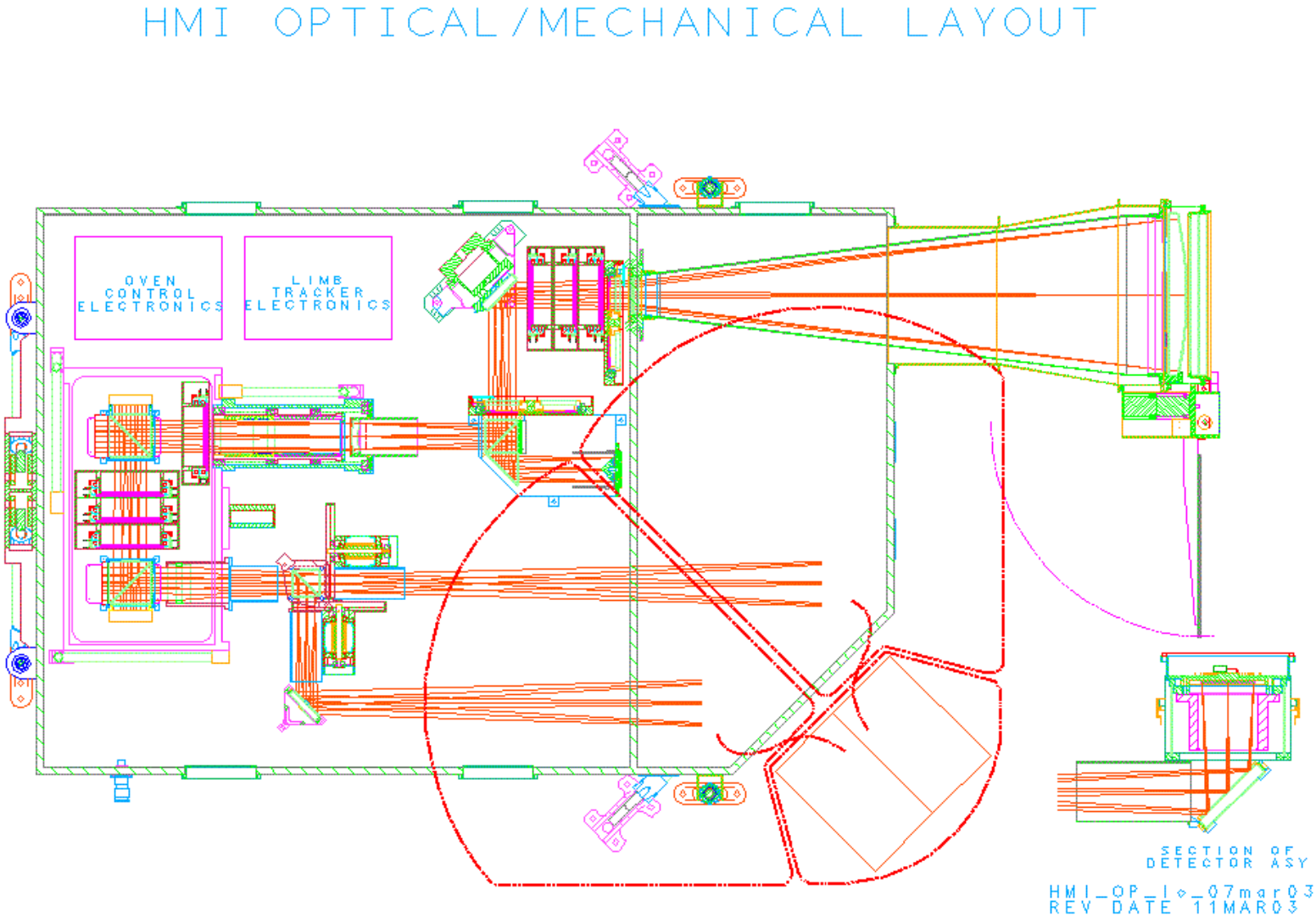
HMI Subsystems

- **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



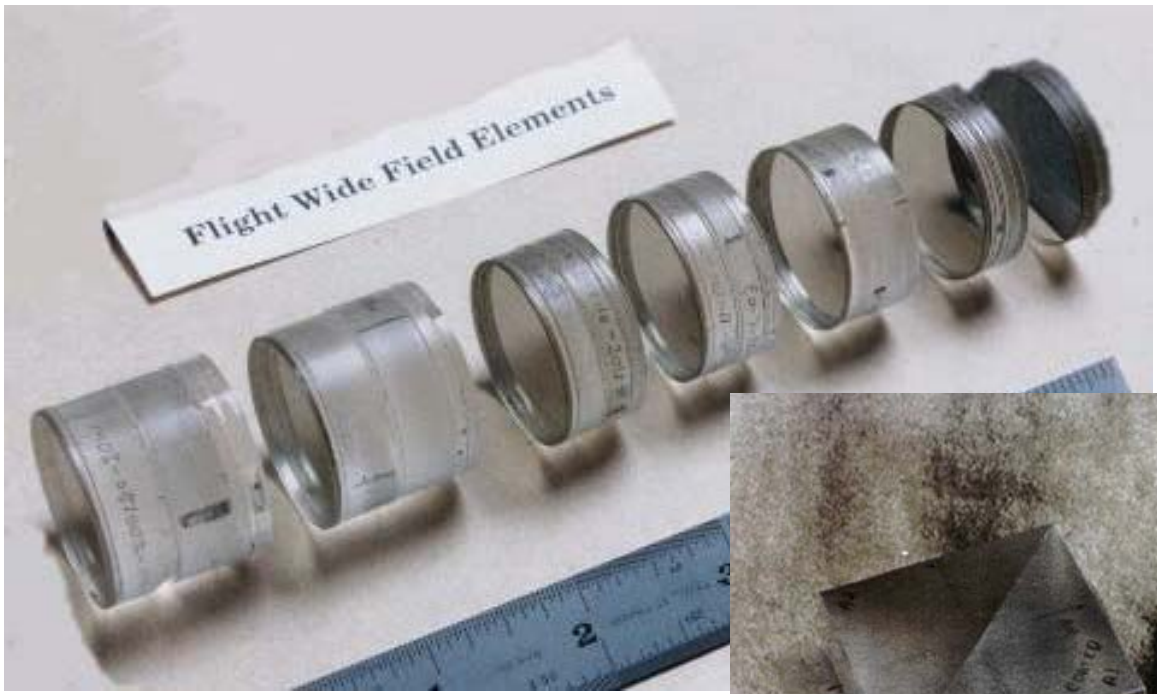
Optics Subsystem

- **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

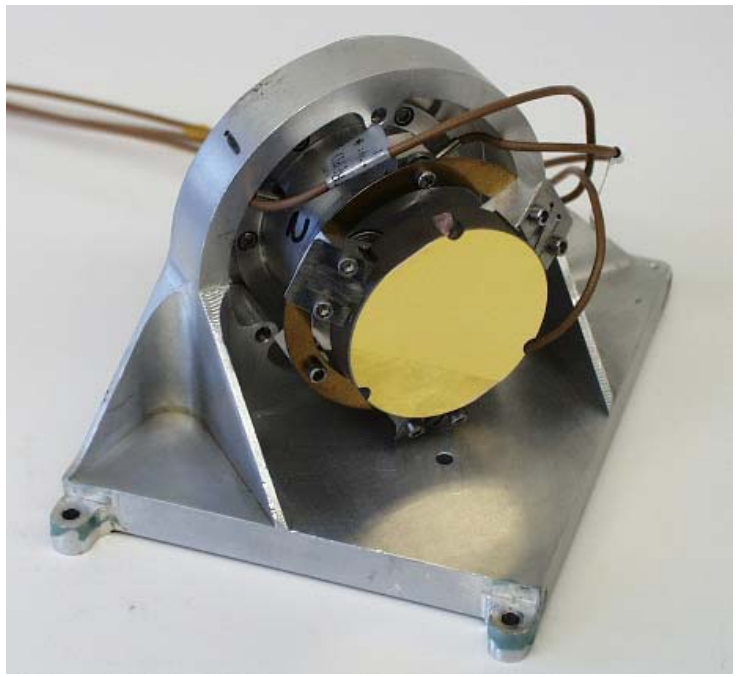


Thermal Subsystem

- **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



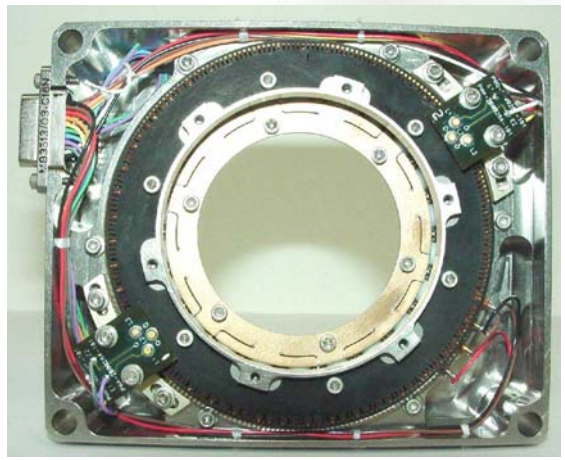
Mechanisms (1 of 2)

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**



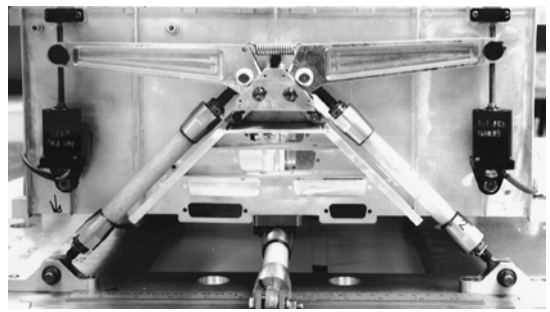
Mechanisms (2 of 2)

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**

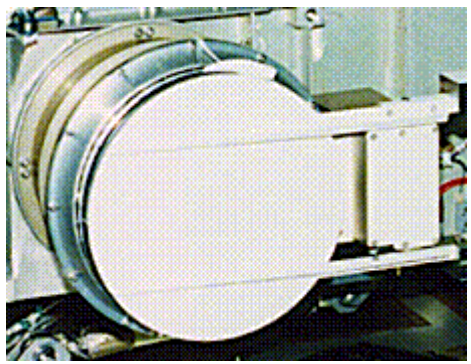
Alignment system

- **Movement range** — **± 200 arc-sec**
- **Step size** — **2 arc-sec**



Aperture door

- **Robust fail open design**



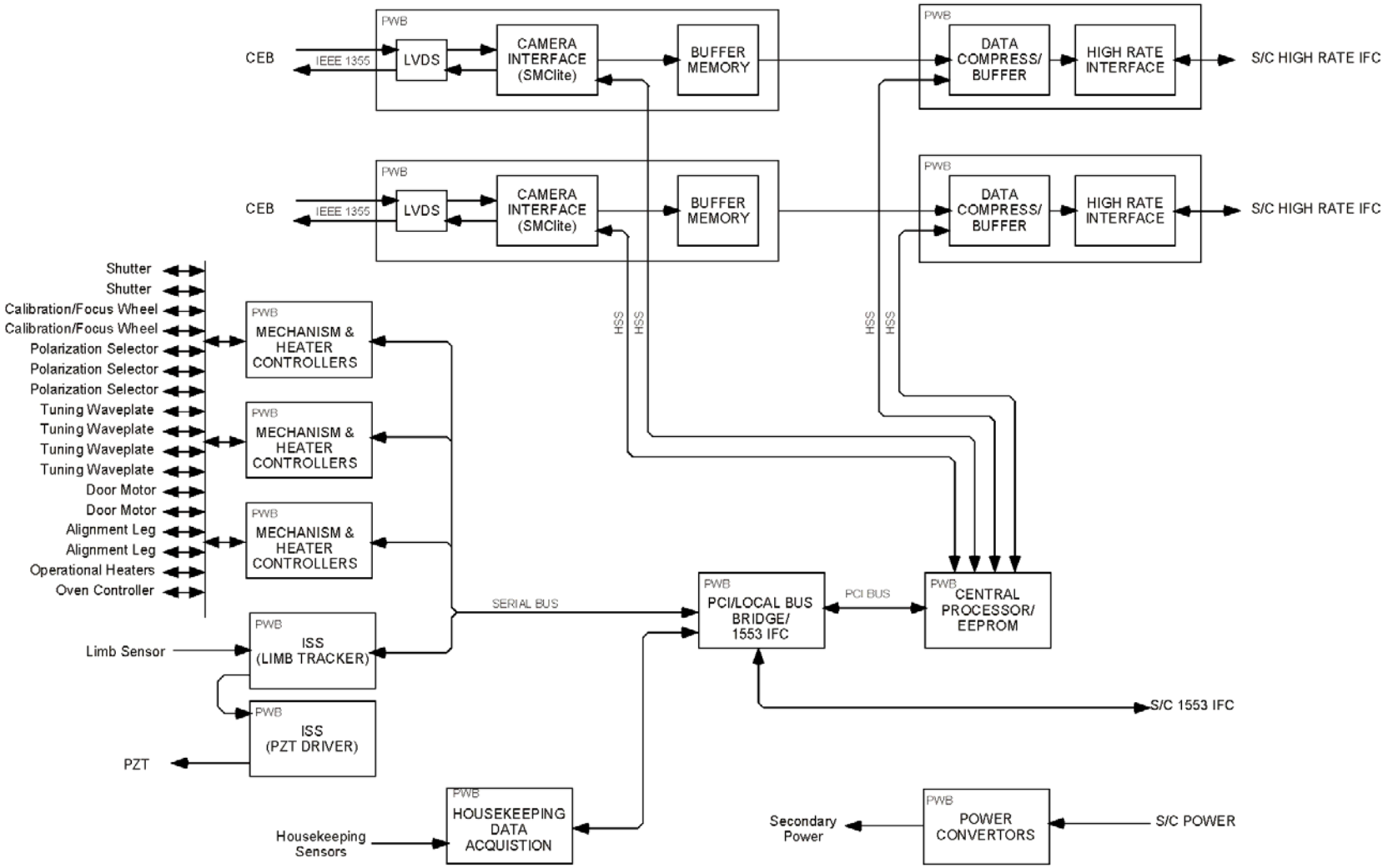
CCD Camera Subsystem

- **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

HMI Electrical Block Diagram



HMI ELECTRONICS

R Lindgren
31 Mar 03

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**