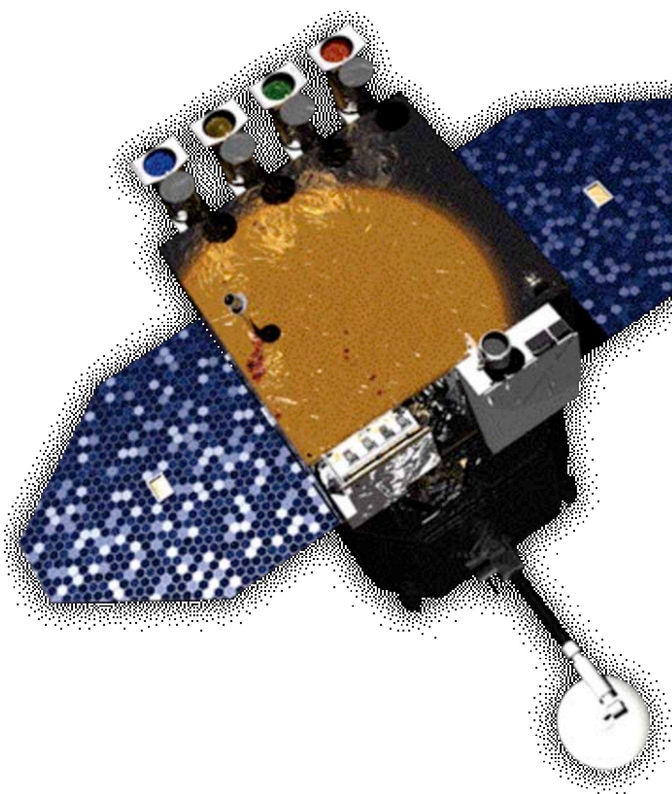
SDO Update to the LWS MOWG



W. Dean Pesnell
Project Scientist

Barbara Thompson
Deputy Project Scientist

Outline

SDO Mission Summary

SDO Mission Status

SDO Launch Delay Proposal

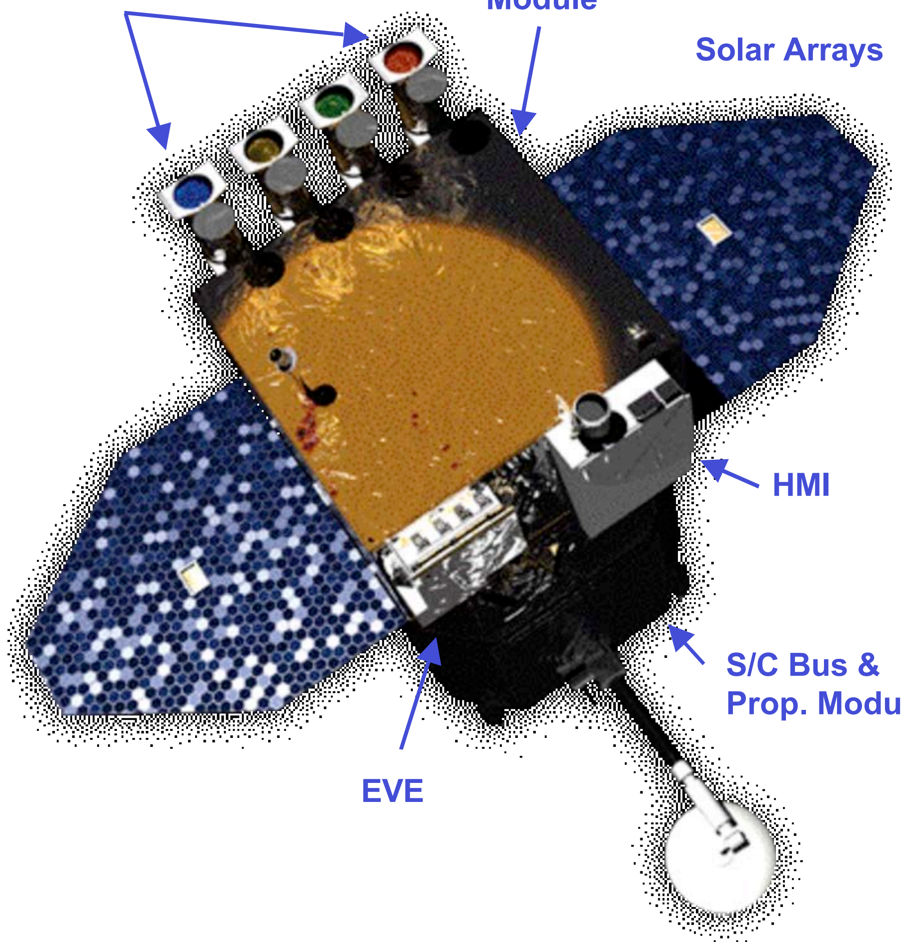
SDO Observatory

SDO Investigations:

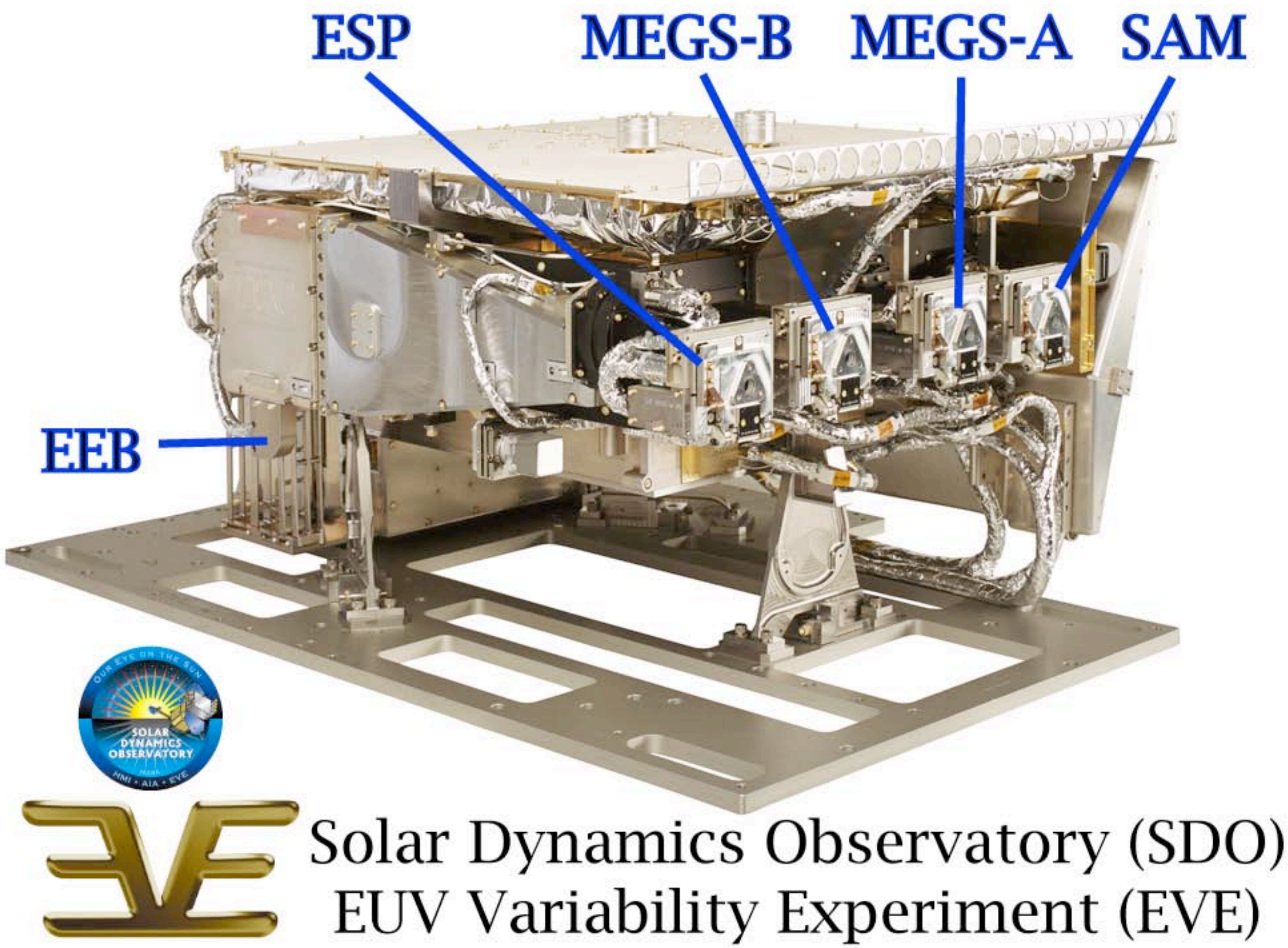
- **Extreme Ultraviolet Variability Experiment (EVE);** PI: Tom Woods – LASP, Univ. of CO; measures the solar extreme ultraviolet (EUV) irradiance to understand variations.
  Helioseismic Magnetic Imager (HMI); PI: Phil Scherrer – Stanford Univ.; Images the Sun's helioseismic and magnetic fields to understand the Sun's interior and magnetic activity.
- **Atmospheric Imaging Assembly (AIA) and Guide Telescopes (GT);** PI: Alan Title – LMSAL; Multiple simultaneous, high-resolution images of the corona over a wide range of temperatures.

Approximate deployed characteristics (current best estimates):

- **Mass: 3000 kg**
- **Power: 1000 W**
- **Width: 6 m**
- **Height: 4.7 m**

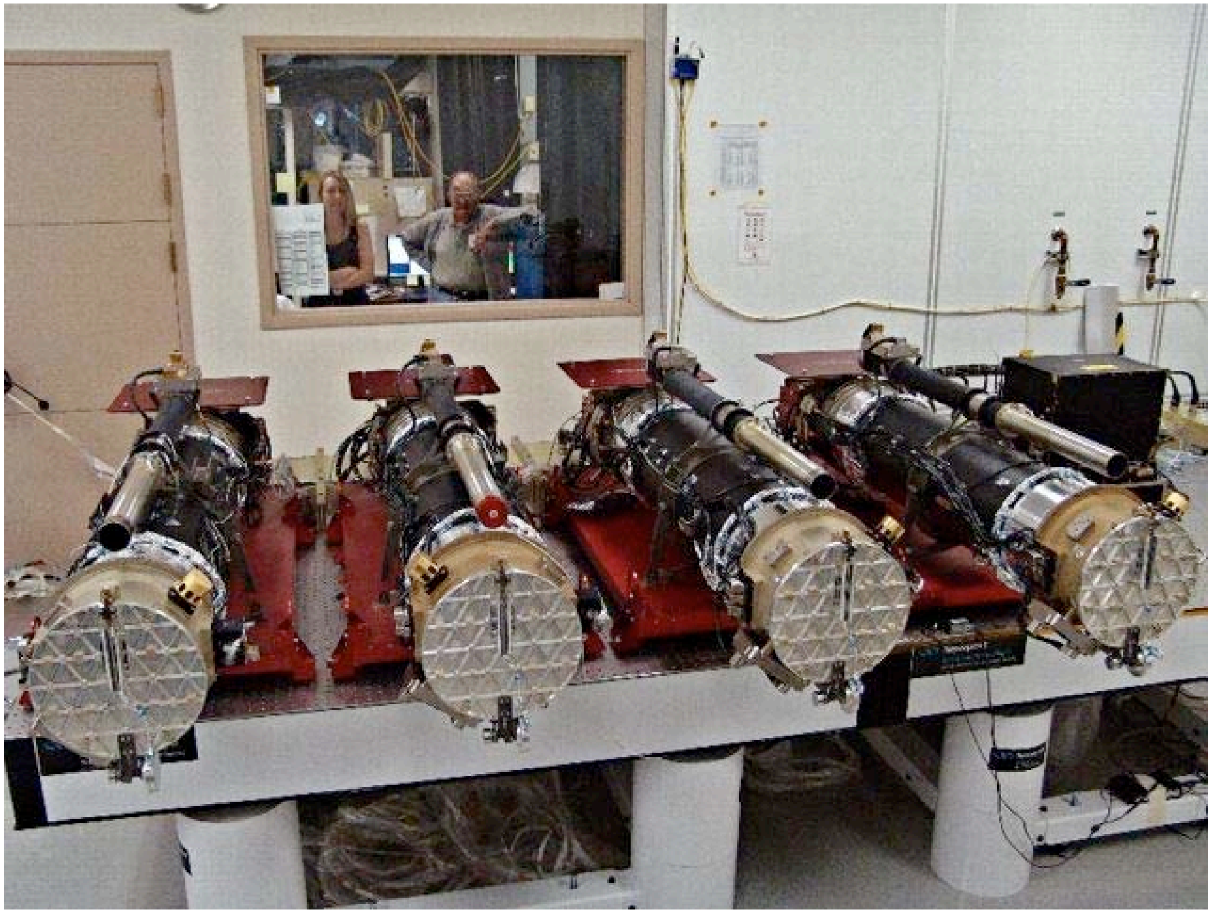


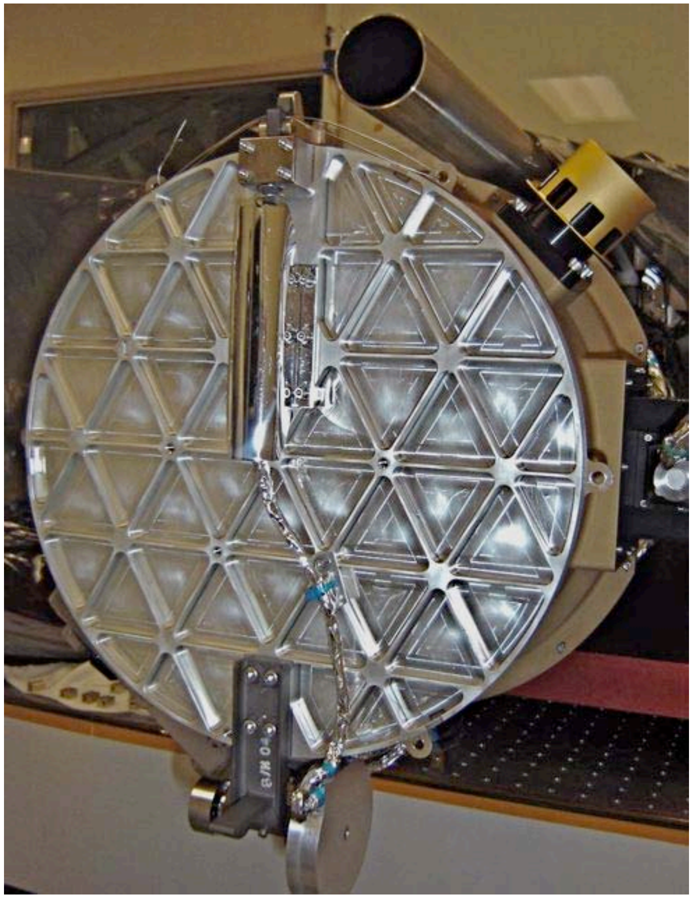
EVE


ESP
MEGS-B
MEGS-A
SAM
EEB
Solar Dynamics Observatory (SDO)
EUV Variability Experiment (EVE)

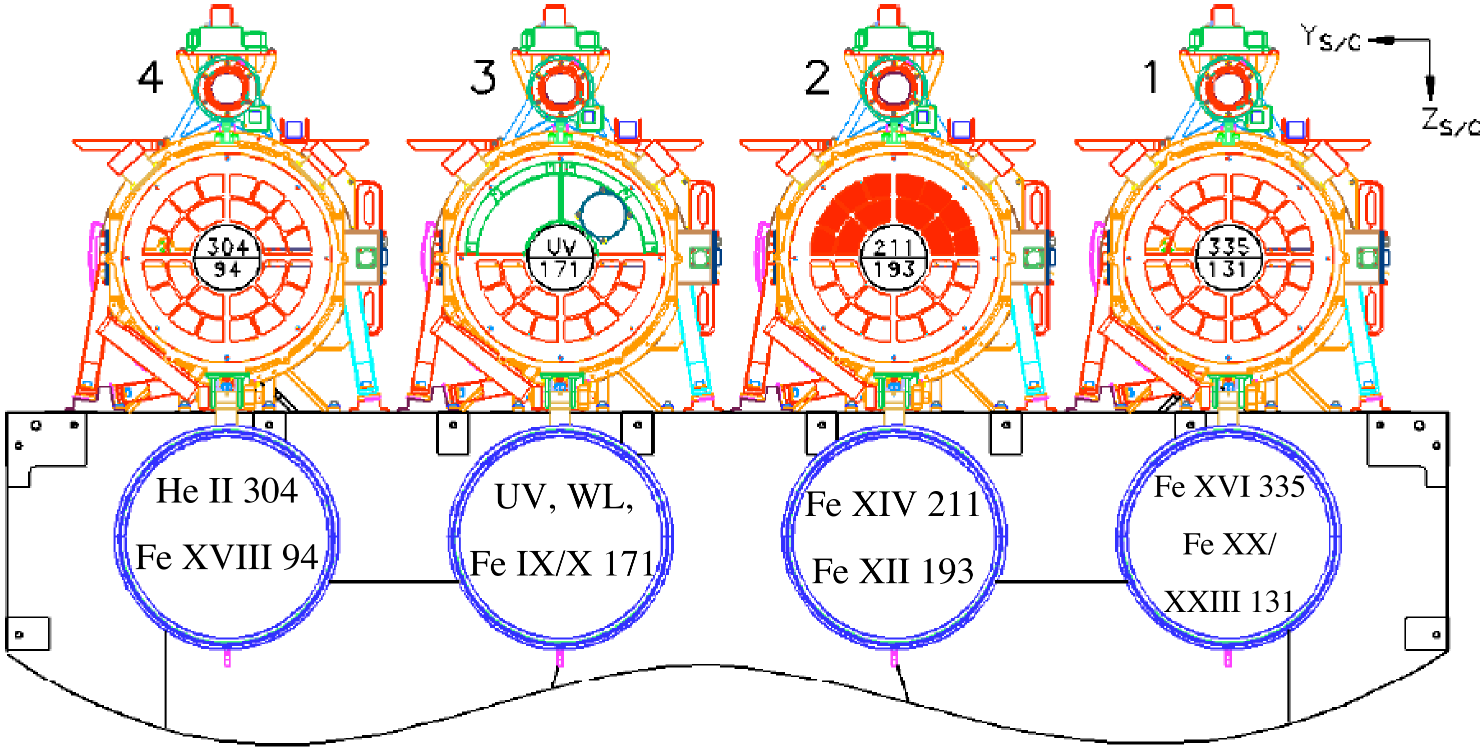
HMI

AIA





AIA Telescopes



AIA's goal is to resolve features in observed coronal loop evolution that could be caused by either density or temperature changes.

AIA observes the coronal plasma with 1.5 arc second spatial resolution and a 10 second cadence resolution, over a wide and continuous temperature range.

Using a set of Iron (Fe) lines minimizes abundance effects and give a broad spectral coverage. The Helium (He II 304) and Carbon (C IV 1600) lines extend temperature coverage to the Transition Region and Chromosphere. A UV continuum (1700 Å) and white light continuum (4500 Å) complete the set.

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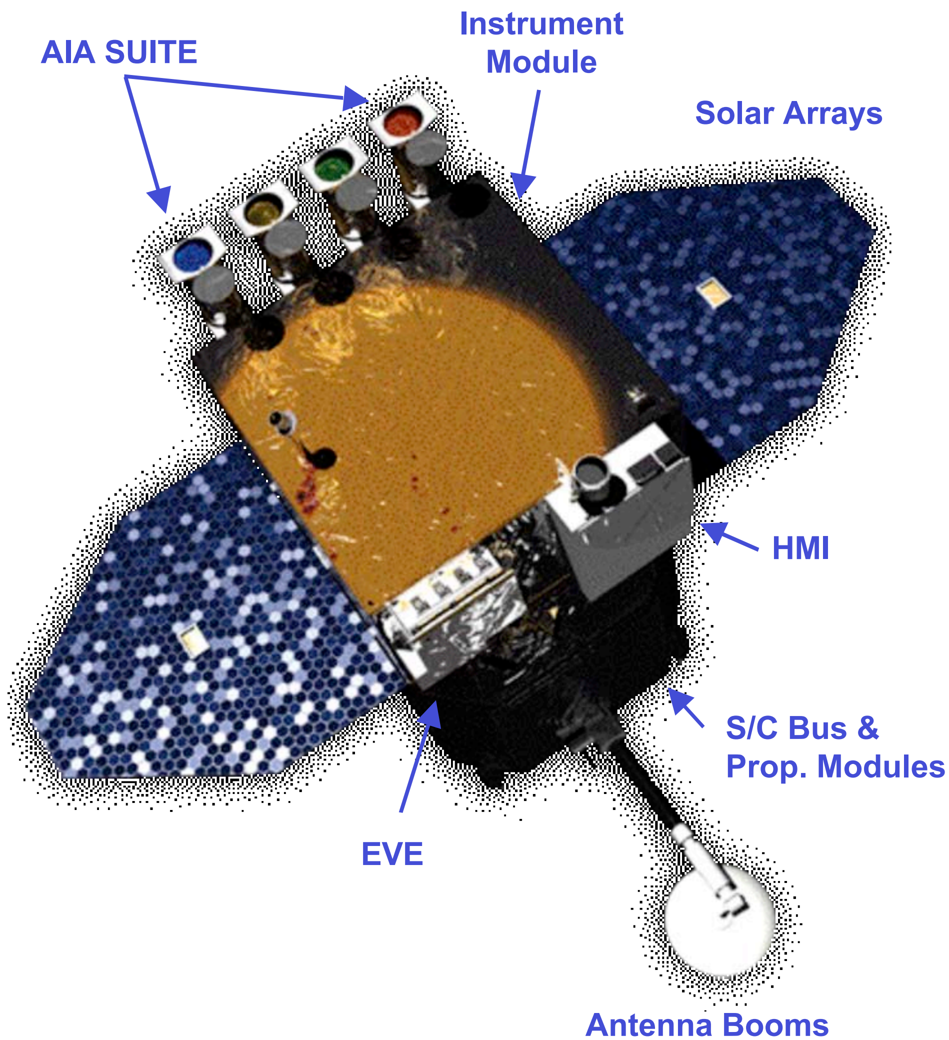


SDO Science Questions

SDO has seven science questions underlying its requirements.
What mechanisms drive the quasi-periodic 11-year cycle of solar activity?
How is active region magnetic flux synthesized, concentrated, and dispersed across the solar surface?
How does magnetic reconnection on small scales reorganize the large-scale field topology and current systems and how significant is it in heating the corona and accelerating the solar wind?
Where do the observed variations in the Sun's EUV spectral irradiance arise, and how do they relate to the magnetic activity cycles?
What magnetic field configurations lead to the CMEs, filament eruptions, and flares that produce energetic particles and radiation?
Can the structure and dynamics of the solar wind near Earth be determined from the magnetic field configuration and atmospheric structure near the solar surface?
When will activity occur, and is it possible to make accurate and reliable forecasts of space weather and climate?

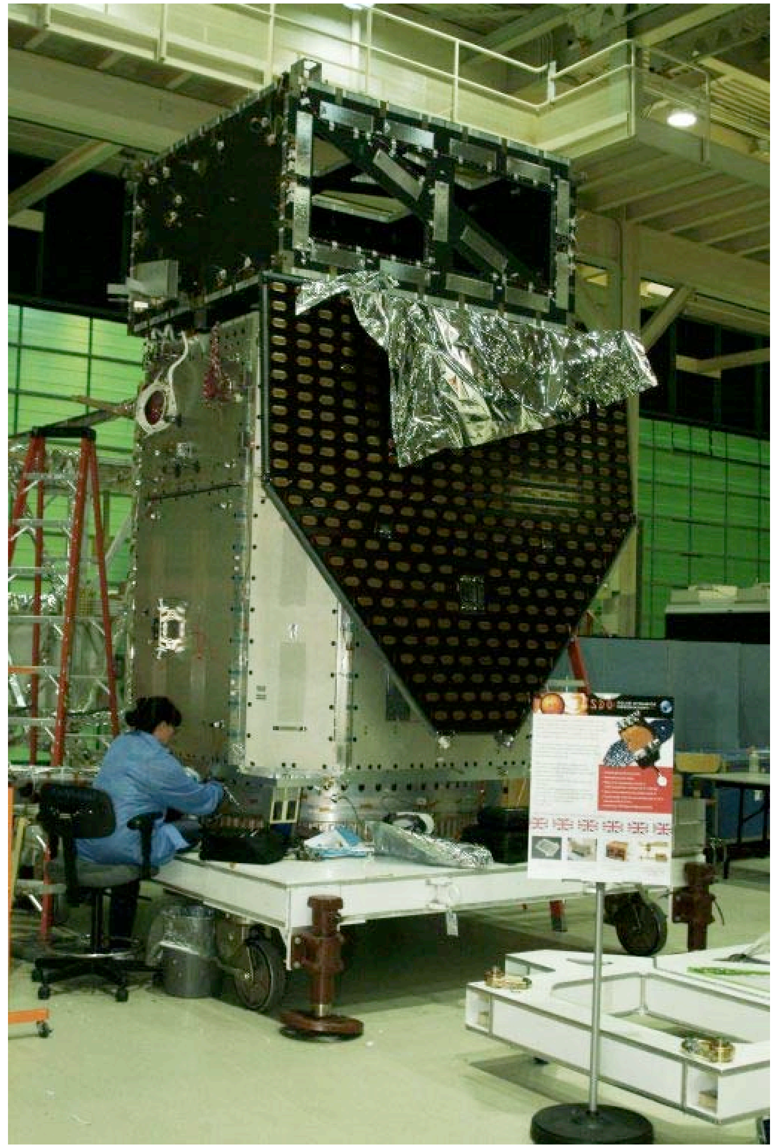
SDO Design Drivers

- **High data volume, coupled with tight requirements on data loss and degradation**
  - 130 Mbps science data rate (150 Mbps downlink with overhead); data completeness of 99% over 10 minute periods and data capture of 95% over 72 day periods
  - Dedicated ground station
- **Geosynchronous orbit**
  - Design requirement for near-continuous downlink of science data
  - Requires propulsion system to get to orbit
- **Long mission life**
  - Science requirement to investigate solar dynamics at high/low activity phases of solar cycle
  - Mission life requirement is 5 years, goal of 10 years—requires redundancy
  - Long life combined with geo-sync orbit means a severe radiation environment
- **Instrument pointing and stability**
  - HMI and AIA instruments drive pointing, jitter, and co-registration requirements
  - Resolution requirements are 0.14” rms at HMI focal plane and 0.17” rms at AIA focal planes (instruments have image stabilization systems to attenuate disturbance over limited bandwidth)

SDO Mission Status

- **Instrument environmental testing is in progress**
  - EVE completied final calibrations at NIST and arrived at GSFC September 6
  - HMI has completed EMI/EMC and is in thermal vacuum
  - AIA has completed thermal balance; three of four telescopes have completed vibe; EMI/EMC testing is complete; thermal vacuum is in preparation
- **Spacecraft Integration Continues**
  - Most components have been delivered and many have been integrated to the bus
  - In-house avionics boxes are in test
  - Propulsion module is in environmental testing, proof pressure found some problems, vibe is next
- **Ground System development is going well**
  - Construction at White Sands is almost finished; antennae are built and are being tested
  - Data links to EVE are in place, the OC3 lines to Stanford are almost installed
  - Operational release of the ground system has been delivered

Current Status



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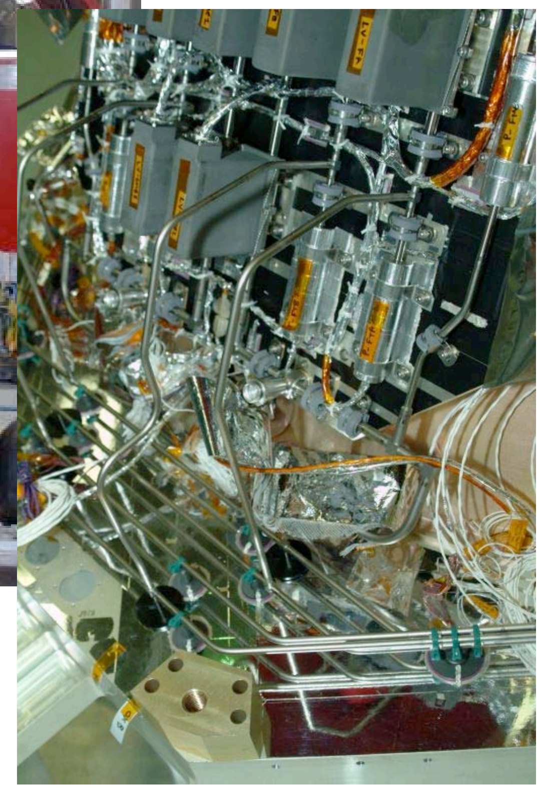
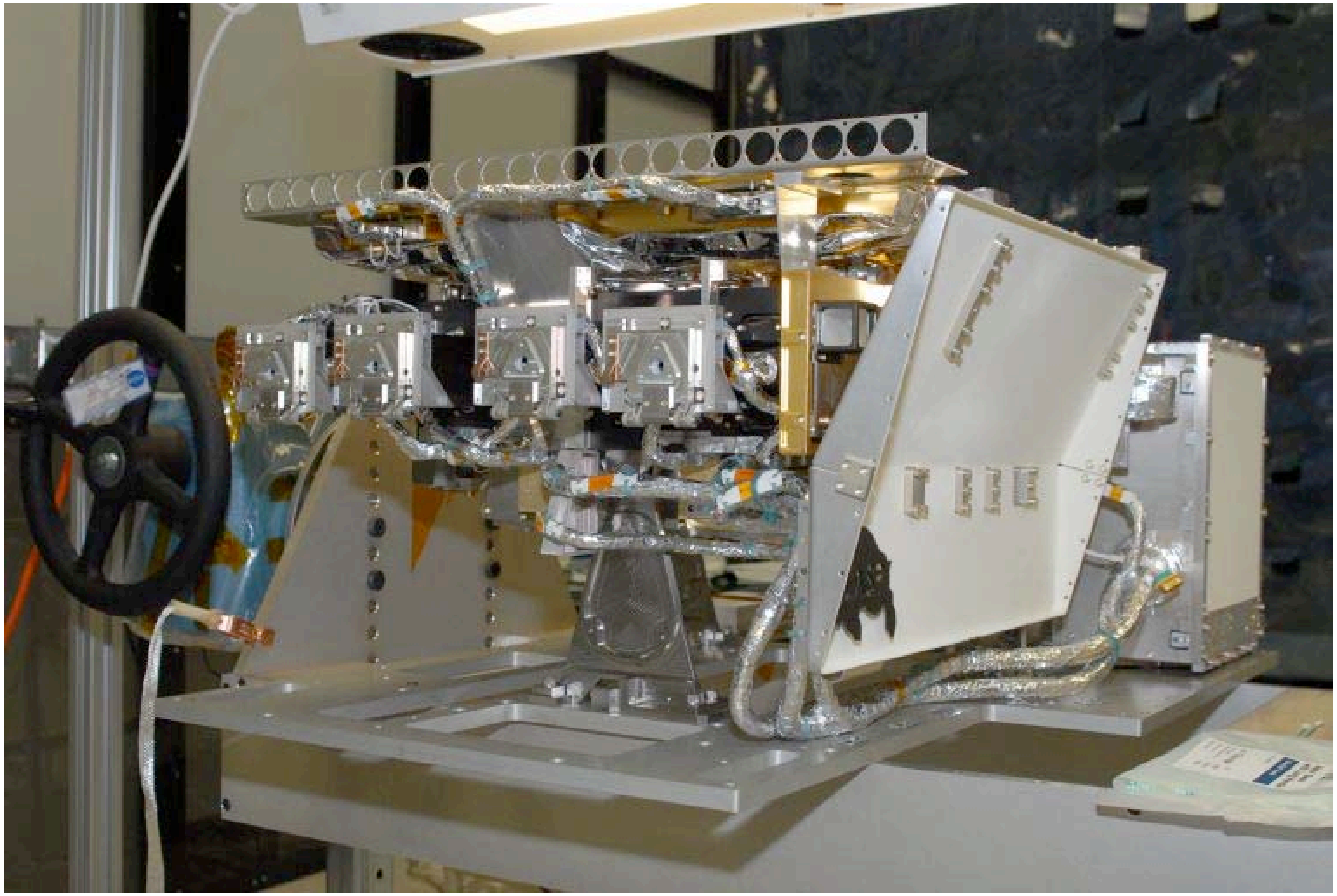
Current Status

The propulsion module, 9/12



The plumber's dream

Current Status



06-SEP-2007

Current Status

SDO 2 at WSC.

During testing a rain storm passed between both antennae and the Ka source. Both antennae maintained lock!

Current Status

- Launch is planned for late 2008/early 2009 on an Atlas V EELV from Cape Canaveral
- SDO will be placed into an inclined geosynchronous orbit ~36,000 km (21,000 mi) over New Mexico for a 5-year mission
- SDO will produce an enormous amount of data
  - 1.5 Terabytes each day
  - About 0.75 petabytes each year
  - A 2 hour movie every 4 minutes for 5 years!
- DDS is a data cache, forwarding data to SOCs, who archive and serve the data

Data Distribution System being test in Building 14 (60 TB raid storage)

Current Status

- Science teams are beginning to finalize their investigation plans
- Users of quicklook data (public, SWx, and some scientists) should have access soon after launch
- Users of research-grade data may need to wait until the software is better understood
- Heavy users of data are encouraged to work with the HMI/AIA teams to place their analysis software into the data pipeline

Launch Delay

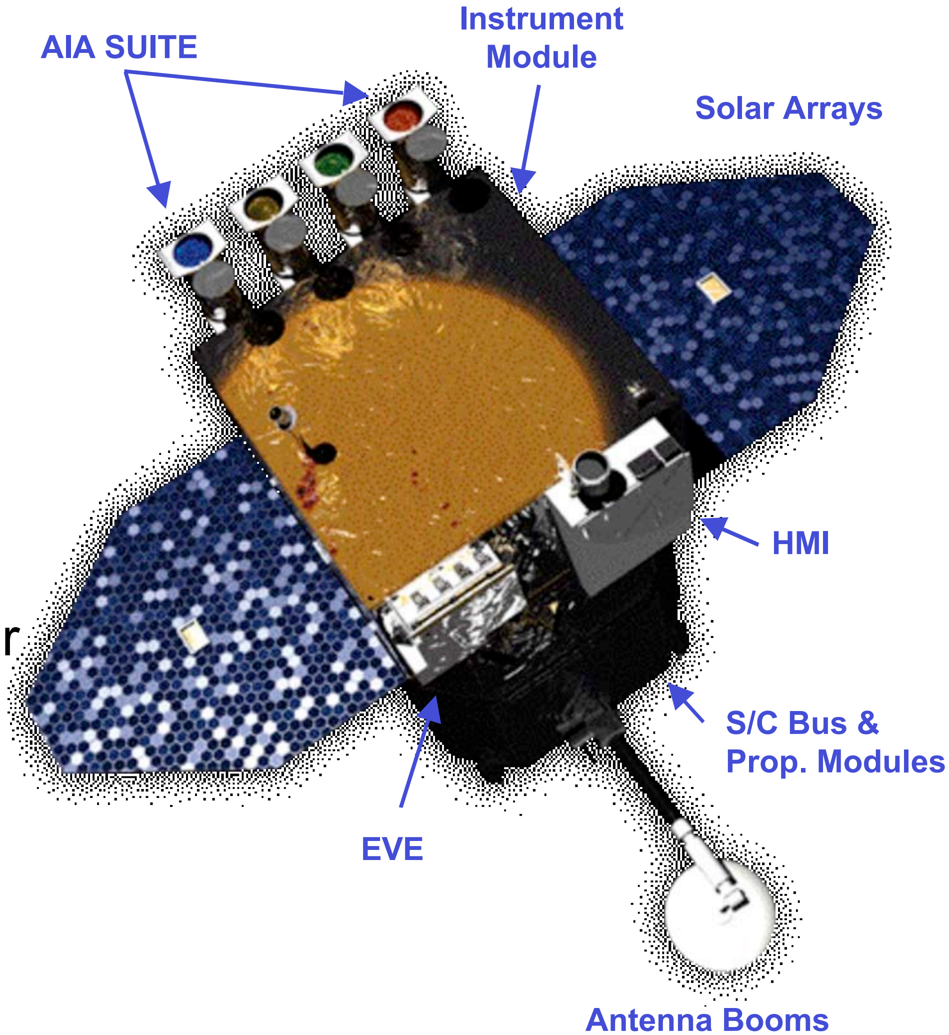
- In May SDO went “red” for schedule when several subsystems fell too far behind to be accommodated within the current schedule
- An Independent Review Team was convened to examine the proposed re-baselined project
- A termination/continuation review was scheduled (as have other missions)
- That re-baselined project was not accepted by HQ
- A new version of the project will be presented to HQ this Friday and in October
  - Scheduled tests were removed
  - Schedule contingency was removed
  - An APL-led team (another IRT) reviewed the project’s suggestions

Launch Delay Proposal

- SDO has asked for a launch delay from August, 2008 to December, 2008
- SDO is almost complete and there is little to no savings in stopping an instrument or other subsystem build
- A list of tests will be descoped to help reduce the length of the integration and test phase of the observatory build and reduce the length (i.e., cost) of the delay
- This has resulted in a request for a cost-cap increase of approximately $20 M
- Various other options were studied to pay for this increase
- One option is to remove MO&DA funding at the far end of the prime mission
- Another is to remove E&PO funding

Summary

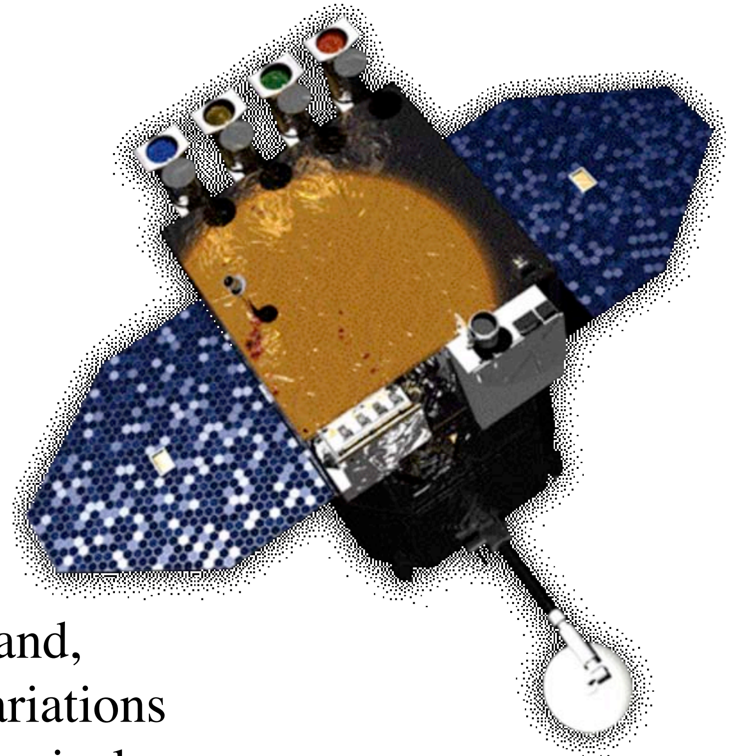
- SDO is almost finished and ready to meet its Level 1 Requirements
- No insurmountable technical problems are being worked
- The launch delay is being worked through HQ
- Getting the most science out of the enormous data stream is our next challenge



- W. Dean Pesnell: William.D.Pesnell@nasa.gov
- http://sdo.gsfc.nasa.gov

Solar Dynamics Observatory

The Solar Dynamics Observatory (SDO) is the first Living With a Star mission. It will use telescopes to study the Sun's magnetic field, the interior of the Sun, and changes in solar activity. Some of the telescopes will take pictures of the Sun, others will view the Sun as if it were a star.



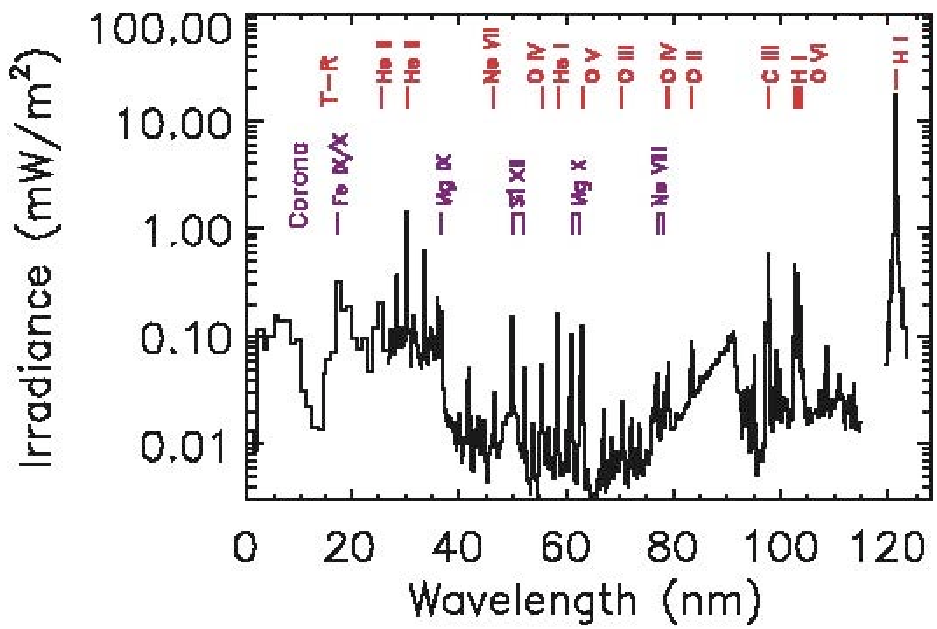
- The primary goal of the SDO mission is to understand, driving towards a predictive capability, the solar variations that influence life on Earth and humanity's technological systems by determining:
  - *How the Sun's magnetic field is generated and structured*
  - *How this stored magnetic energy is converted and released into the heliosphere and geospace in the form of solar wind, energetic particles, and variations in the solar irradiance.*

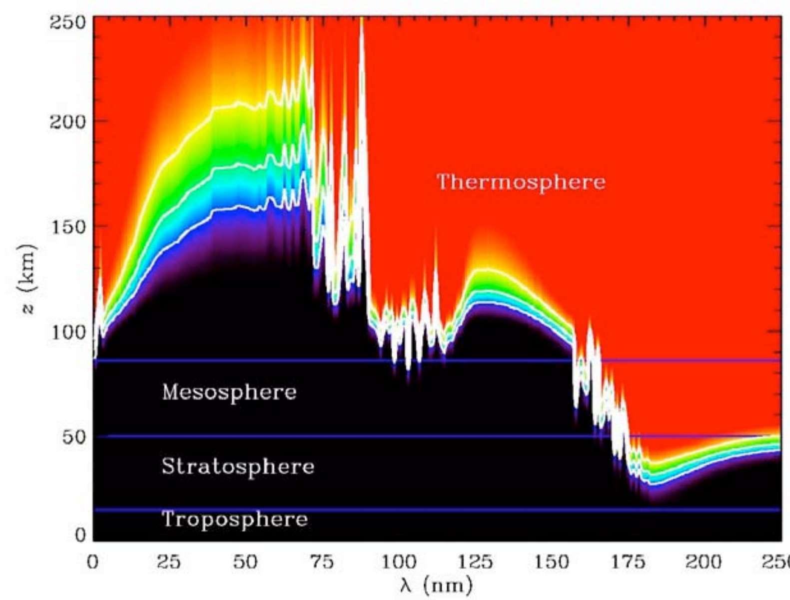
EVE Data & Research

- One spectrum every 10 seconds is the primary product
- Drive real-time models of the upper atmosphere of the Earth and other planets
- Identify sources of EUV irradiance (with AIA)
- Predict the future of EUV irradiance (with HMI)

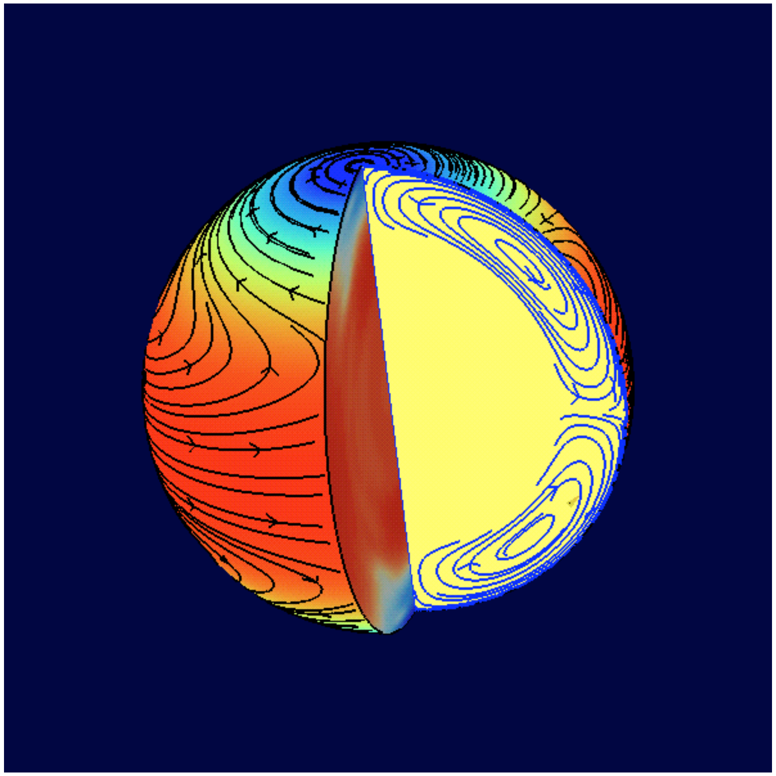
Below (left): Example EVE spectrum. Some of the lines are identified and where the lines are formed in the solar atmosphere is noted at the top.

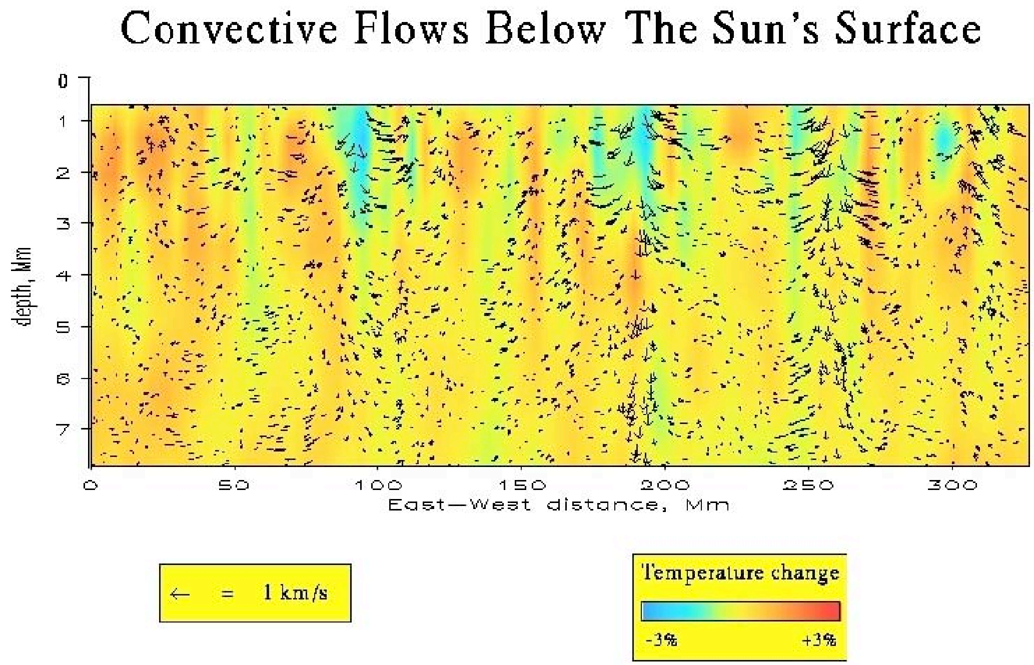
(right) Absorption of radiation by the Earth’s atmosphere. Red areas show altitudes that do not absorb a wavelength, black means complete absorption. The layers of the atmosphere are also listed. All of the radiation measured by EVE is absorbed above 75 km, most above 100 km.





HMI: An Ultrasound of the Sun



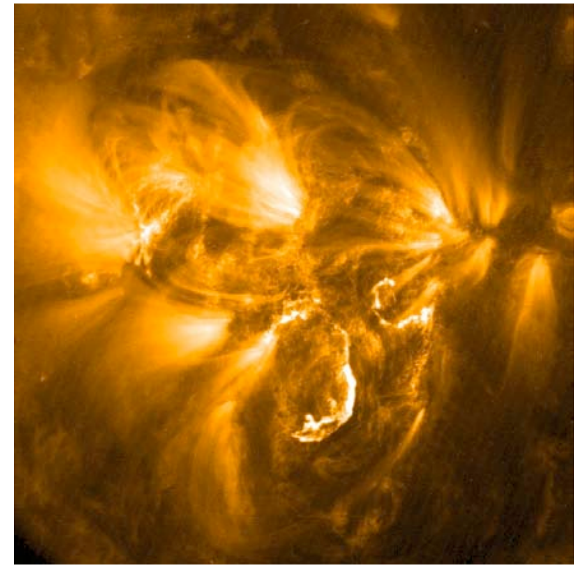


A vertical cut through the outer 1% of the Sun showing flows and temperature variations inferred by helioseismic tomography. These measurements show the short-term behavior of a small part of the Sun—truly Solar weather!

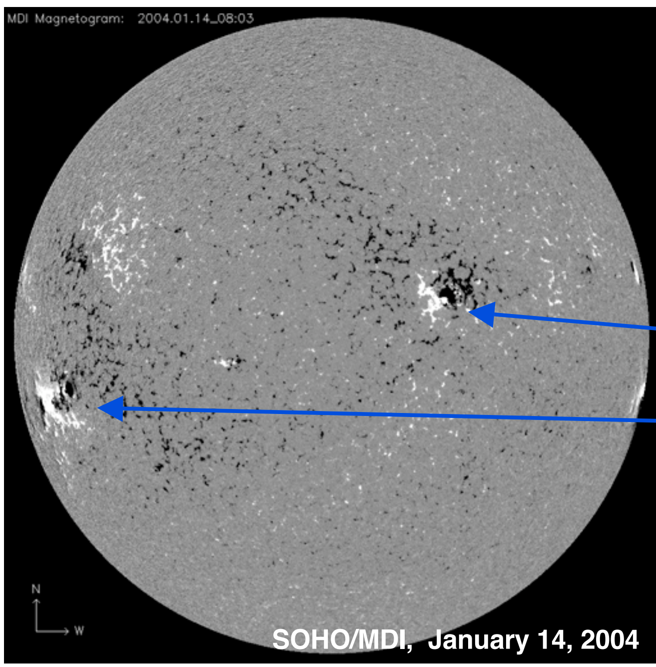
Simplified meridional and zonal velocities inside the Sun. These velocities are inferred from helioseismic measurements and represent the long-time evolution of the solar convection zone.

HMI: “Seeing” Magnetic Fields

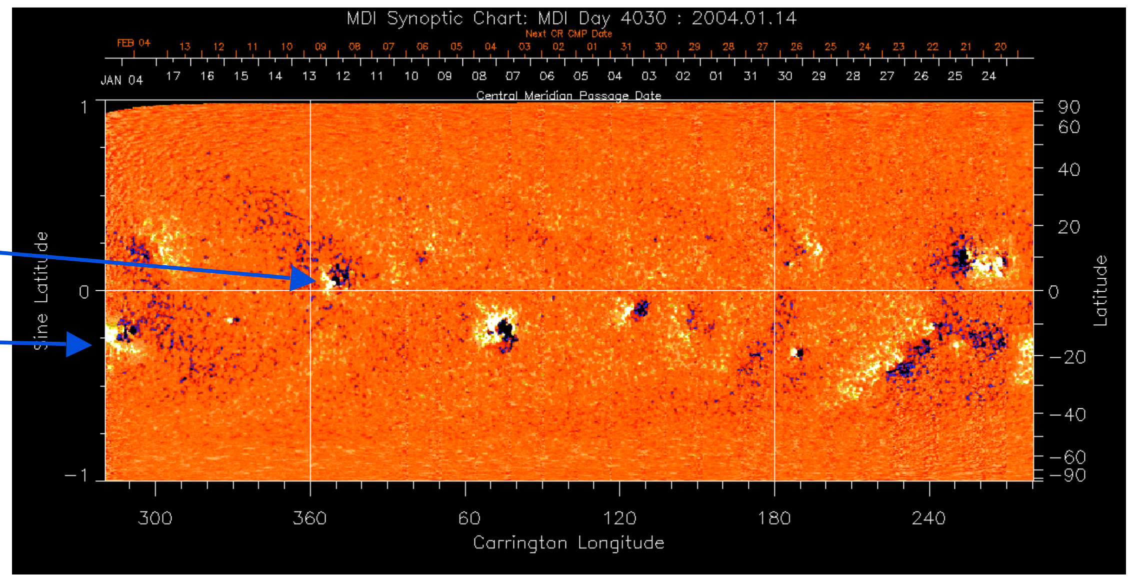
- **Magnetic fields can be measured at and above the surface**
  - Longitudinal field has several cycles of coverage
  - Vector magnetic field is just beginning
  - Helisiesmology tracks the field from inside
- **EUV images show how magnetic loops lace the corona**
  - Hot material with strong magnetic fields (right)
  - C2 flare in AR 10871, 1822 UT on April 11, 2006 (TRACE, 171 Å)



Below: Image of the Sun’s magnetic field.

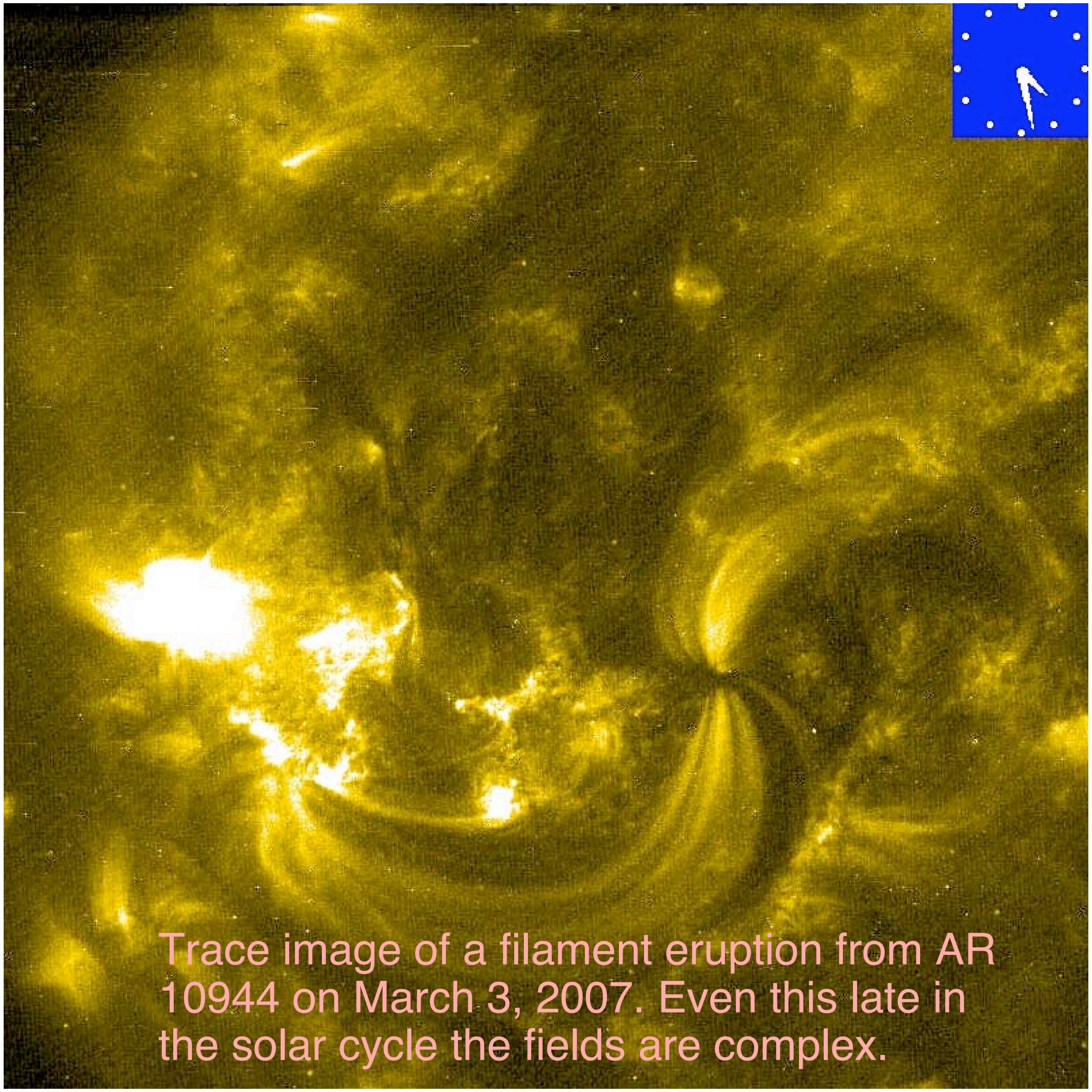


Below: One ‘day’ in the life of the Sun’s magnetic field (January 2004.) Lines join the same active regions in different views.



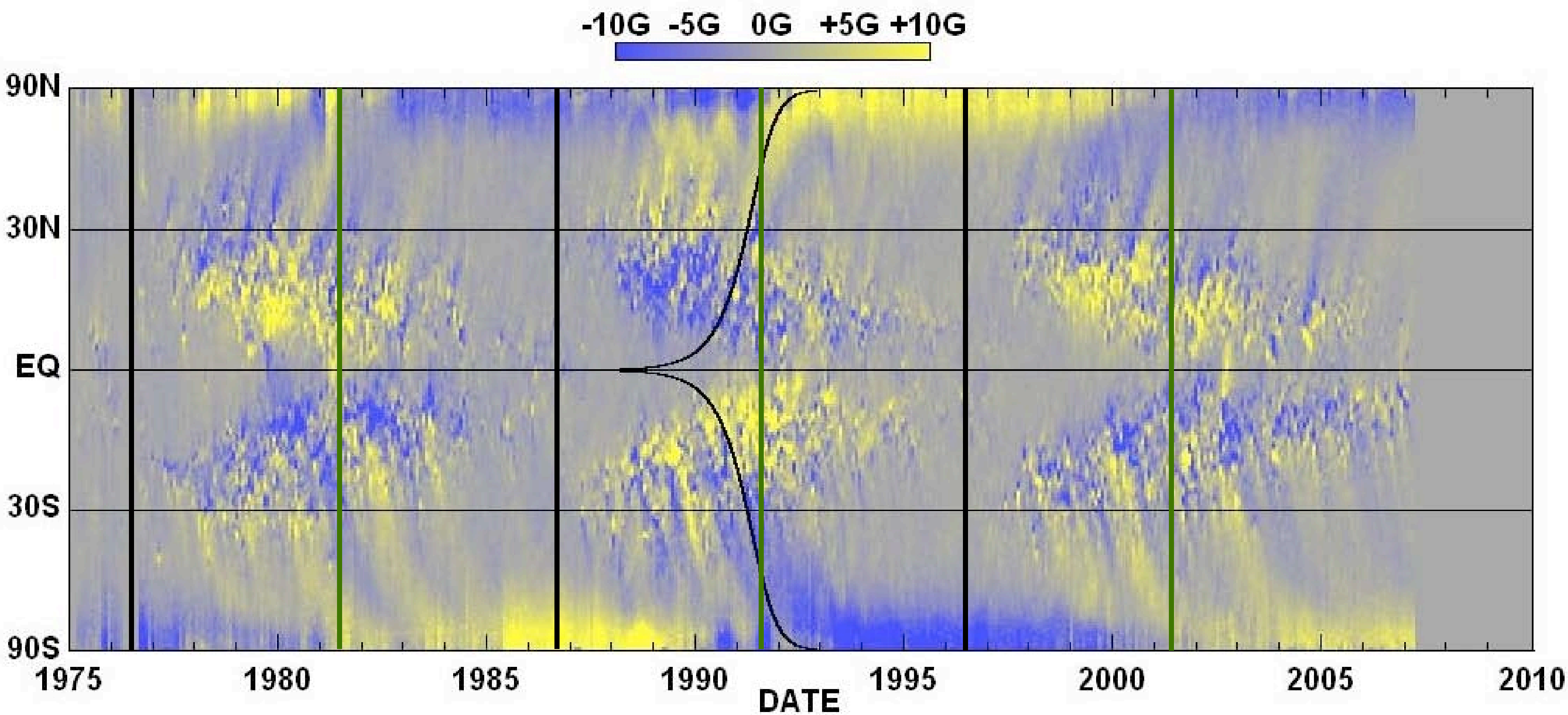
AIA: It's the Time Dependence

- Images of the Sun in eight bandpasses covering temperatures from 50,000 K to 3 million K
- Images of the corona and chromosphere
- The dissipation and redistribution of magnetic field
- Coronal seismology, understand the magnetic field by the waves generated along a coronal loop
- Combined with the magnetic field of HMI, models of the magnetic field throughout the corona



Trace image of a filament eruption from AR 10944 on March 3, 2007. Even this late in the solar cycle the fields are complex.

Solar Cycle at the Poles



A 5-year mission starting at minimum does have a good chance of observing the polar field reversal and many of the surges of magnetic field from lower latitude (courtesy Hathaway/NASA).