National Aeronautics and
Space Administration

Heliophysics

Studying the Earth-Sun System

As humans extend their reach into space, understanding the origin and nature of solar activity and its effect on the space environment and the Earth becomes critical for the operation of both robotic and manned systems. Marshall Space Flight Center has researched this environment since the 1970s, creating the Apollo Telescope Mount, an 8-instrument science platform on Skylab that performed the earliest space-based heliophysics observations.

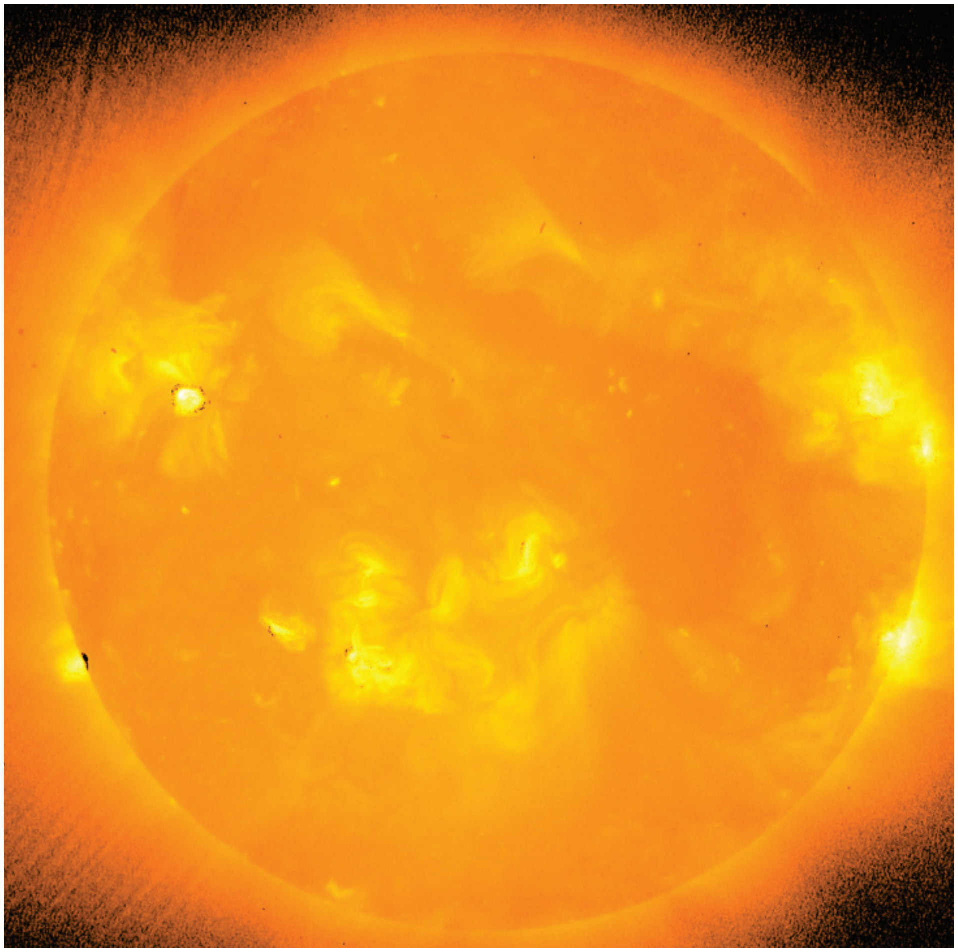
Marshall continues to advance understanding of the interconnected Earth-Sun system to provide knowledge and predictive capabilities essential to future use and exploration of space. The colocation of space scientists and engineers at Marshall provides a collaborative environment for the development of instruments and achievement of science.

Expertise

Marshall's heliophysics research is organized into three primary themes: the Sun and the heliosphere, the terrestrial magnetosphere and ionosphere, and space weather. Of primary interest at the Sun is its internal processing of magnetic fields that leads to a periodic cycle of activity and the dynamics of the extended magnetic field into the corona where energy is irregularly released in tremendous eruptions of particle and electromagnetic energy. The response of the Earth's magnetic environment to solar activity is the focus of magnetospheric research. Thermal plasma in the ionosphere and its extension into the magnetosphere play important roles influencing the propagation of waves and the transport of energy and particles through the magnetospheric system. Both of these research areas lead to the bridging activity of space weather where the derived knowledge of processes taking place at the Sun and its extended plasma environment are needed to characterize the climate in space and predict its dynamic conditions or weather.

At-A-Glance:

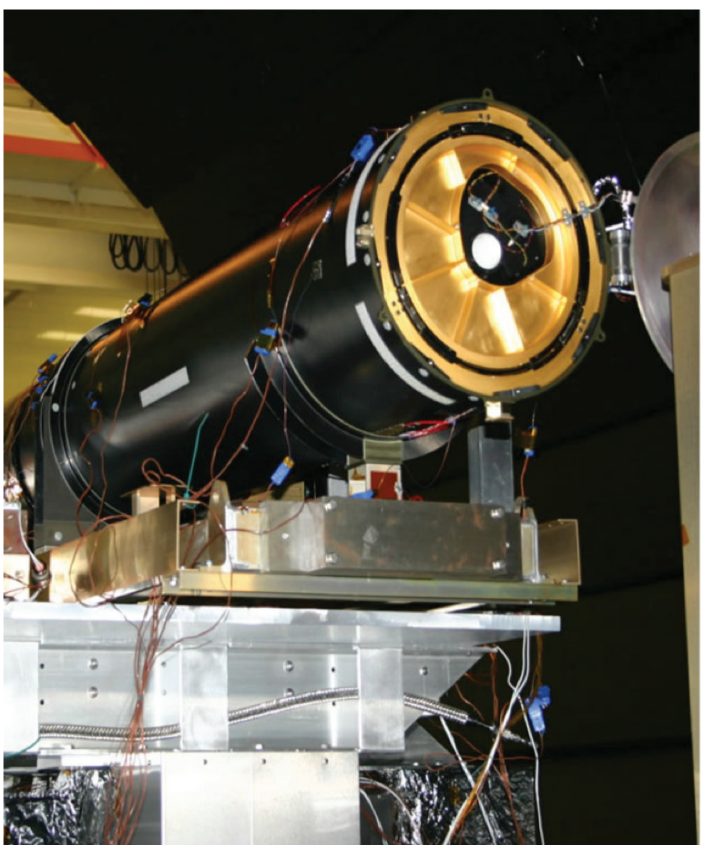
Marshall Space Flight Center consistently provides high-value heliophysics science to NASA because of its colocation of engineering and science resources, and is focused on finding and developing affordable approaches to expanding and delivering new heliophysics research.



Hinode studies the generation, transport, and dissipation of magnetic energy from the photosphere to the corona. Image of full sun taken by Hinode May 31, 2013.

By studying the sun and its magnetic field, Marshall scientists are advancing understanding of explosive solar activity that can interfere with satellite communications and can damage electric power transmission grids on Earth. Solar flares can also threaten spacecraft, or astronauts on the way to or working on the surface of the moon, asteroids, and Mars. Marshall engineers build the instruments and Marshall scientists manage the science to study how changes in the sun's magnetic field trigger these explosive solar events. Information is shared with Marshall space weather experts who model the data for planned missions to ensure future spacecraft are well prepared to withstand space environments.

Marshall heliophysicists work closely with the Center's technical experts in areas of high-energy optical instruments and materials science. The Center's replication method for creating grazing-incidence optics is unique in the nation and provides support to scientists studying high-energy solar radiation. Marshall is also home to the High-Intensity Solar Environment Test (HISET) facility, which provides scientists and engineers with the means to test spacecraft materials and systems in a wide range of solar wind and solar photon environments. Featuring a solar simulator capable of delivering approximately 1 MW/m^2 of broad spectrum radiation at maximum power, HISET provides a means to test systems or components that could explore the solar corona.



Hinode's X-ray Telescope was characterized and calibrated at the XRCF in 2005.

Understanding Solar Magnetic Fields

Hinode

Hinode is providing cutting-edge understanding of the interaction between convection and the solar magnetic fields, helping reveal the source of high-energy particles and hard X-rays in large solar flares, and creating major new insights into the mechanisms that heat the solar atmosphere and produce the UV and X-ray emission. Marshall managed the development of the Hinode satellite's scientific instrumentation and manages the U.S. portion of the science derived from the spacecraft's three advanced solar telescopes. Marshall engineers characterized and calibrated Hinode's X-ray Telescope at its X-ray and Cryogenic Facility (XRCF) in 2005.

SUMI

Not all Marshall heliophysics projects are in orbit. NASA's suborbital sounding rocket program has proven to be a successful, low-cost method for Marshall scientists to study magnetic fields in a region of the sun where they have never been measured. Marshall scientists are currently studying the data from the successful Solar Ultraviolet Magnetograph Investigation (SUMI), launched to study magnetic fields in the sun's chromosphere. No other instrument is looking at this layer of the Sun. The SUMI development began as a set of programs to improve the efficiency of polarization measurements in the ultraviolet.

Hi-C

The High-resolution Coronal Imager (Hi-C) is an extreme ultraviolet imaging telescope that produced the highest spatially resolved images of the solar million-degree corona to date during its flight in 2012. Marshall scientists and engineers designed and built the camera and mirror systems for the Hi-C telescope. The clarity of the images help scientists better understand the behavior of the solar atmosphere and its impacts on Earth's space environment.

High-Energy Replicated Optics to Explore the Sun (HEROES)

Scientists from Marshall and Goddard Space Flight Center developed HEROES, the High-Energy Replicated Optics to Explore the Sun, launched in 2013 to study solar flares during the day and the stars at night. It is based on the successful Marshall-designed High Energy Replicated Optics (HERO) balloon-borne x-ray telescope. It featured 110 Marshall-fabricated, nickel-alloy, hard x-ray mirrors focused onto 8 custom-built focal plane detectors.

Focusing Optics X-ray Solar Imager (FOXSI)

Also building on HERO's success is the Focusing Optics X-ray Solar Imager (FOXSI) mission to study solar nanoflares. Marshall engineers built it with 49 new iridium-coated nickel/cobalt mirror shells using its unique replicated optics manufacturing capability, saving time and money.

Solar Probe Plus

Marshall scientists are developing instrument prototypes for the Solar Probe Plus (SPP) mission set to launch in 2018 to sample the sun's plasma and magnetic field closer than any previous spacecraft. Marshall instruments will count electrons, protons and helium ions, and measure their properties.

The investigation will catch the solar wind in a Faraday cup, part of the Solar Wind Electrons, Alphas, and Protons (SWEAP) instrument. It will enable researchers to determine the speed and direction of solar particles. SWEAP will be tested for performance and survivability at Marshall. Because the Faraday cup must operate at temperatures exceeding 1,500 K, components of it will be fabricated at Marshall, leveraging technology development in the field of advanced composite materials.

Hi-C launches July 11, 2012 from White Sands Missile Range. Hi-C captured the highest resolution imagery of the corona ever captured, revealing features as small as 100 miles across.

Modeling the Terrestrial Magnetosphere

The plasmasphere is a toroidal-shaped region surrounding the Earth that is the extension of the ionosphere at sub-auroral latitudes. The region is characterized by ionized gases, or plasmas, that are of much higher densities and lower energies than the radiation belts and other plasmas in near-Earth space. As a result of its properties, plasmaspheric plasma exerts a strong influence over the transport of mass and energy through space near Earth, consequently its behavior is critical to understand in order to predict and protect people and machines from the damaging high-energy particles that permeate this region.

The plasmasphere has been a topic of scientific research and experimental investigation at Marshall for over 35 years. This research has resulted in the development of widely used empirical and dynamic models of the plasmasphere. Recent research has focused on the details of plasmaspheric dynamics as it affects coupling between the Sun's and Earth's magnetic fields and the coupling between near-Earth space and the ionosphere.

Improving Space Weather Forecasting

As the demand for space weather forecasting models grows, so does the need for accurate models of the near-Earth space environment. Thus, it is important to have reliable statistical models that accurately represent the most probable state of the space environment for any given time and location. Space-based and ground-based data sources from all over the world are used to construct these models. However, with such a large amount of data comes a need to organize those data in a way such that trends within the data are easily discernable.

With the suite of data mining codes available at Marshall, scientists have the capability to analyze large, complex data sets and quantitatively identify fundamentally independent effects from consequential or derived effects. Using these techniques, Marshall's space weather researchers have examined the accuracy of ionospheric climate models with respect to trends in ionospheric parameters and space weather effects.

The team at Marshall has also worked in collaboration with teams at JSC and UAH to develop a forecast tool called Mag4 for solar flares, coronal mass ejections, and solar energetic particle events, based on near real-time measurements of the solar surface magnetic field. Mag4 is a first of its kind forecasting tool that is able to translate magnetic field patterns on the solar surface into operational probability measures.

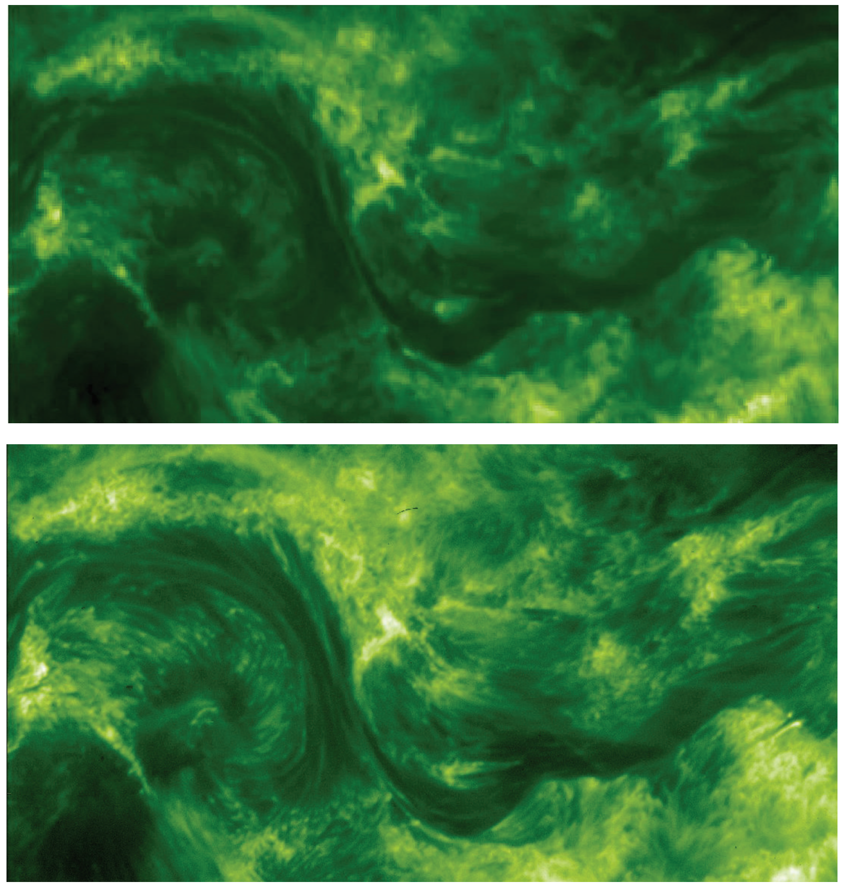
Suborbital Solutions: Low-cost, high-impact science

Launched aboard a sounding rocket in July 2012, Marshall's Hi-C succeeded in capturing the highest-resolution images ever taken of the sun's corona. The image clarity can help scientists better understand how the Sun's atmosphere is heated, as well as understand its behavior, and its impacts on Earth's space environment.

Data was acquired at a rate of roughly one image every five seconds during its 620-second flight. Its resolution is approximately five times more detailed than the Atmospheric Imaging Assembly (AIA) instrument aboard NASA's Solar Dynamics Observatory (SDO). For comparison, AIA can see structures on the sun's surface with the clarity of approximately 675 miles and observes the sun in 10 wavelengths of light. Hi-C can resolve features down to roughly 135 miles, but observed the sun in just one wavelength of light.

The images were made possible because of innovations on Hi-C's optics array, led by Marshall. The high-quality optics were aligned to determine the spacing between the optics and the tilt of the mirror with extreme accuracy. Scientists and engineers worked to complete alignment of the mirrors, maintaining optic spacing to within a few ten-thousandths of an inch.

Long before Hi-C took flight, the telescope had to be tested. To perform the necessary tests, Marshall enhanced the XRCF and a vacuum chamber at its National Space Science and Technology Center to include a strong EUV source, an EUV monochromator for wavelength calibrations, and the detectors and data system that would be needed to support testing for space-based telescopes.



Hi-C image (bottom) compared to the same image from the Atmospheric Imaging Assembly flying aboard NASA's Solar Dynamics Observatory (top), showing Hi-C's superior resolution.

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