HMI Subsystems

- **Optics Package Structure**
  - The optic package subsystem includes the optics package structure, optical components mounts and legs that attach the optics package to the spacecraft.

- **Optics Subsystem**
  - Includes all the optical elements except the filters.

- **Filter subsystem**
  - The filter subsystem includes the front window, blocking filter, Lyot filter and Michelson interferometers
  - Provides the ability to select the wavelength to image

- **Thermal Subsystem**
  - Controls the temperature of the optics package, the filter oven, CCDs, and the front window.
  - Implements the decontamination heating of the CCD.

- **Image Stabilization Subsystem**
  - Consists of active mirror, limb sensor, precision digital & analog control electronics
  - Actively stabilizes the image reducing the effects of jitter

- **Mechanisms Subsystem**
  - The mechanisms subsystem includes shutters, hollow-core motors, calibration/focus wheels, alignment mechanism, and the aperture door.

- **CCD Camera Subsystem**
  - The CCD camera subsystem includes 4Kx4K CCDs and the camera electronics box(es).

- **HMI Electronics Subsystem**
  - Provides conditioned power and operation of all HMI subsystems as well as HMI C&DH hardware.

- **Software Subsystem**
  - The software subsystem includes the C&DH spacecraft interface and control of HMI subsystems
HMI Optics Package Layout
Optics Subsystem

- 1 arc-sec diffraction limited image at the sensor
  - Requires 14 cm aperture
  - Requires 4096x4096 pixel sensor
- Solar disk at the sensor 4.9 cm
  - For sensor with 12 um pixels
- Focus adjustment system with ±3 (TBC) depth of focus range and 16 steps
- Provide calibration mode that images the pupil on the sensor
- Provide beam splitter to divide the telescope beam between the filter oven and the limb tracker
- Provide telecentric beam through the Lyot filter
- Provide beam splitter to feed the output of the filter subsystem to two sensors
- Minimize scattered light on the sensor
Filter subsystem

- Central wavelength 6173Å Fe I line
- Reject 99% of solar heat load from the OP interior
- Total bandwidth 76 mÅ FWHM
- Tunable range 500 mÅ
- Wavelength selection stability and repeatability of 0.18 mÅ
- The required bandwidth obtained by cascading filters as follows
  - Front window 50Å
  - Blocker 8Å
  - Lyot filter (5 element 1:2:4:8:16) 306 mÅ
  - Wide Michelson 172 mÅ
  - Narrow Michelson 86 mÅ
- Tuning range requires use of three co-tuned elements
  - Narrowest Lyot element
  - Wide Michelson
  - Narrow Michelson
MDI Lyot Elements and Michelson Interferometers
Thermal Subsystem

- **Optics package thermal control**
  - Operating temperature range 15 to 25 °C
  - Active control to ± 0.5 °C
  - Control loop in software

- **Filter oven**
  - Operating temperature range 35 ± 4 °C
  - Temperature accuracy 0.5 °C
  - Temperature stability 0.01 °C /hour
  - Changes in internal temperature gradients as small as possible
  - Dedicated analog control loop in controlled thermal environment

- **Sensor (CCD detector) thermal control**
  - Operating –100 °C to –30 °C
  - Decontamination mode raises CCD to between 20 °C and 40 °C

- **Front window thermal control**
  - Minimize radial gradients
  - Return to normal operating temperature within 60 minutes of eclipse exit
Image Stabilization Subsystem

- Stability is 0.1 arc-sec over periods of 90 seconds (TBC)
- Range ± 14 arc-sec
- Frequency range 0 to 50 Hz
- Continuous operation for life of mission
Mechanisms (1 of 2)

Shutters
- Repeatability 100 us
- Exposure range 50 ms to 90 sec
- Knowledge 30 us
- Life (5 year) 40 M exposures

Hollow core motors
- Move time (60 deg) < 800 ms
- Repeatability 60 arc-sec
- Accuracy 10 arc-min
- Life (5 year) 80 M moves
Mechanisms (2 of 2)

Calibration / focus wheels
- Positions: 5
- Move time (1 step): 800 ms
- Accuracy: TBD arc-min
- Repeatability: TBD arc-min
- Life (5 Years): 20 K moves

Alignment system
- Movement range: ± 200 arc-sec
- Step size: 2 arc-sec

Aperture door
- Robust fail open design
CCD Camera Subsystem

- Format: 4096 x 4096 pixels
- Pixel size: 12 um
- Full well: > 125K electrons
- Readout noise: 40 electrons
- Readout time: < 3.4 seconds
- Digitization: 12 bits
- Dark current: 10 –e/sec/pixel at -60 °C
HMI Electronics Subsystem

- Provide conditioned power and control for all HMI subsystems
- Provide processor for:
  - Control all of the HMI subsystems
  - Decoding and execution of commands
  - Acquire and format housekeeping telemetry
  - Self-contained operation for extended periods
  - Program modifiable on-orbit
- Provide stable jitter free timing reference
- Provide compression and formatting of science data
- Provide dual interface for 55 Mbps of science date
- Provide spacecraft 1553 interface
  - Commands 2.0 kbps
  - Housekeeping telemetry 2.5 kbps
  - Diagnostic telemetry 10 kbps for short periods upon request
Software Subsystem

• The HMI flight software will perform the following functions
  – Process commands from spacecraft
  – Acquire and format housekeeping telemetry
  – Store and execute operational sequences
  – Control all of the HMI subsystems
  – Accept code modifications while in orbit

• The HMI sequencer is designed to take filtergram images at a uniform cadence with observing wavelengths and polarizations driven by on-board tables

• The HMI flight software does not handle any of the CCD camera data, and has no image processing requirements