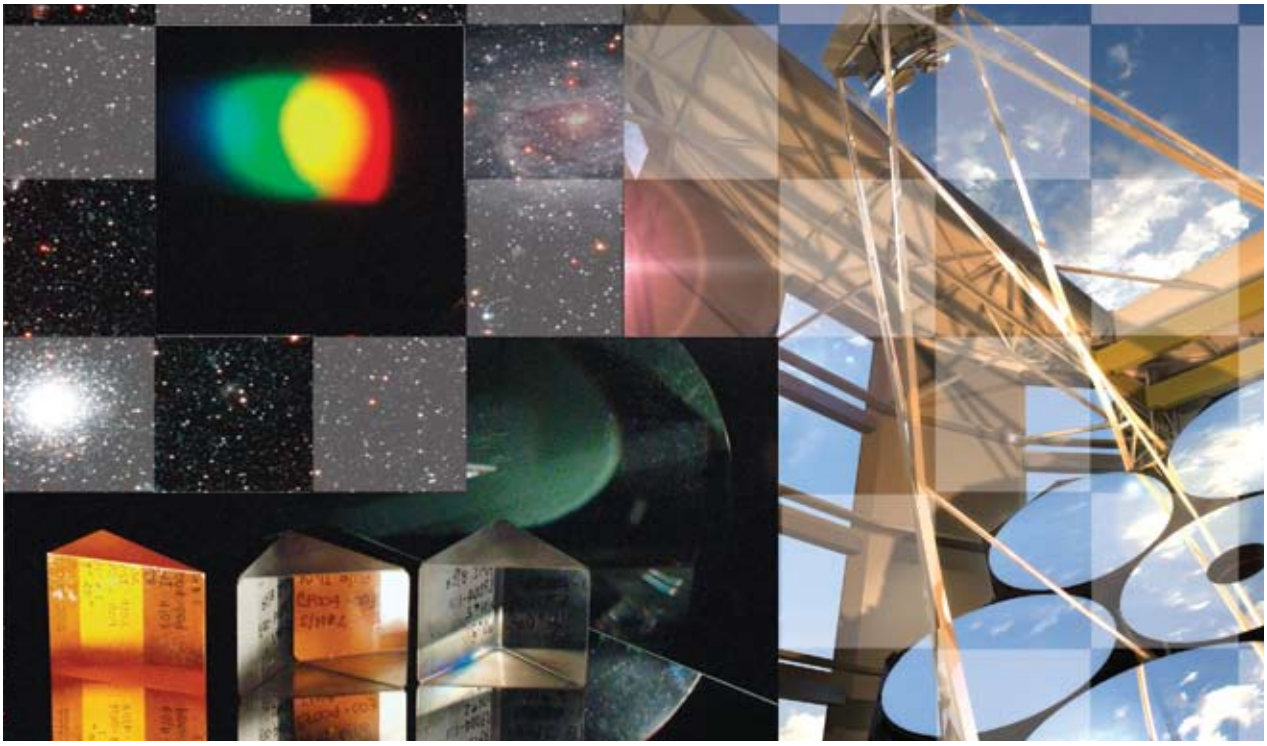
National Aeronautics and Space Administration

Goddard's CHARMS Facility Characterizes Material Properties for Advanced Optics

Agreements with four organizations highlight the facility's state-of-the-art capabilities



Goddard's CHARMS facility characterizes the material properties of prismatic samples (examples shown above left) for researchers in industry and academia. The Harvard-Smithsonian Center for Astrophysics will use the refractive index measurements to design an infrared spectrograph for the Giant Magellan Telescope (right).

As part of reimbursable Space Act Agreements (SAAs) with the University of Oxford, the Aerospace Corporation, Harvard College Observatory, and the University of California Observatories/LICK, NASA's Goddard Space Flight Center used its state-of-the-art Cryogenic High Accuracy Refraction Measuring System (CHARMS) facility to characterize material properties of prismatic samples provided by the participating organizations. The testing measured the refractive index of the prisms (i.e., how the glass processes light), enabling the partner organizations to design optical systems that will behave correctly when cooled to cryogenic temperatures. The resulting data also is available to NASA to improve future instrument designs, as well as to the scientific community. Benefits to NASA and the larger optics and aerospace industries as a whole include access to new refractive index measurement data that will lead to improved optical designs for instruments operating at cryogenic temperatures.

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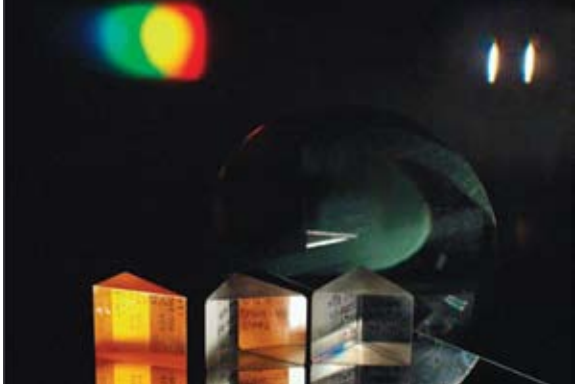
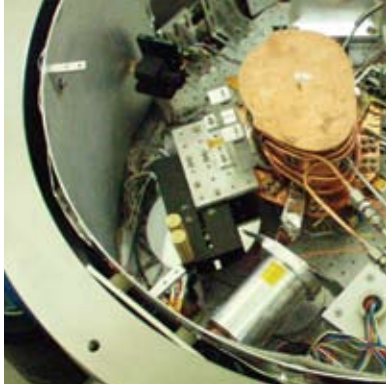




Goddard's CHARMS facility (shown above center) is the only facility of its kind. The facility publishes

About the Partners

The University of Oxford (Oxford, UK) is internationally renowned for the quality and diversity of its research, enhanced by the ongoing development of interdisciplinary research centers and collaboration with international academic and industrial partners. The University is also a world leader in commercializing the results of its research. Isis Innovation, its wholly owned technology transfer company founded in 1988, pioneered the successful commercial exploitation of academic research and invention.

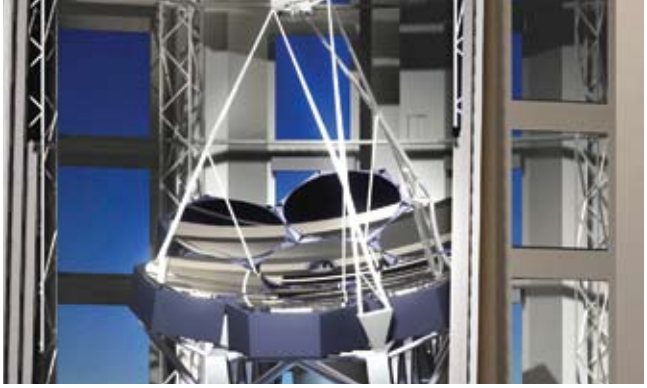
Formed in 1960, The Aerospace Corporation (El Segundo, CA) is a unique nonprofit organization serving the U.S. Air Force in the scientific and technical planning and management of its missile space programs. The corporation assists the military and intelligence communities in the development and acquisition of our nation's critical defense space assets. It offers decades of experience in space hardware and software to civil and commercial space ventures.

The University of California Observatories (UCO)/Lick Observatory (Santa Cruz, CA) is a Multi-Campus Research Unit of the University of California, and operates on behalf of the astronomers at all ten UC campuses. The organization is comprised of extensive technical facilities, a business office, telescopes on Mauna Kea in Hawaii, support facilities at the Lick Observatory on Mt. Hamilton, and a staff of astronomers. Lick Observatory conducts both research and public programs, while the UCO Technical Labs engage in designing and fabricating state-of-the-art instrumentation for observatories throughout the world.

Founded in 1839, the Harvard College Observatory (Cambridge, MA) conducts a broad program of research in astronomy and astrophysics, collaborating with the Smithsonian Astrophysical Observatory (SAO) at the Harvard-Smithsonian Center for Astrophysics (CfA) and providing substantial support for teaching activities to Harvard's Department of Astronomy. Currently, some 300 Smithsonian and Harvard scientists cooperate in broad programs of astrophysical research supported by Federal appropriations and University funds as well as by contracts and grants from government agencies. These scientific investigations touch on almost all major topics in astronomy.

Benefits of Technology Transfer

- **Benefits for partner organizations**: Ability to obtain knowledge of the optical properties of their respective sample prism materials at cryogenic temperatures, thus enabling them to improve instrument design and performance, as well as to simplify the integration and test phase of development
- **Benefits for NASA**: Capability to utilize refractive index data generated for partner organizations at various wavelengths and temperatures without investing research funds to perform additional measurements of this material in the future
- **Benefits for NASA and larger optics and aerospace industries**: Opportunity to improve optical designs for scientific instruments operating at cryogenic temperatures through the use of new published data regarding the measurements of the partner-supplied samples


refractive index data for use by research organizations worldwide.

Technology Origins

Established in 2003, the CHARMS facility is part of Goddard's Optics Branch. This highly versatile facility can provide measurements at cryogenic temperatures and a wide range of wavelengths with unsurpassed accuracy. The success of future NASA infrared missions depends on the availability of accurate refractive index data for optics operating at cryogenic temperatures. Several NASA missions, including the James Webb Space Telescope (JWST) and the Kepler Photometer, have directly benefited from the facility.

For JWST, CHARMS researchers measured the refractive index of lens materials used in the telescope's Near Infrared Camera (NIRCam) to understand how the all-refractive design would operate at the instrument's cryogenic operating temperature. The data enabled a design that would reach its scientific goal and improve the efficiency of cryogenic testing of NIRCam on the ground, adding to CHARMS' world-class reputation.

Finding a New Use

Unlike NASA's applications for the capabilities provided by CHARMS, Oxford's application is not for optics that will actually fly in space. Rather, this work will benefit a ground-based infrared instrument—the K-band Multi-Object Spectrometer (KMOS)—to be used on one of the European Southern Observatory's Very Large Telescopes. Knowledge of refractive index is required at cryogenic temperatures for many ground-based applications as well as those using optics cooled during operation. In the case of KMOS, if the optics are too warm, the camera will see infrared light coming from the optics as well as its science target, thus reducing the quality of the scientific data. Once the optics are cooled, this background light is reduced and the science target is more visible. Testing at CHARMS will provide the University with knowledge of the optical properties of its sample material at KMOS operating temperatures.

At the Harvard-Smithsonian Center for Astrophysics, Dr. Daniel Fabricant will use the refractive index measurements to design an infrared spectrograph for the Giant Magellan Telescope (GMT), a next-generation extra-large telescope (ELT). The spectrograph will operate over a wavelength range of 0.9 to 2.5 micrometers. Scheduled for completion in 2018, the GMT will have more resolving power and a larger collecting area than any existing telescope of its type, and promises to help answer many questions of paramount interest in astrophysics today. Areas of exploration will include the origin and evolution of planetary systems; the formation of stars, galaxies, and black holes; and the properties of dark matter and dark energy. Although completion of the GMT will not occur until 2018, it is critical for HCO to understand the refractive index of the optical materials at cryogenic temperatures now, to develop the spectrograph design. The CHARMS facility is the only lab available that can provide HCO with accurate measurements of the behavior of the optics materials at specified cryogenic temperatures, helping them ensure an accurate telescope design. In addition, HCO has used previously published data from the CHARMS facility to verify the accuracy and performance of other optics materials at various temperatures, and plans to continue to use the CHARMS published data as a valuable and unprecedented resource for such data.

Researchers at UCO/Lick will use the refractive index data provided by the CHARMS facility for the Multi-Object Spectrometer for InfraRed Exploration (MOSFIRE), planned for use on the Keck-1 telescope in Mauna Kea, Hawaii. Its proper operation requires vacuum-chamber containment at approximately –160°Celsius. Therefore, researchers at UCO/Lick must understand how the glass optics on the spectrometer will behave at such temperatures in order to properly design the instrument. This spectrometer is a critical component of Keck-1, one of two telescopes observing galaxies at the edge of the universe, used to determine the rate of expansion of the universe by observing supernovae, detect atomic gasses between galaxies, better understand gamma ray bursts, and identify and characterize planets around other sun-like stars, among other discoveries.

On the Record

"Technology transfer at NASA benefits outside organizations through specific innovations but also through test and measurement capabilities like those offered by the CHARMS facility. These efforts benefit our partners, and the resulting data can provide returns to NASA missions as well." — *Ted Mecum, Technology Transfer Manager, Goddard's Innovative Partnerships Program Office*

"The MOSIFRE Spectrograph is a $13 million project, and a large portion of that goes into salaries. If we had not received the precise data from CHARMS, we would have had to think twice about launching a costly project that might flop. So in that sense, the existence of CHARMS enabled us to produce an effective design and pay the technical people to execute it." — *Dr. Harland Epps, Astronomer, Professor, and Optics Design Consultant, UCO/Lick*

"We're benefiting not only from our own agreement but also from others. We've used data from several other measurements the CHARMS facility has taken in the past, and I anticipate we will benefit from more of the facility's published data in the future. It's a great benefit for everyone in aerospace to have that information made public." — *Dr. Harland Epps*

"There were many details to work out with the agreement, and the people in the IPP Office were effective and took care of these details in a timely manner. It was quite an effective process." — *Dr. Harland Epps*

"CHARMS is a facility that deserves support because of its uniqueness. This facility was built from the ground up specifically for the purpose of doing refractive index measurements accurately. If you're building multi-million dollar instruments, you want to be sure you're operating with the right data. The measurements we're getting would be next to impossible to obtain without the CHARMS facility." — *Dr. Daniel Fabricant, Senior Physicist and Associate Director, Harvard-Smithsonian Center for Astrophysics*

The Transfer Process

Researchers at the University of Oxford and The Aerospace Corporation were well aware of the capabilities of the CHARMS facility, thanks to the networking efforts of Goddard innovators as well as notable mentions of the facility in industry publications and conference proceedings. Through these industry networks, the two organizations contacted Goddard and expressed interest in utilizing the facility. Goddard's Innovative Partnerships Program (IPP) Office administered the agreement, helping to facilitate discussions between NASA and University researchers, and arriving at an arrangement to benefit both organizations.

Researchers at UCO/Lick and the Harvard-Smithsonian Center for Astrophysics learned of the CHARMS capabilities by word of mouth as well as through the facility's published refractive index data. In fact, both group's optics engineers had used published CHARMS data and found it to be very valuable. When the design teams for the MOSFIRE spectrograph and the GMT began looking into their respective instrument's optics properties, they contacted Goddard to set up formal agreements. The IPP Office administered the agreements to enable mission-critical optics designs for both UCO/Lick and HCO.

Looking Ahead

As part of the agreements, Goddard provided the partner organizations with a report of the CHARMS results. The findings also will be published in scientific papers, notably the Proceedings of the Society of Photo-Optical Instrumentation Engineers (SPIE). Follow-on agreements may be considered to conduct further measurements for partner organizations.

For More Information

If you would like additional information about the CHARMS facility, please contact:

Innovative Partnerships Program Office
NASA's Goddard Space Flight Center
techtransfer@gsfc.nasa.gov
http://ipp.gsfc.nasa.gov