

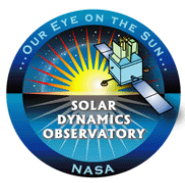
The Helioseismic and Magnetic Imager Instrument

Jesper Schou and the HMI Team

Stanford University and other places

jschou@solar.stanford.edu

(650) 725-9826



Abstract



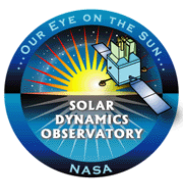
An overview of the HMI investigation is given in the talk by Scherrer. Here we will describe the HMI instrument and its capabilities in more detail.

We will start by describing the design of the instrument, including the optical and mechanical layout and how wavelength and polarization selection is performed.

We will then describe how the various observables will be generated from the observations and how we plan to operate the instrument.

This will be followed by an overview of the standard data processing which will be performed and what data products will be available.

Finally the design requirements and the schedule and status of the investigation will be summarized.

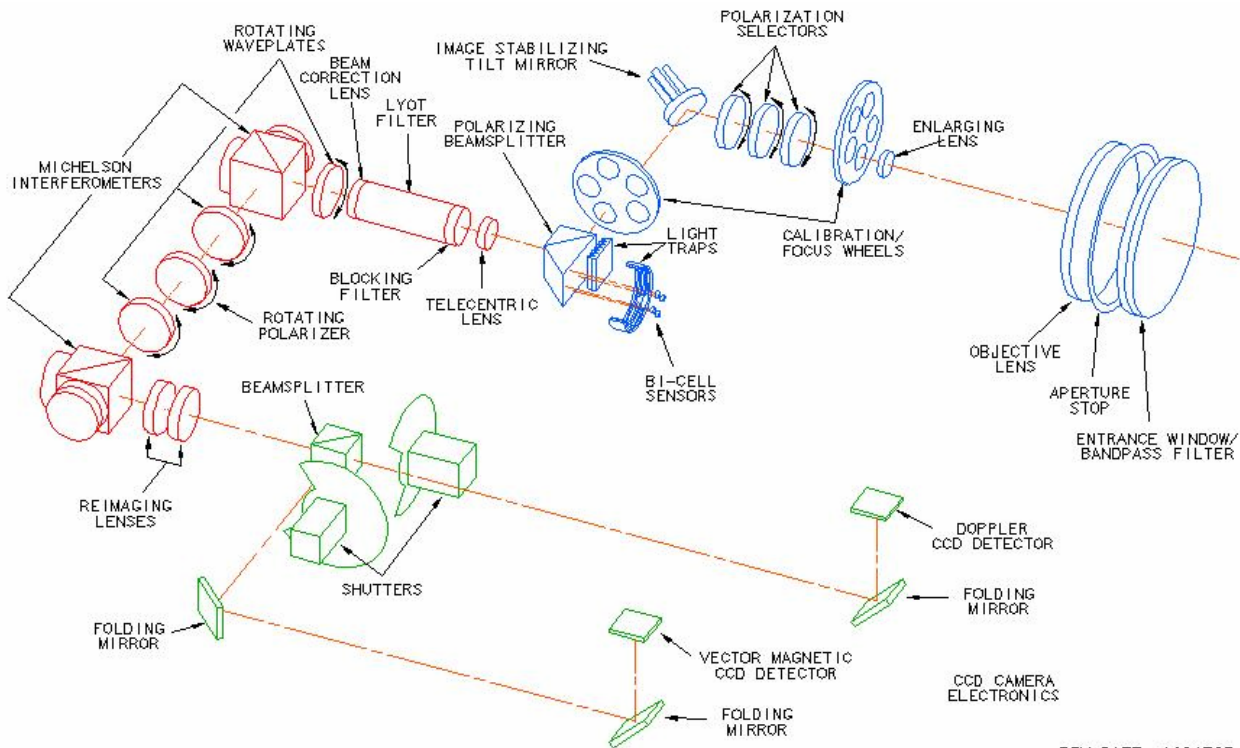


Instrument Overview



- **Optics Package**
 - Telescope section
 - Polarization selectors – 3 rotating waveplates for redundancy
 - Focus blocks
 - Image stabilization system
 - 5 element Lyot filter. One element tuned by rotating waveplate
 - 2 tunable Michelson interferometers. 2 waveplates and 1 polarizer for redundancy
 - Reimaging optics and beam distribution system
 - Shutters
 - 2 functionally identical CCD cameras – “Doppler” and “Magnetic”
- **Electronics package**
- **Cable harness**

Instrument Overview – Optical Path

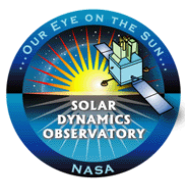


Optical Characteristics:

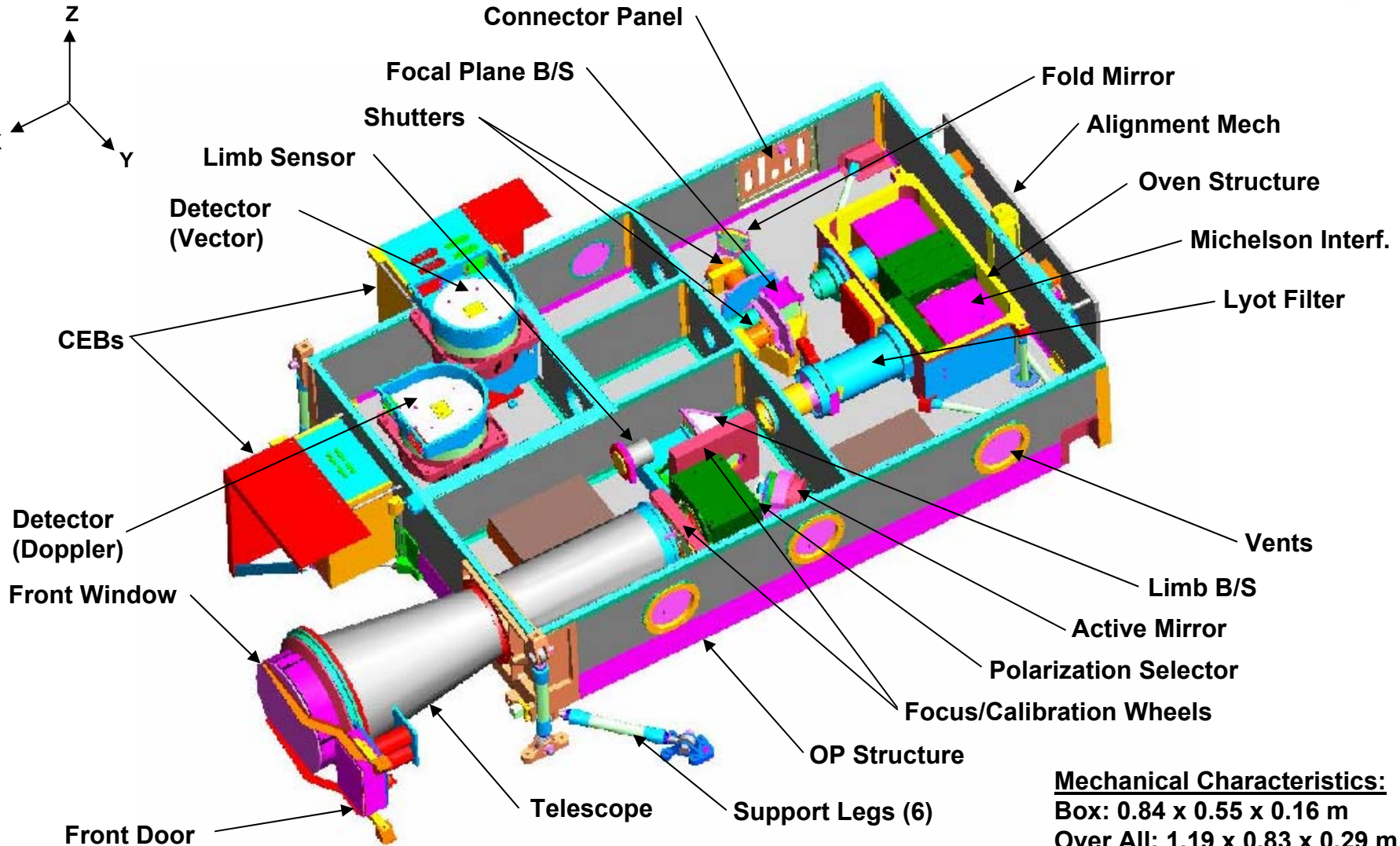
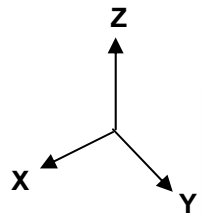
Focal Length: 495 cm
Focal Ratio: f/35.2
Final Image Scale: 24 μ m/arcsec
Re-imaging Lens Magnification: 2
Focus Adjustment Range: 16 steps of 0.4 mm

Filter Characteristics:

Central Wave Length: 613.7 nm
Front Window Rejects 99% Solar Heat Load
Bandwidth: 0.0076 nm
Tunable Range: 0.05 nm
Free Spectral Range: 0.0688 nm



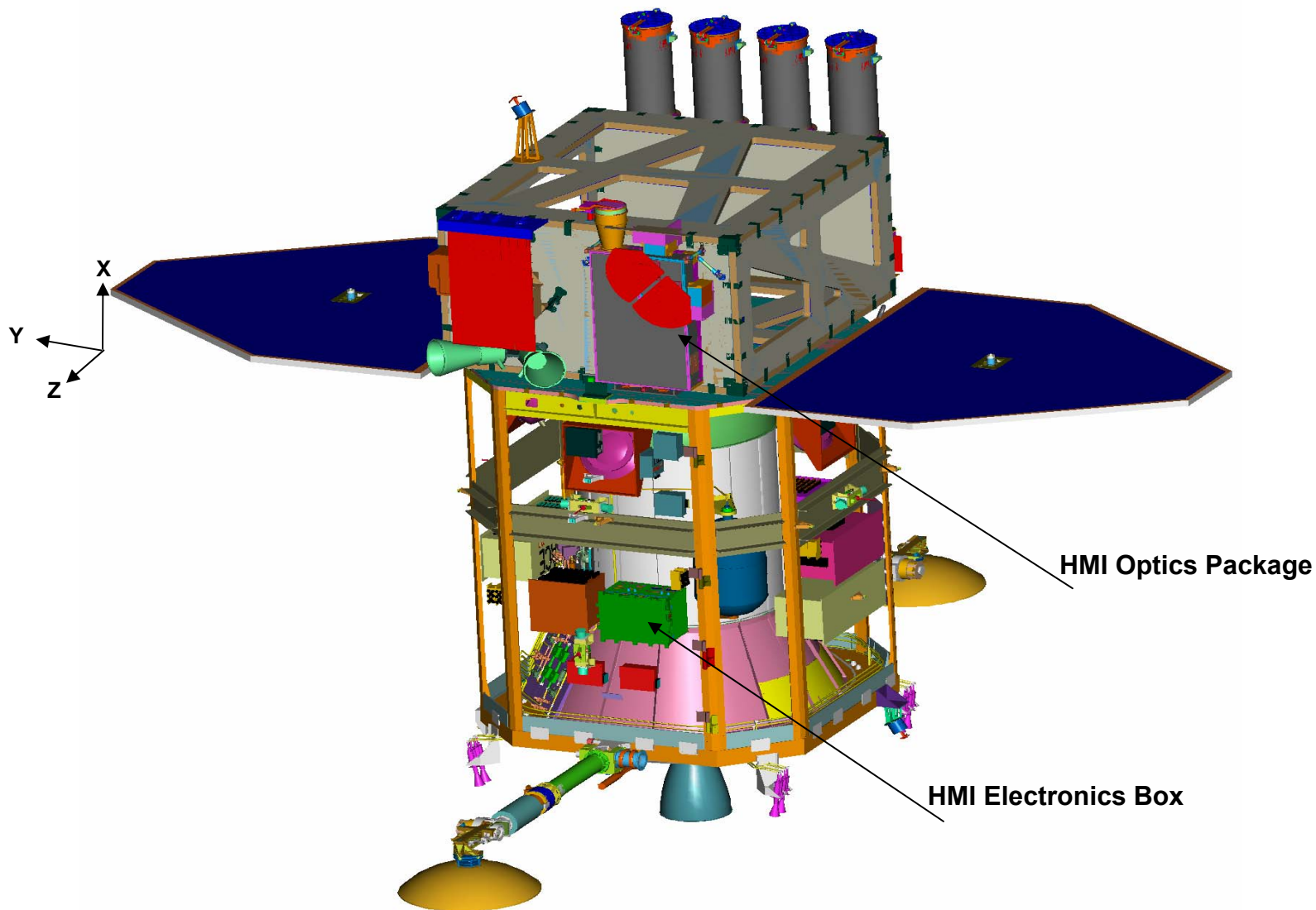
Instrument Overview – HMI Optics Package (HOP)

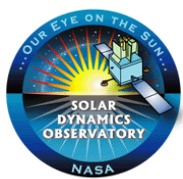


Mechanical Characteristics:
 Box: 0.84 x 0.55 x 0.16 m
 Over All: 1.19 x 0.83 x 0.29 m
 Mass: 39.25 kg
 First Mode: 63 Hz



S/C Accommodations





Observing Scheme

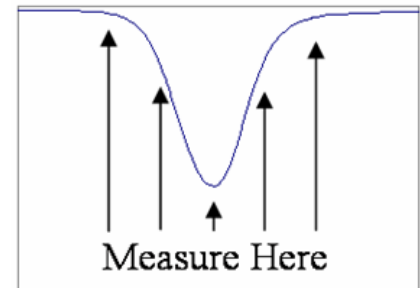
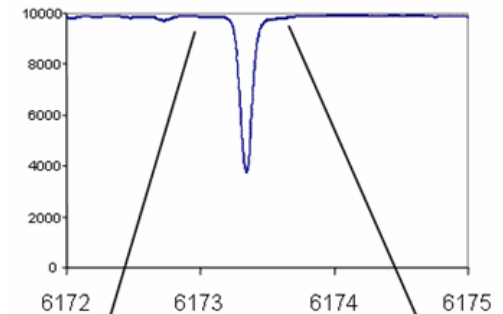


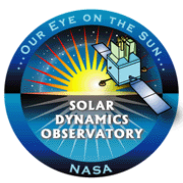
- **Observables**
 - Dopplergrams
 - Magnetograms, vector and line-of-sight
 - Others: Intensity, line depth, etc.
- **Observables made from filtergrams described by framelists**
- **Filtergram properties**
 - Wavelength – selected by rotating waveplates (polarizer for redundancy only)
 - Polarization state – selected by rotating waveplates
 - Exposure time
 - Camera ID
 - Compression parameters, ...
 - Determined by subsystem settings
 - E.g. motor positions
- **Framelists**
 - List of filtergrams repeated at fixed cadence during normal operations
 - Entirely specified in software – Highly flexible

5 Position Framelist

Time(s)	0	8	16	24	32	40	48	56	64	72
Tuning	I1	I2	I3	I4	I5	I1	I2	I3	I4	I5
Doppler pol.	L R	L R	L R	L R	L R	L R	L R	L R	L R	L R
Vector pol.	1 2	1 2	1 2	1 2	1 2	3 4	3 4	3 4	3 4	3 4

- **Time:** Time of first exposure at given wavelength since start of framelist execution
- **Tuning:** I1, I2, ... specify the tuning position
- **Doppler pol.:** Polarization of image taken with Doppler camera
 - L and R indicate left and right circular polarization
 - Used for Doppler and line of sight field
- **Vector pol.:** Polarization of image taken with vector camera
 - 1, 2, 3, 4: Mixed polarizations needed to make vector magnetograms
 - Used for vector field reconstruction





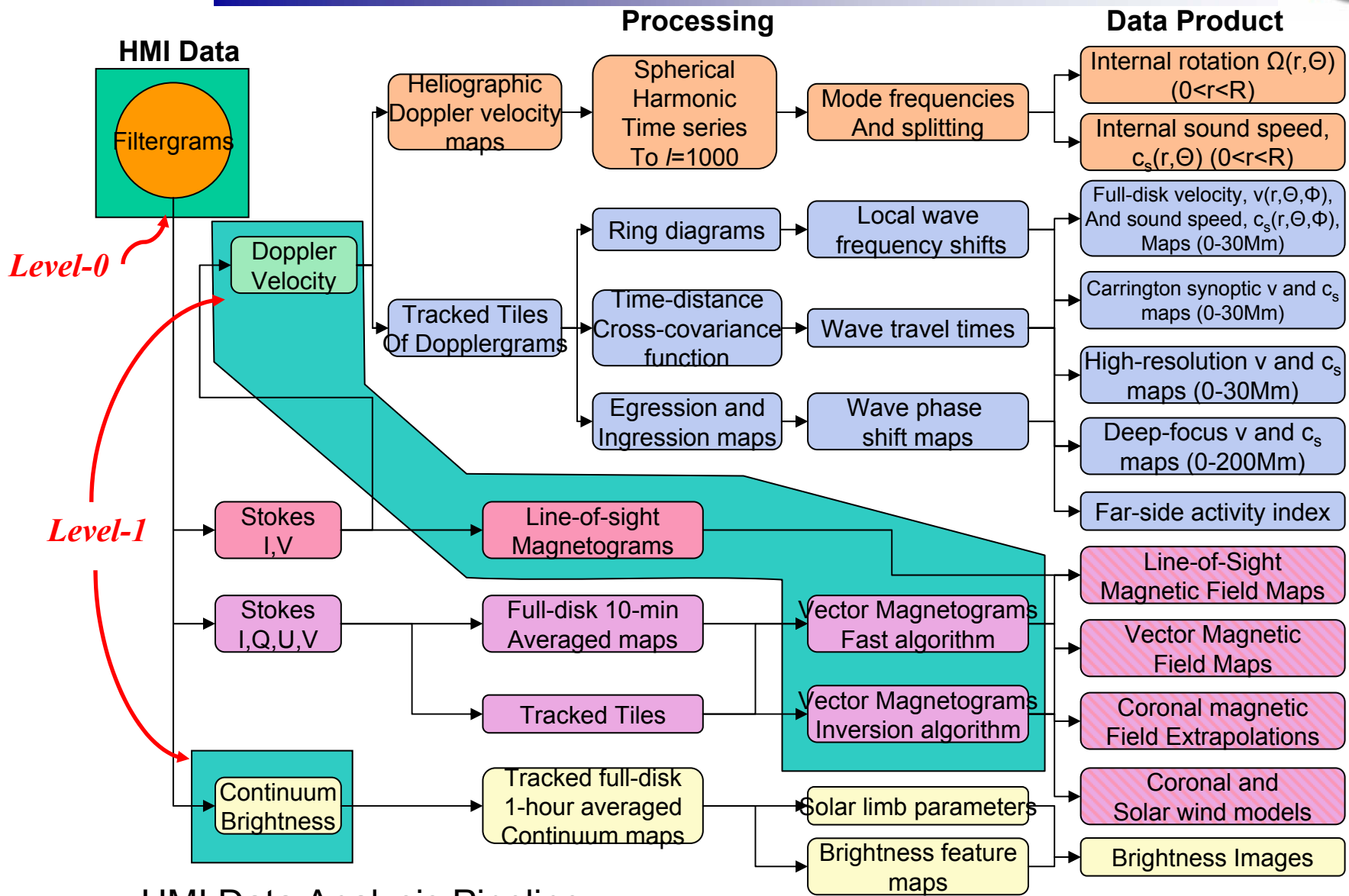
Operations



- **Turn on instrument at beginning of mission**
- **Turn off instrument at the end of the mission**
- **But...**
 - Commissioning
 - Calibrations
 - Eclipses
 - Emergencies
 - ...



HMI Data Processing and Products



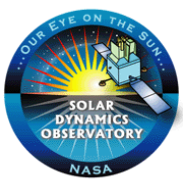
HMI Data Analysis Pipeline



Requirements



Parameter	Requirement
Central wavelength	6173.3 Å ± 0.1 Å (Fe I line)
Filter bandwidth	76 mÅ ± 10 mÅ fwhm
Filter tuning range	680 mÅ ± 68 mÅ
Central wavelength drift	< 10 mÅ during any 1 hour period
Field of view	> 2000 arc-seconds
Angular resolution	better than 1.5 arc-seconds
Focus adjustment range	± 4 depths of focus
Pointing jitter reduction factor	> 40db with servo bandwidth > 30 Hz
Image stabilization offset range	> ± 14 arc-seconds in pitch and yaw
Pointing adjustment range	> ± 200 arc-seconds in pitch and yaw
Pointing adjustment step size	< 2 arc-seconds in pitch and yaw
Dopplergram cadence	< 50 seconds
Image cadence for each camera	< 4 seconds
Full image readout rate	< 3.2 seconds
Exposure knowledge	< 5 microseconds
Timing accuracy	< 0.1 seconds of ground reference time
Detector format	> 4000 x 4000 pixels
Detector resolution	0.50 ± 0.01 arc-second / pixel
Science telemetry compression	To fit without loss in allocated telemetry
Eclipse recovery	< 60 minutes after eclipse end
Instrument design lifetime	5 years at geosynchronous orbit



Schedule and Status



- **Mar 2004: Mission PDR**
- **Dec 2004: Mission CDR**
- **Jan 2006: Start system integration**
- **Apr 2006: Start system tests**
- **Nov 2006: Deliver instrument**
- **Apr 2008: Launch**
- **May 2008: Begin science observations**
- **May 2013: End of science observations**
- **May 2014: End of mission**

Program Status – CCDs and Cameras

Packaged thin gate CCD



Image 1

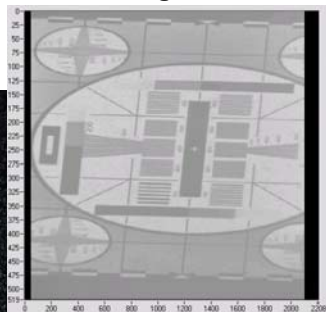
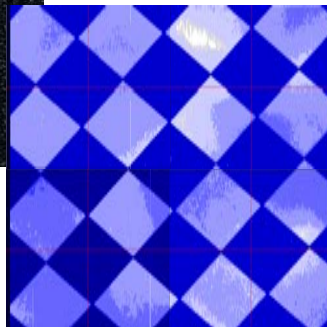
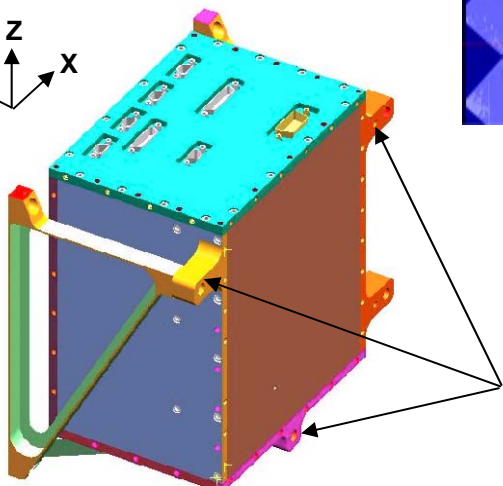
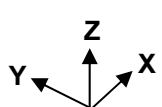


Image 2



CCD Status:

- Three batches of devices processed
- Images from first packaged device
- Image 1: Probe image (thin gate, room temp)
- Image 2: Commissioning image (thin gate, room temp)



HMI Mounting Feet

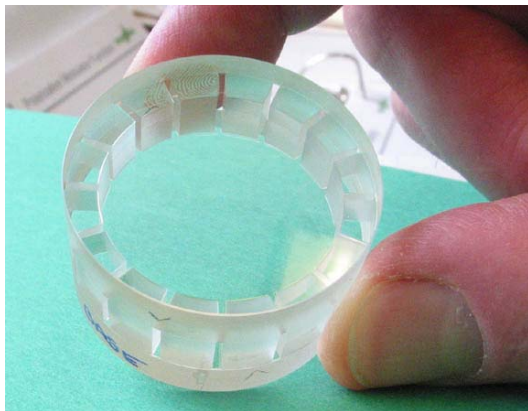
CEB Enclosure
(Mounted on -Y panel of HOP)

Camera Electronics Box Status:

- Video board schematic is complete
- Characterized the ghosting affect
- CDS/ADC ASIC is being processed
- Existing wave form generator ASIC are being packaged

Program Status – Filters & Optics

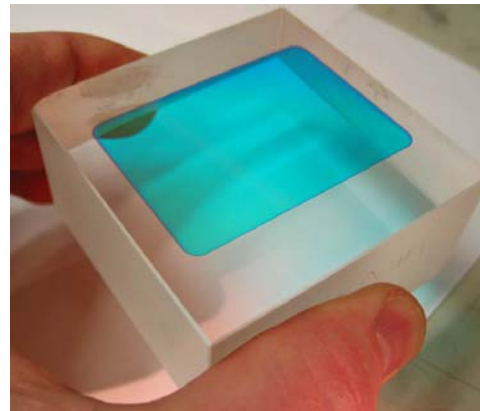
Sample Calcium Fluoride Spacer



Beam-splitter Blank



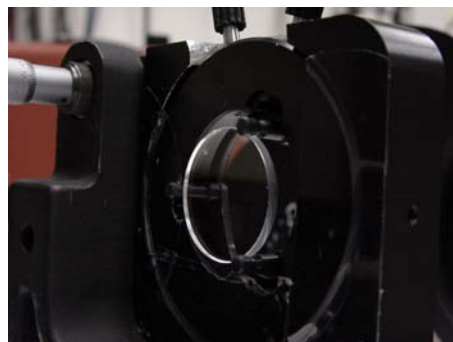
Beam-splitter Coating



Raw Calcite



Evaluation ADP



Shutter Status:

- **Prototype Shutter assembled and tested**
- **Life Test Shutters**
 - All parts are in house
 - Three Shutters are being assembled for the life test
 - Life test will begin mid March

Shutter Life Test Partial Assemblies



Hollow Core Motor Prototype



Hollow Core Motor Status:

- **Prototype HCM**
 - Delivered and assembled
 - Currently testing
- **Life Test HCM**
 - Drawings updated and released
 - Order being placed
 - Life test is scheduled to start mid July

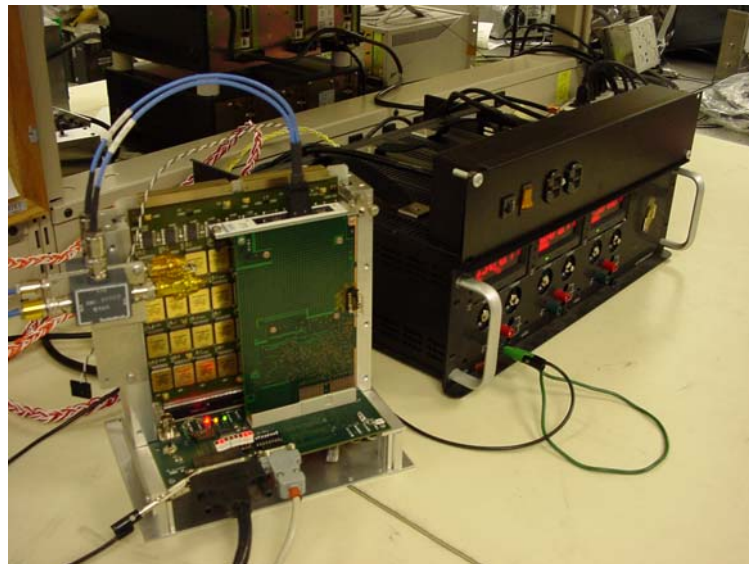
Electronics Status:

- **Specification and Schematic reviews:** bridge board, test mother board, ISS and oven control board, high rate board, and interconnect diagram.
- **Generating drawings for HMI Brass Box enclosure.**
- **Board out for layout:** bridge board and test mother board
- **SMDS space-wire parts for brass board testing in house**

Software Development EGSE



RAD6000 Prototype Board w/ 1553 Card & Power Supply



Software Status:

- **Received non-flight RAD6000 board from BAE**
- **Extensive work on command and telemetry lists**
- **Completely integrated EGSE system for software development**
- **Ran first simulation**