The Helioseismic and Magnetic Imager

Stanford University
Lockheed Martin Solar and Astrophysics Laboratory
Science Co-Investigators
HMI Major Science Objectives

B – Solar Dynamo

C – Global Circulation

D – Irradiance Sources

E – Coronal Magnetic Field

F – Solar Subsurface Weather

G – Magnetic Stresses

H – Far-side Imaging

I – Magnetic Connectivity

J – Sunspot Dynamics

A – Interior Structure

NOAA 9393

1997

1998

1999

2000

2001

2002

Latitude

Year

Far-side
HMI Heritage

- The HMI instrument is an evolution of the successful Michelson Doppler Imager operating on the SOHO spacecraft.
- The primary differences are that HMI has no on-board image processing, and that two identical 4096x4096 pixel format CCD cameras are used to obtain both Doppler and vector magnetic field measurements.
Michelson Doppler Imager Flight Optics Package
HMI Observables

- Dopplergrams computed from filtergrams at 5 wavelengths across the Ni 6768 Å line.
- Longitudinal magnetograms generated from the LCP and RCP Dopplergrams.
- Vector magnetograms computed from filtergrams at 4 polarizations and 5 wavelengths.
- Continuum image filtergrams.
MDI observables similar to those expected from HMI
HMI Tunable Filter

• The HMI filter design has a Lyot filter with one tunable element and two tunable Michelson interferometers. The tuning is adjusted by rotating waveplates.

• The solid color lines on the next page show the HMI filter transmission profiles at 75 mÅ spacing. The dotted line shows the Ni line profile. The black dashed line shows the continuum filtergram tuning profile.
HMI Filter Profiles and Observing Line

\[ \delta V \text{ (km/s)} \]

\[ \delta \lambda \text{ (Å)} \]

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MDI Lyot Filter Elements
MDI Flight Michelsons
HMI Optical Design

Superimposed **Calibration** and Imaging Modes

In *calibration mode* the path through filters for pupil image is similar to solar imaging path.

Entrance pupil 14 cm diameter  
EFL 485 cm, Total path 225 cm  
Image size 4.60 cm for 32.64 arc-min

Beam is telecentric through filters  
Focal ratio at final image 34.6  
Focal ratio inside Lyot filter 30.3
HMI Optics Package Layout
HMI Optics Package Bottom View
HMI Functional Block Diagram

- CCD Driver Card (2)
- Clock & sequencer
- CDS/ADC
- Command/data interface
- Housekeeping ADC, & Master Clock
- DC-DC Power Converter
- Image Stabilization System
- Limb Sensor & Active Mirror

Mechanisms:
- Focus/Cal Wheels (2)
- Polarization Selectors (2)
- Tuning Motors (3)
- Shutters (2)
- Front Door
- Alignment Mechanism
- Filter Oven Control
- Structure Heaters
- Housekeeping Data

- LVDS
- Camera Interface (SMClite)
- Buffer Memory (2x4Kx4Kx16)
- Data Compressor & AEC
- Buffer Memory
- ISS (Limb tracker)
- PC/local Bus Bridge/EEPROM
- Central Processor
- Power Converters
- Spacecraft Interface
- Camera data

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### HMI Key Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
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<tbody>
<tr>
<td>Field of view</td>
<td>34 arc-minutes</td>
</tr>
<tr>
<td>Spatial resolution</td>
<td>1.0 arc-seconds</td>
</tr>
<tr>
<td>Observing wavelength</td>
<td>Ni I – 6768 Å</td>
</tr>
<tr>
<td>CCD format</td>
<td>4096x4096 pixels</td>
</tr>
<tr>
<td>Cadence per camera</td>
<td>4.1 s</td>
</tr>
<tr>
<td>Exposure level</td>
<td>125 ke-</td>
</tr>
<tr>
<td>Exposure time</td>
<td>250 ms</td>
</tr>
<tr>
<td>Image Stabilization</td>
<td>0.1 arc-seconds (3 σ)</td>
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### HMI Resources

<table>
<thead>
<tr>
<th>Package</th>
<th>Envelope</th>
<th>Mass</th>
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<tbody>
<tr>
<td>Optics Package</td>
<td>118 cm x 53 cm x 24 cm</td>
<td>28 kg</td>
</tr>
<tr>
<td>Electronics Package</td>
<td>32 cm x 28 cm x 21 cm</td>
<td>15 kg</td>
</tr>
<tr>
<td>Complete Instrument</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass (including cable harness)</td>
<td></td>
<td>46 kg</td>
</tr>
<tr>
<td>Power (including operational heater)</td>
<td></td>
<td>60 W</td>
</tr>
<tr>
<td>Telemetry</td>
<td></td>
<td>50 Mbit/s</td>
</tr>
<tr>
<td>Instrument Reserves</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass</td>
<td>9 kg</td>
<td></td>
</tr>
<tr>
<td>Power</td>
<td>12 W</td>
<td></td>
</tr>
<tr>
<td>Telemetry</td>
<td>5 Mbit/s</td>
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</tr>
</tbody>
</table>

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Major Implementation Drivers

• CCD Cameras are being provided by British science co-investigators.
• Michelson interferometers will be likely provided by foreign vendors.
• High speed data bus for the image data.
Major Concerns

• Phase A contract implementation and funding including ITAR issues.
• The Education and Public Outreach budget is uncertain, and the method of coordinating with the LWS office is not clear.
• There is not adequate funding for Phase E.
Constraints on SDO

- Data continuity for helioseismology requires 95% recovery of “observables”.
- Spacecraft accommodation is critical for thermal design (need cold CCD’s).
- Implementing “roll steering” and support of periodic offpoint and roll maneuvers puts constraints on spacecraft attitude control.
Possible Design Modifications

• Considering observing in the Fe 6173 Å line (g=2.5) instead of the Ni 6768 Å line (g=1.5) in order to increase magnetic field sensitivity.

• This change can be easily accommodated if incorporated before beginning the detailed instrument design.
Conclusions

- The HMI instrument will be designed and built by the same Stanford/LMSAL team that developed the MDI instrument.
- The MDI instrument has been successfully operating in space for over six years, and provides tremendous experience in the science requirements, instrument development and operations.