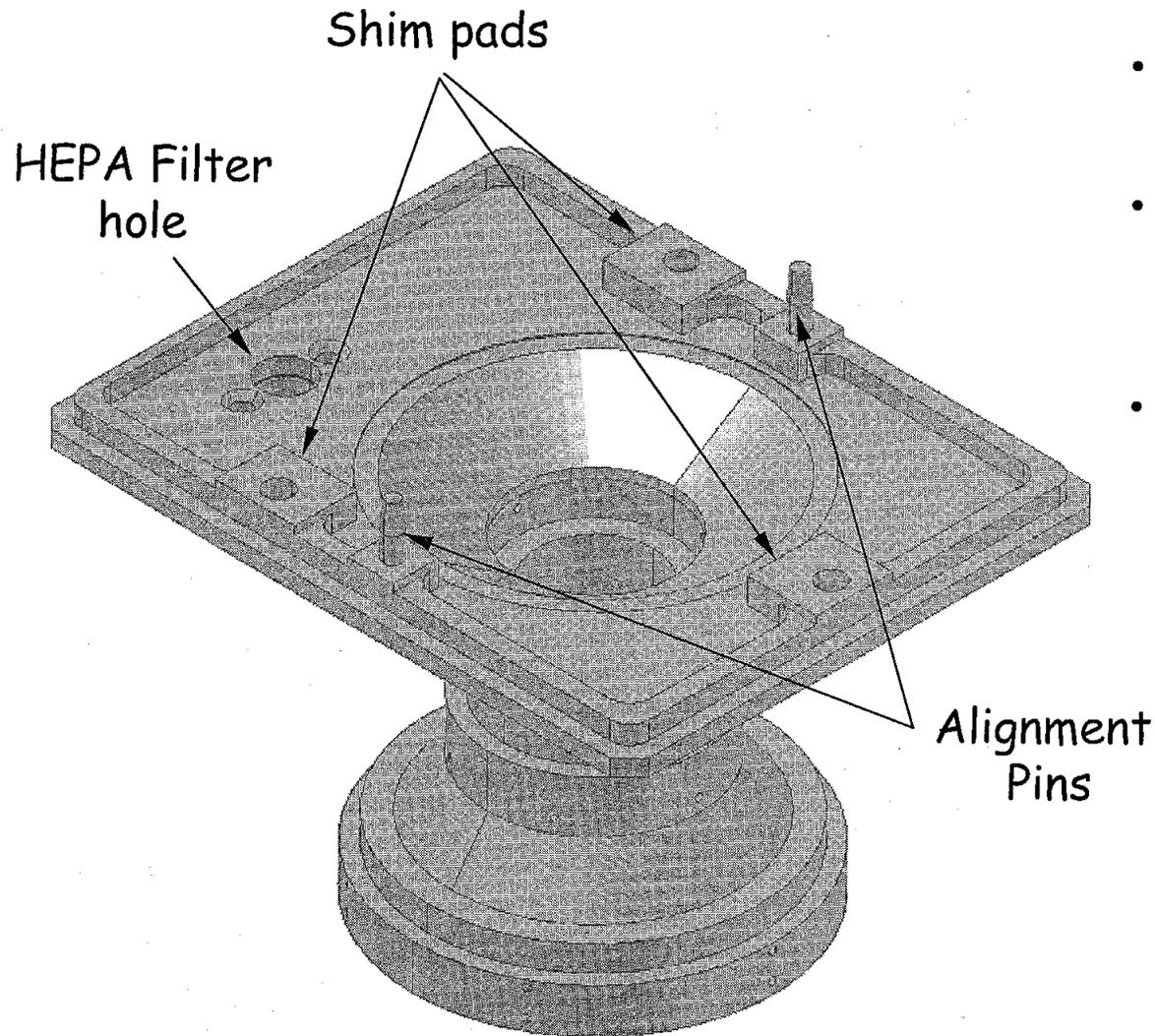
April 9, 2003



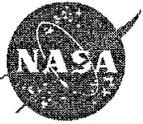
Lens Interface with Detector Assy

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Mars Exploration Rover



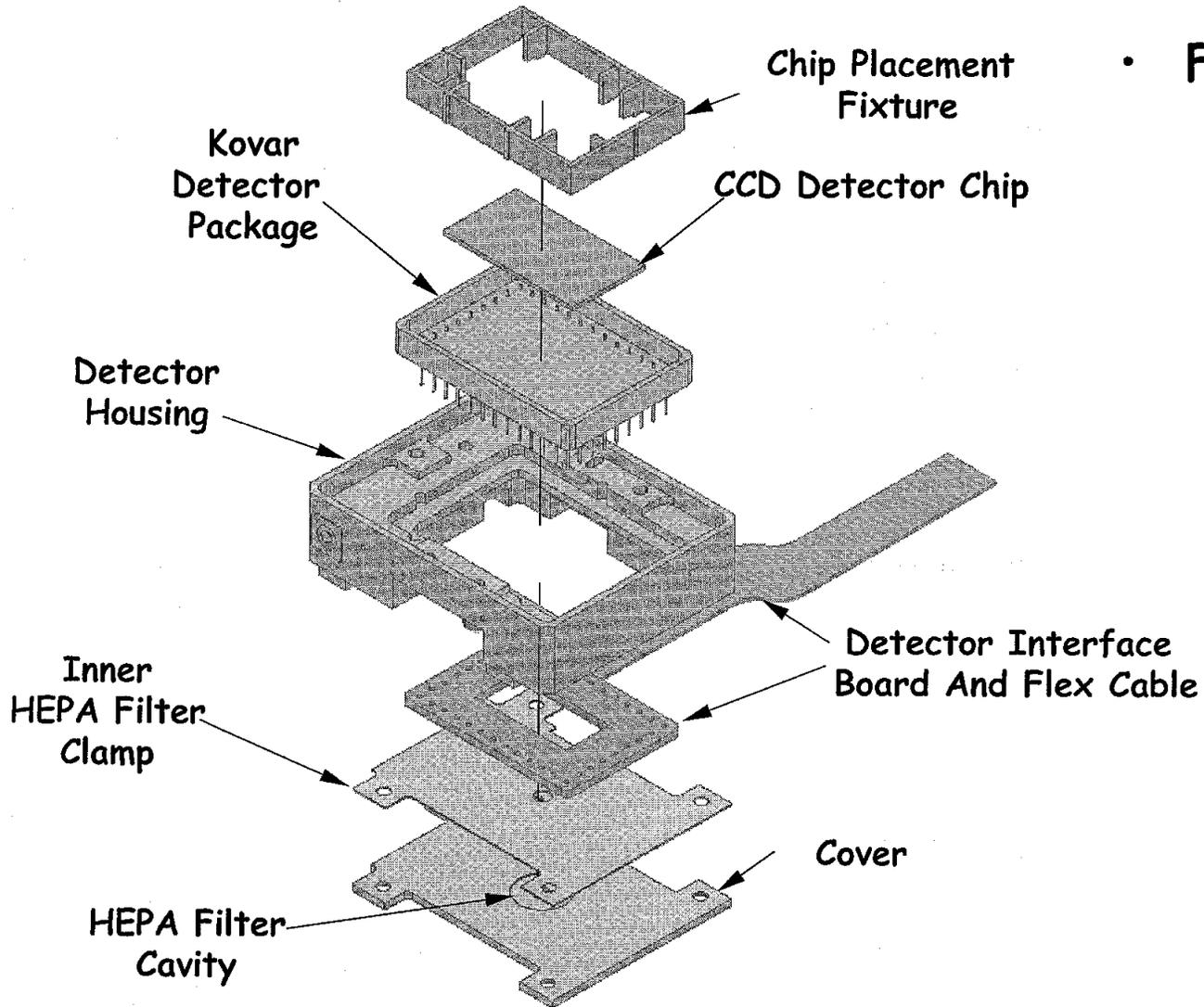
- Same interface for all lens assys
- Two alignment pins engage hole and slot in detector housing
- Three pads rest on pads of detector housing
 - nominal shims planned
 - adjust shim thickness for focus adjust



Detector Assembly

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Mars Exploration Rover



• Features:

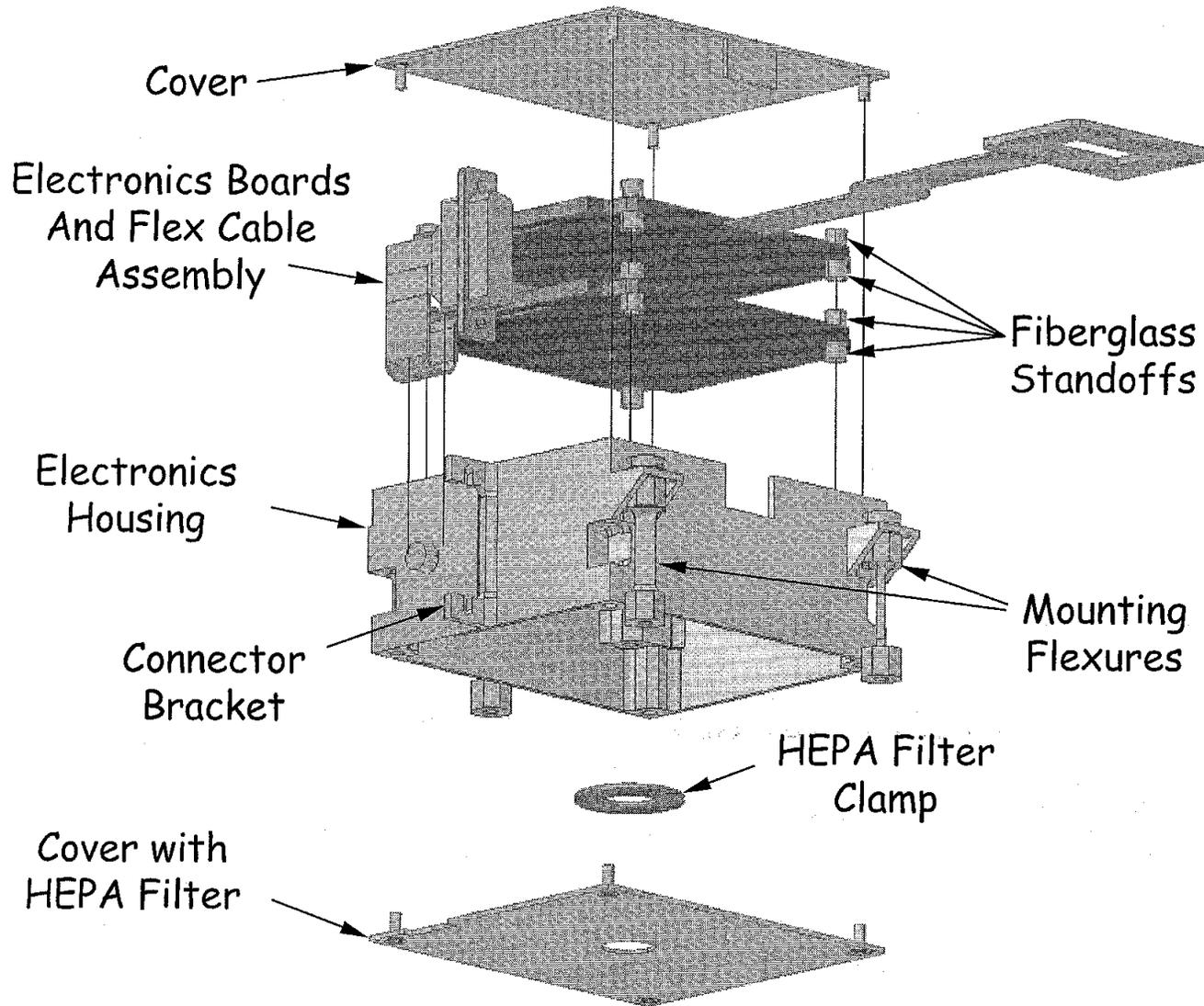
- lens interface
- thermal expansion considerations
 - Kovar detector pkg
 - RTV bond line thickness
- Contamination Control
 - RTV seal around detector package
 - Two layer cover to hold HEPA filter
 - Flex exit slot surrounded by RTV
 - lens to detector lip sealed with RTV



Electronics Assembly



Mars Exploration Rover



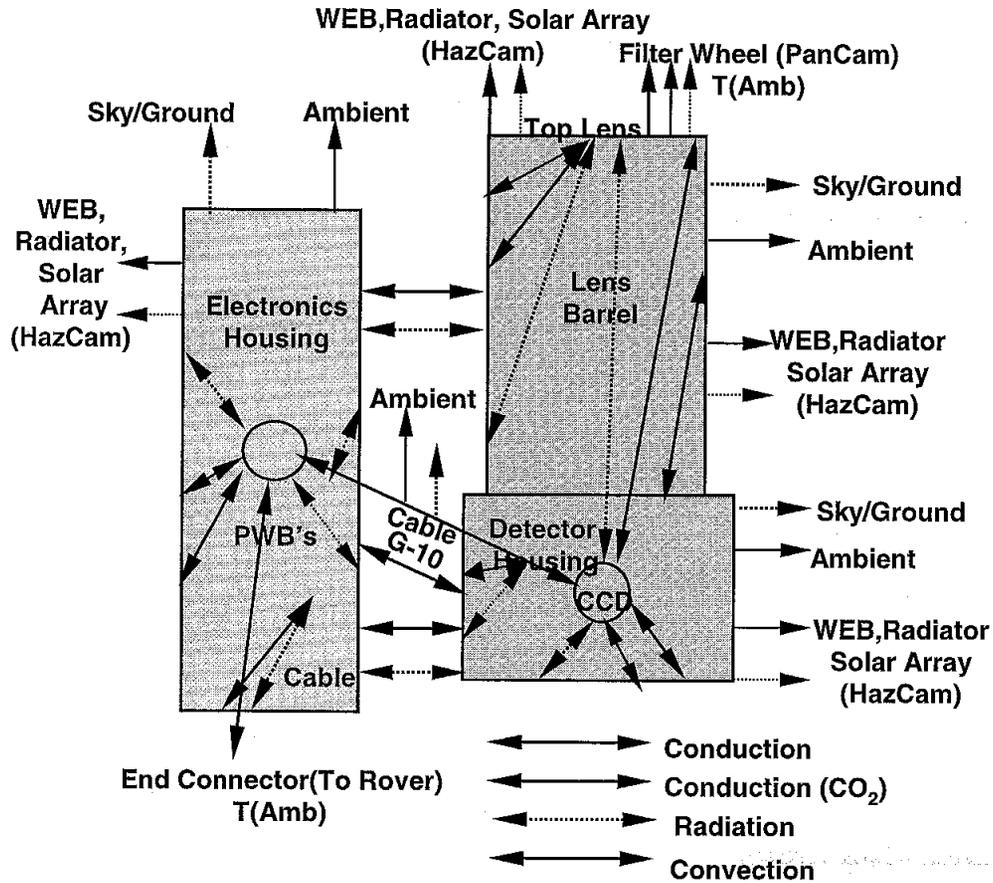
- **Designed to minimize heat transfer from electronics boards to cold outside environment**
 - **Mounting Flexures: titanium**
 - **Fiberglass stand-offs for electronics**



Thermal Concept

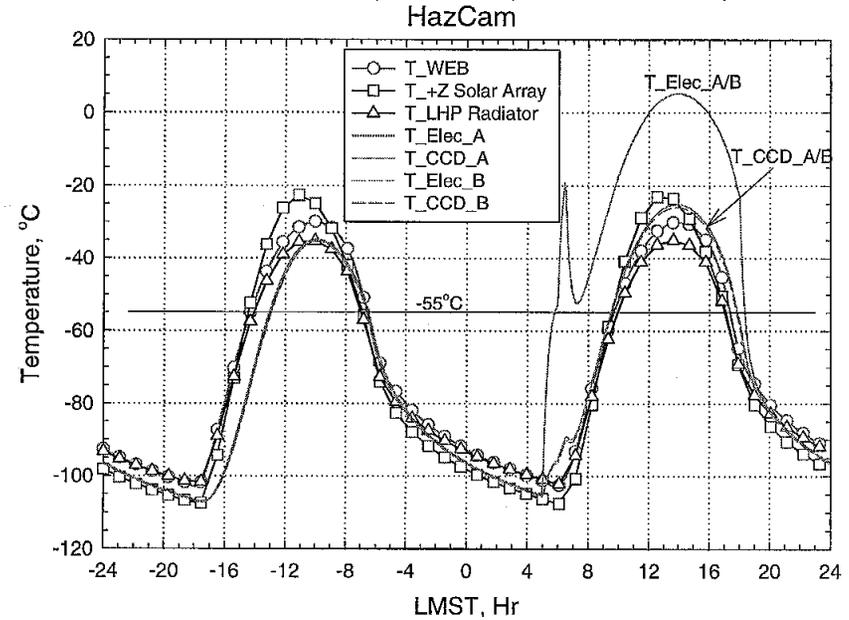


Mars Exploration Rover



Nodal Network Diagram

$Q(\text{heater, 05:00-06:30})=3.5\text{W}$, $Q(\text{Op, 06:30-18:00})=2.75\text{W}$



- Surface of Electronics Housing: shiny mylar
- Surface of Lens Barrel and Detector Housing: machined aluminum

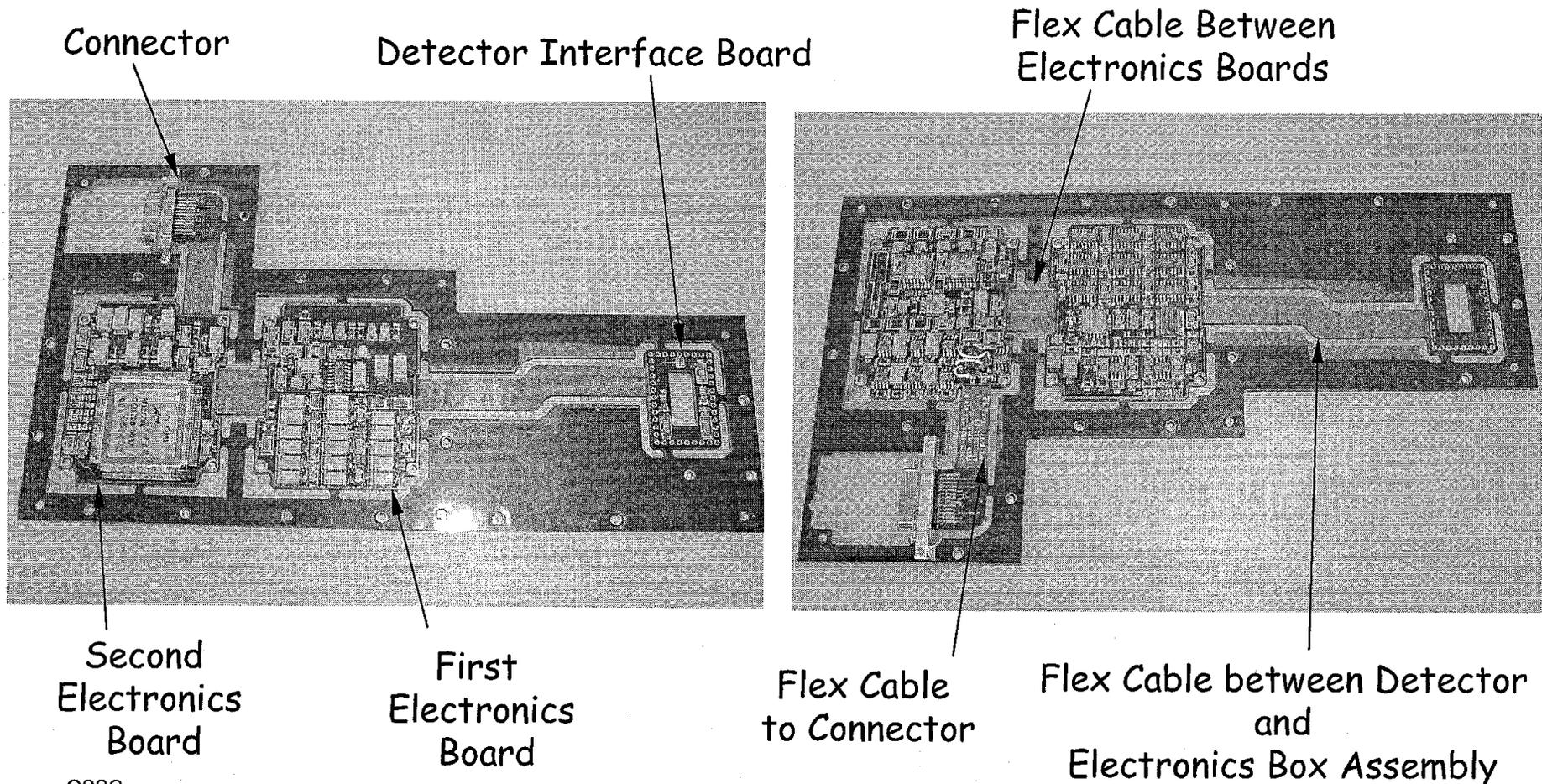


Electronics Boards and Flex Cable Assembly

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- One unit design
 - Advantage: mass and volume
 - Disadvantage: if flex cable damaged lose entire assembly



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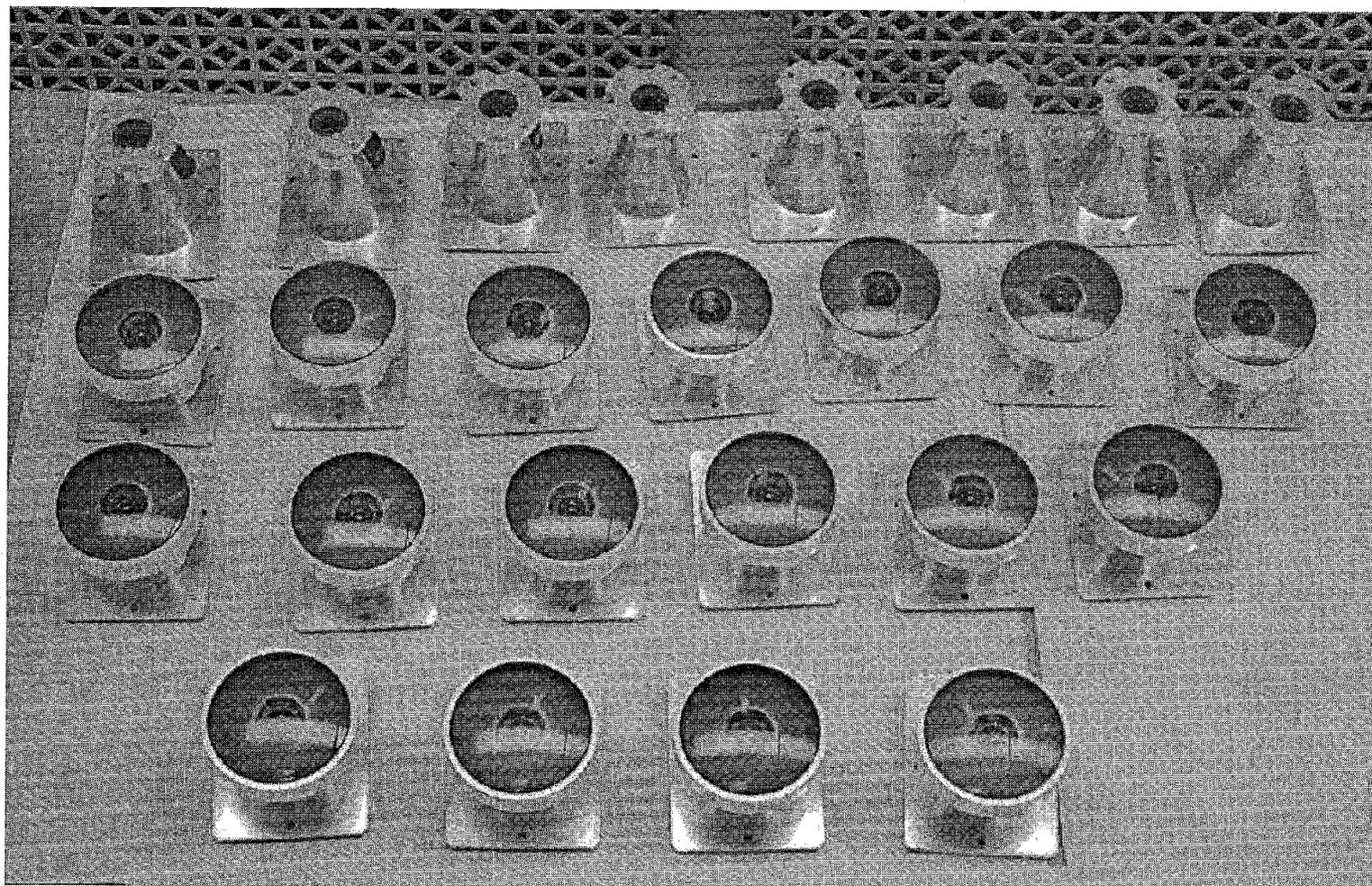
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An Array of Completed Lenses

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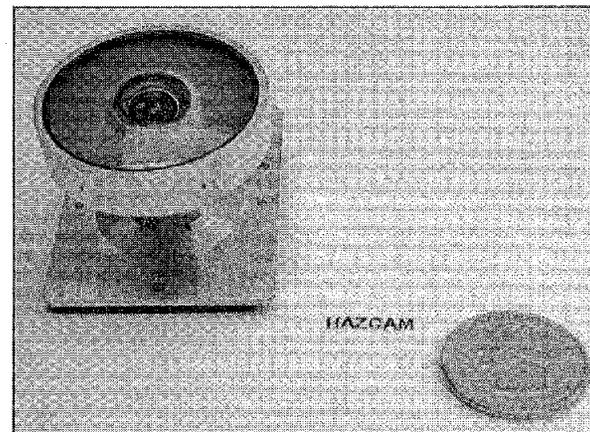
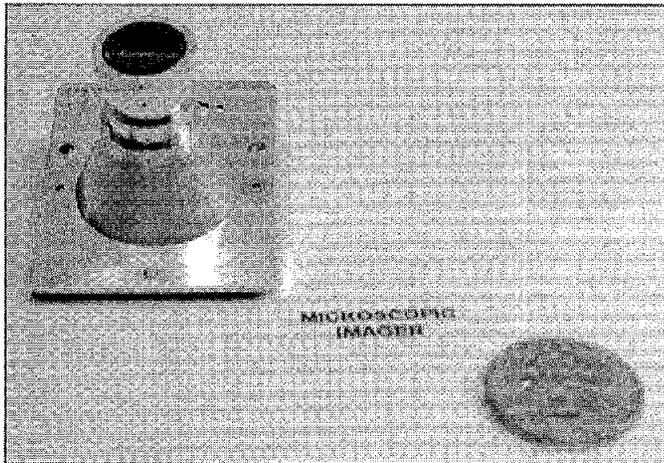
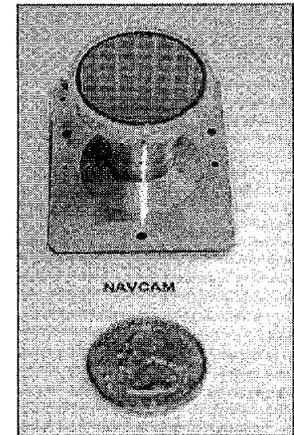
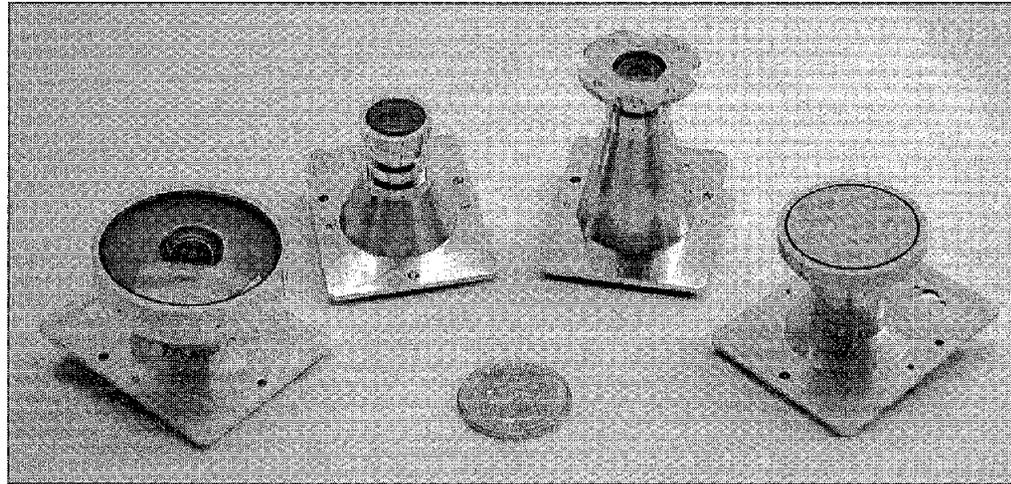
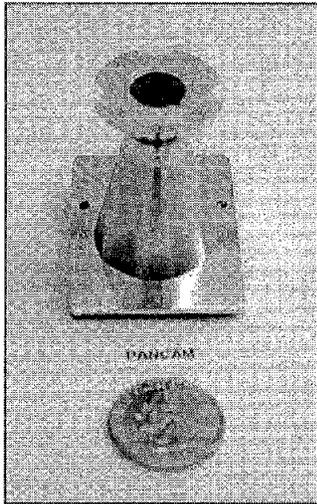




Rover Lenses



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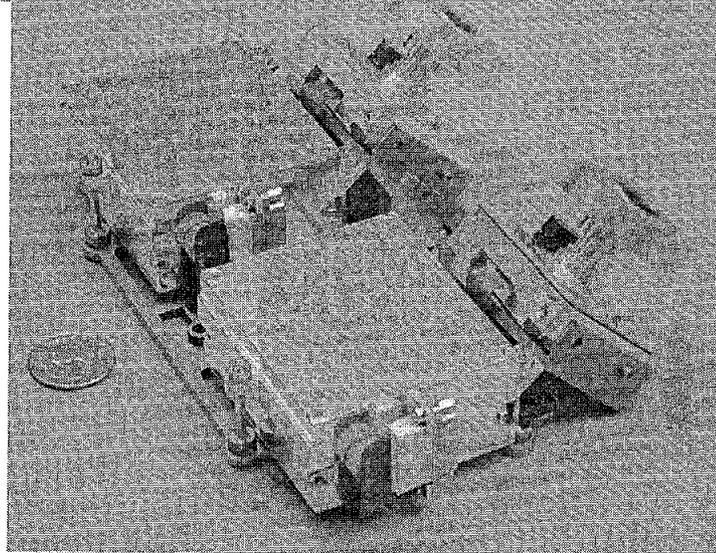
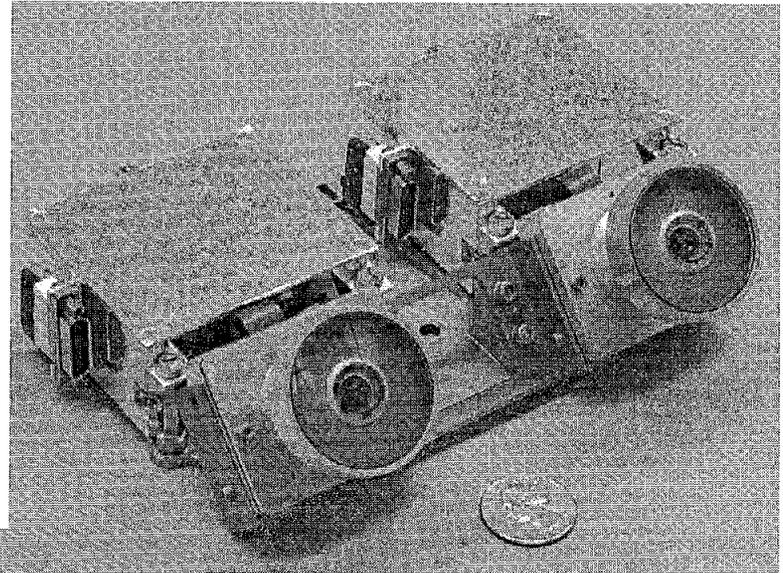
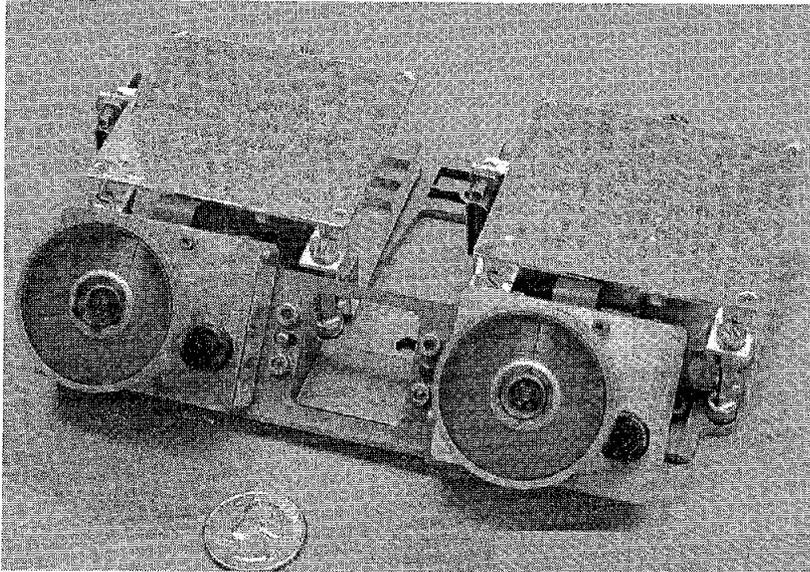
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Rear Hazard Camera Assembly

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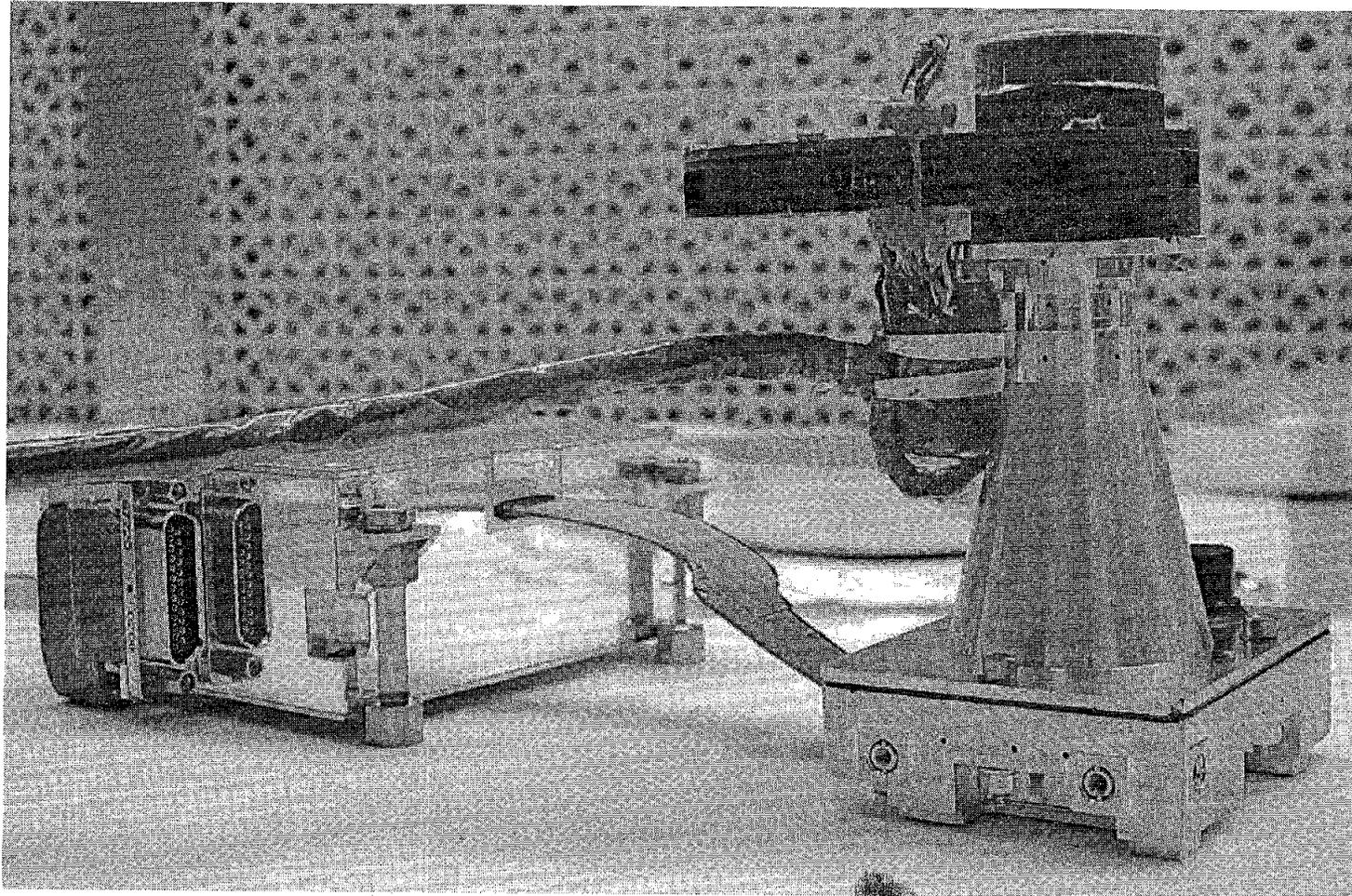
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Panoramic Camera

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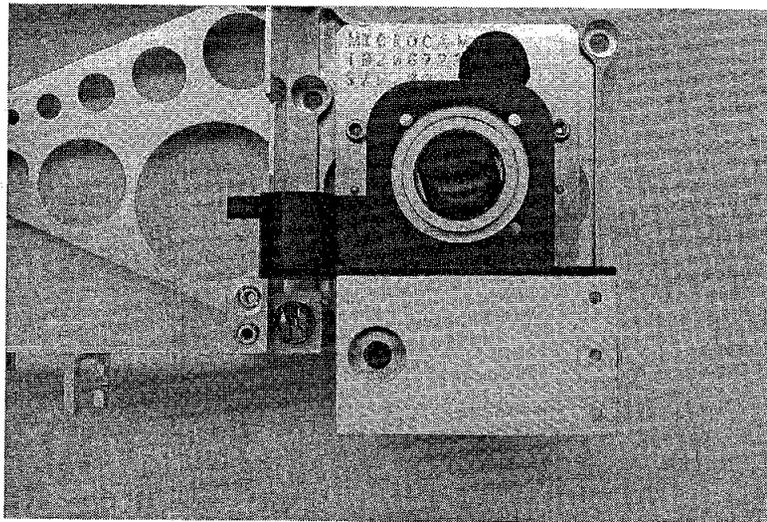
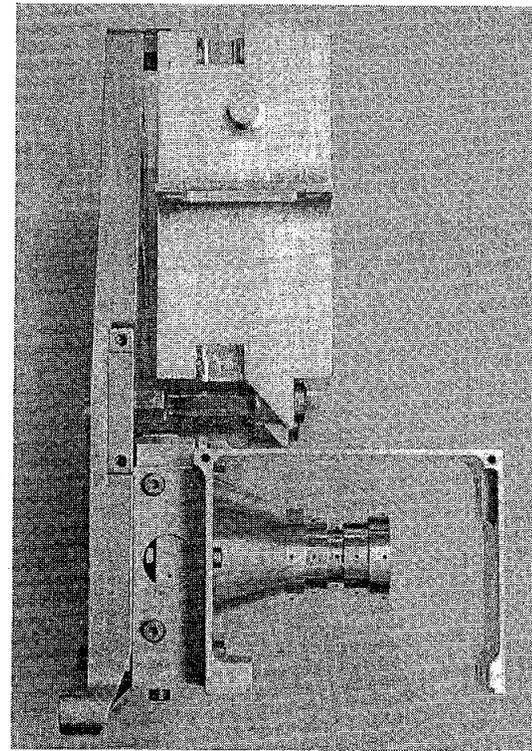
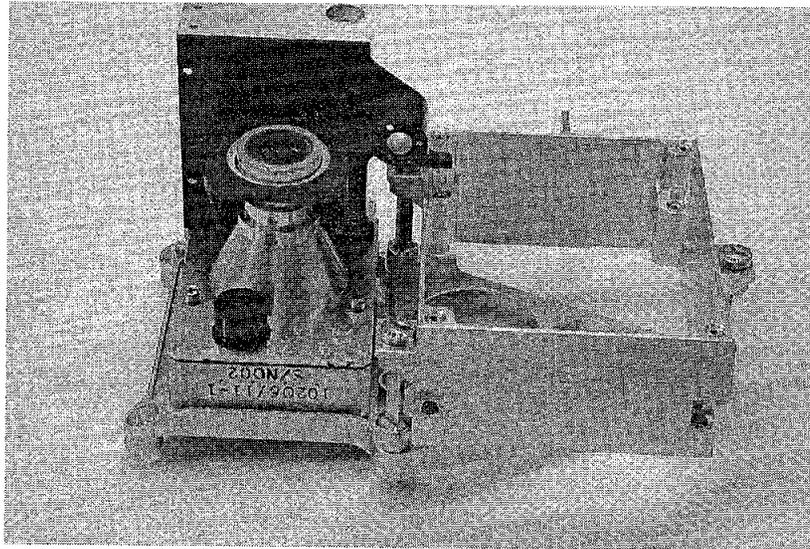
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Partially Assembled Microscopic Imager

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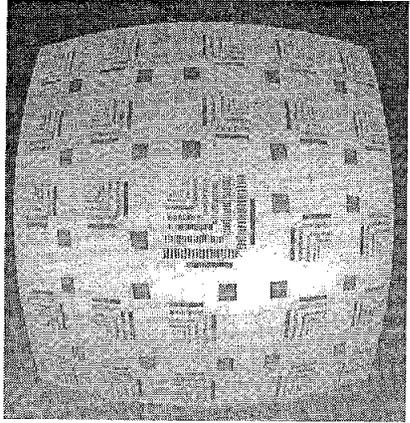
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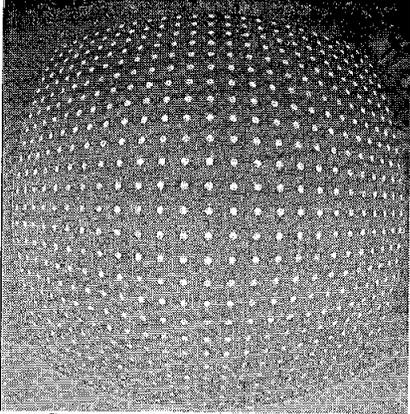
Mars Exploration Rover

• Testing

- All camera types have been tested for image quality
 - No shim adjustment required on any lens
 - All target images have been falling on pixels as predicted
- All cameras have been through thermal vacuum testing and qualification vibration testing successfully
 - All cameras installed on two rovers, 1st Rover shipped for spacecraft installation
- Lessons learned
 - Hazard camera trouble with axial venting holes
 - HEPA filters were transparent

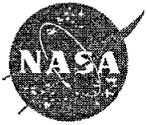


1m x 1m Grid Target



1m x 1m Focus Target

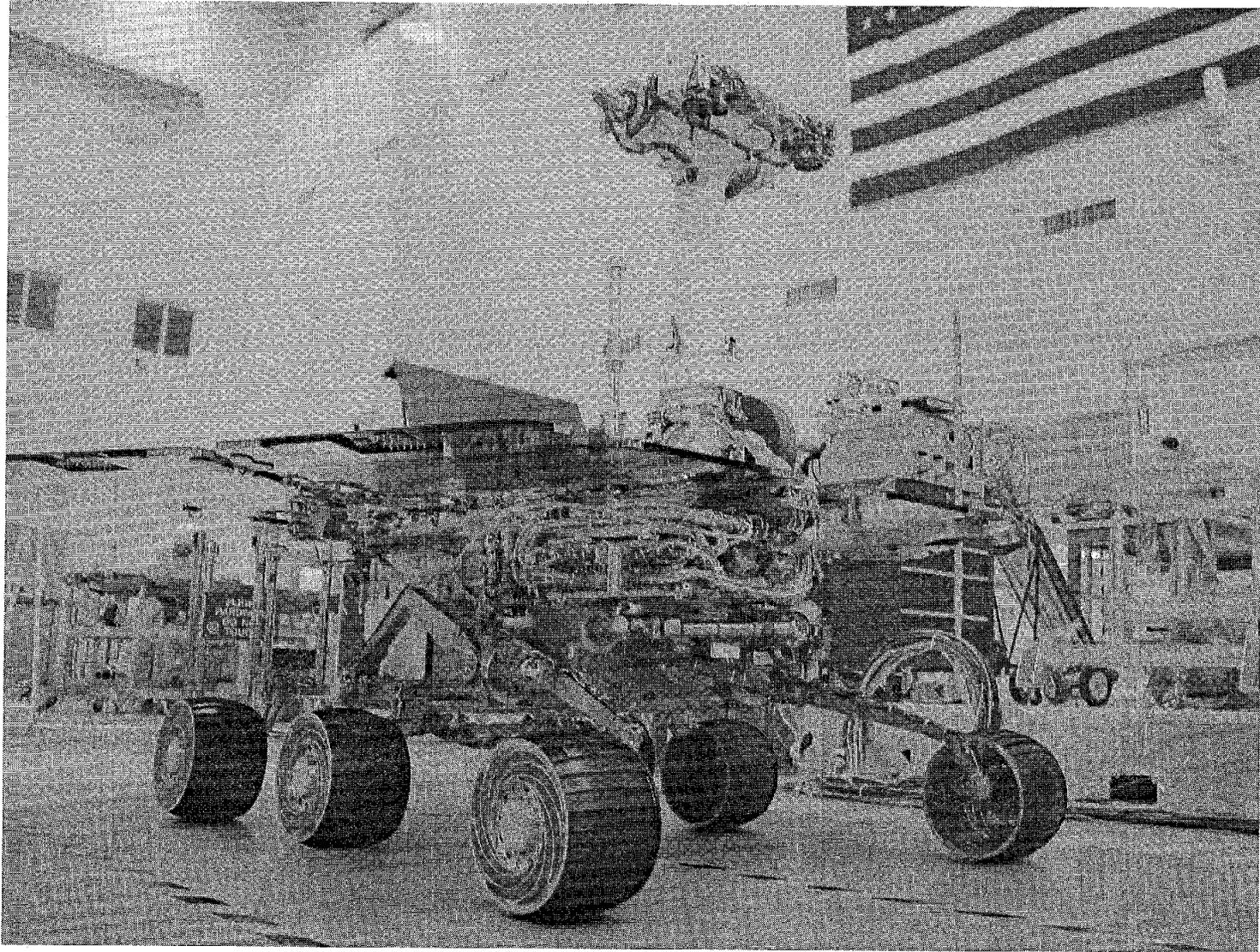
Hazard Camera Test Images



Assembled Rover



Mars Exploration Rover



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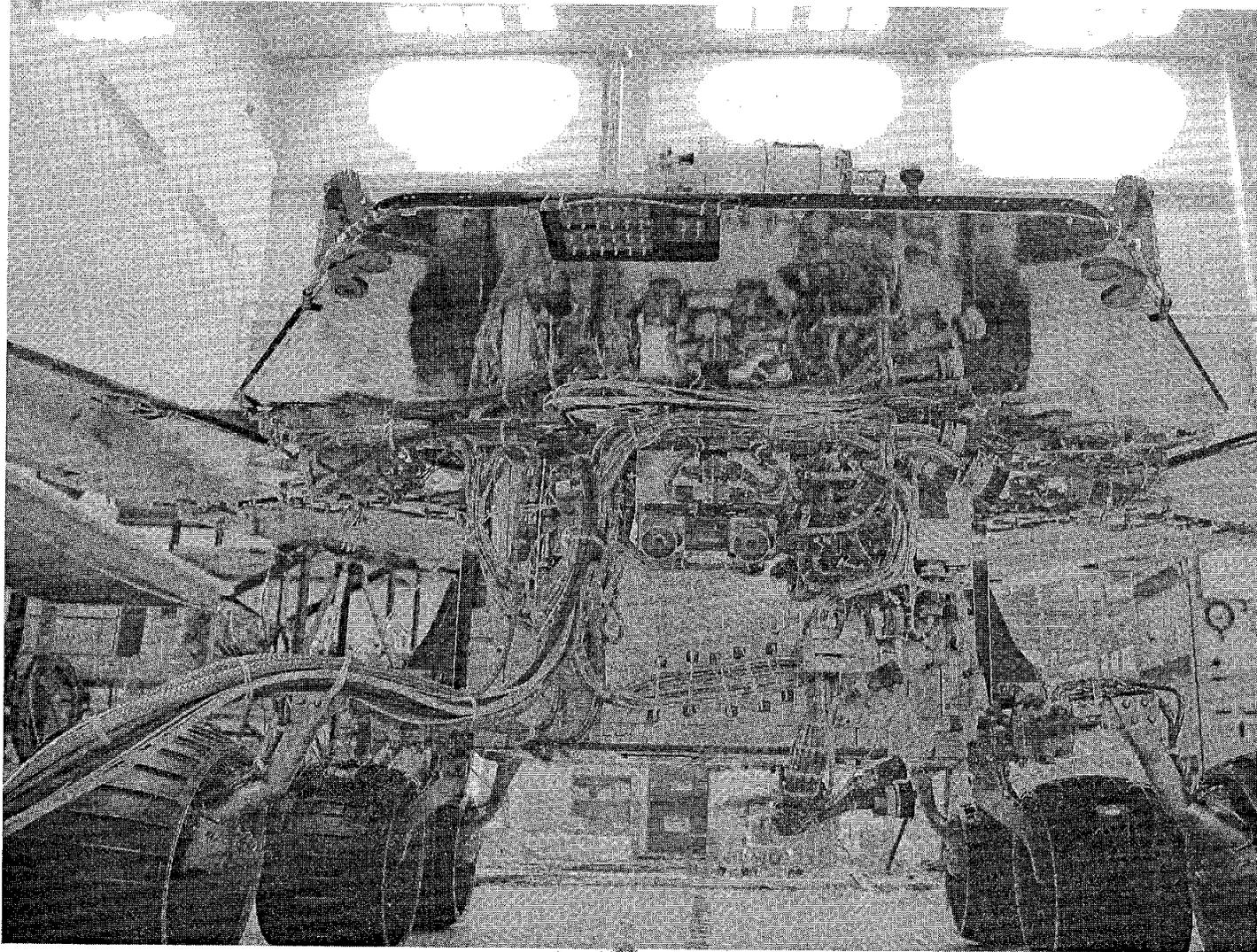
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Hazard Cameras

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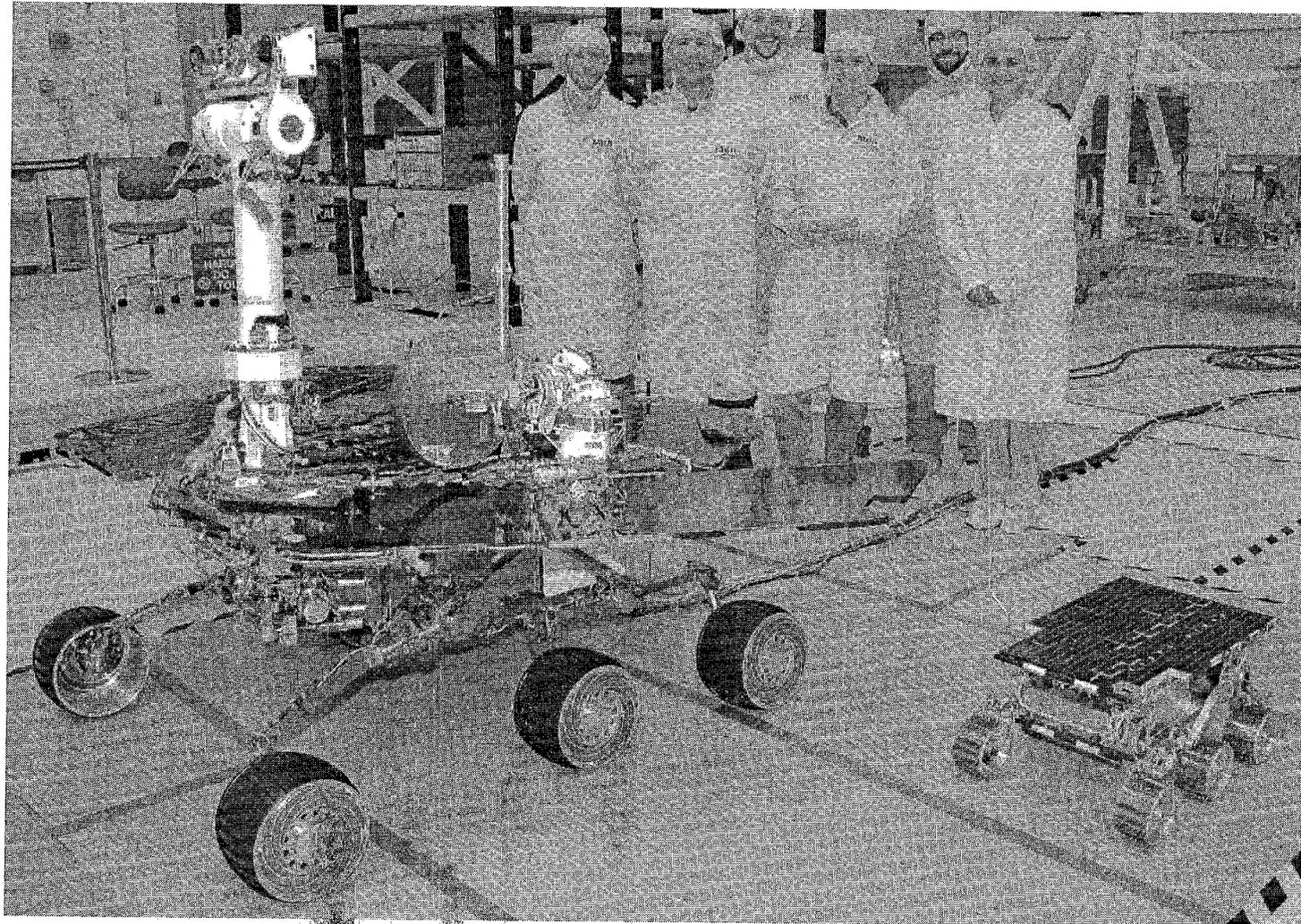
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Mars Rover Family

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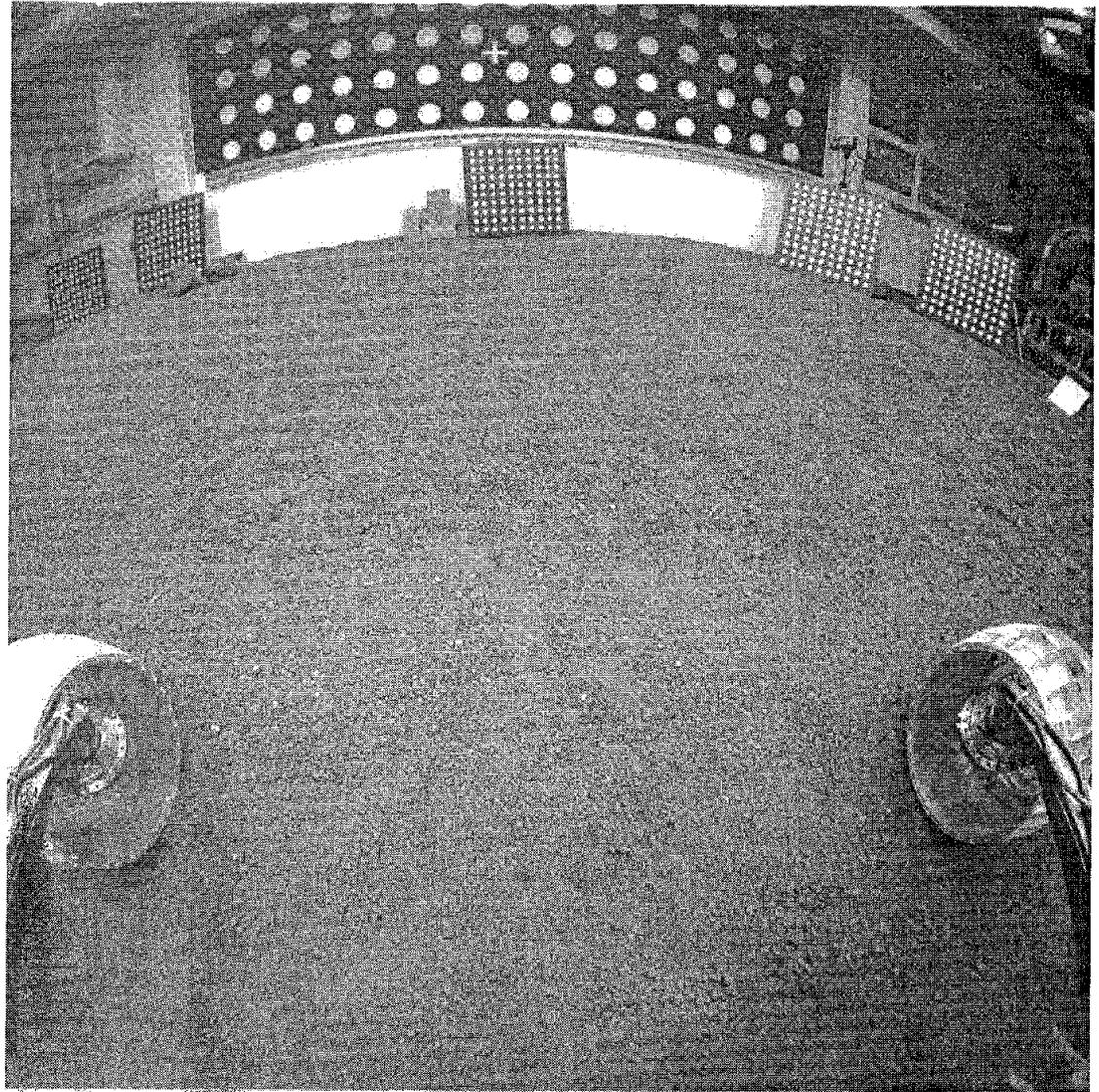


Hazard Camera "Flight-like" Image

JPL

Mars Exploration Rover

Taken in the Mars simulation sandbox using Martian-like illumination





Panoramic Camera pre-launch scan (mosaic) **JPL**

Mars Exploration Rover





ACKNOWLEDGEMENTS



Mars Exploration Rover

- The authors would like to acknowledge the participation of the team members: Mark Schwochert, Enrique Villegas, Ali Pourangi, Mark Wadsworth, Greg Smith, Dave Brown, Dave Thiessen and the efforts of John Fitzpatrick and the team at Kaiser Electro-Optics, Inc. who advised us and worked so diligently to fabricate, assemble and test the lenses
- This work was performed at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration
- Animation provided by Dan Maas of Cornell University