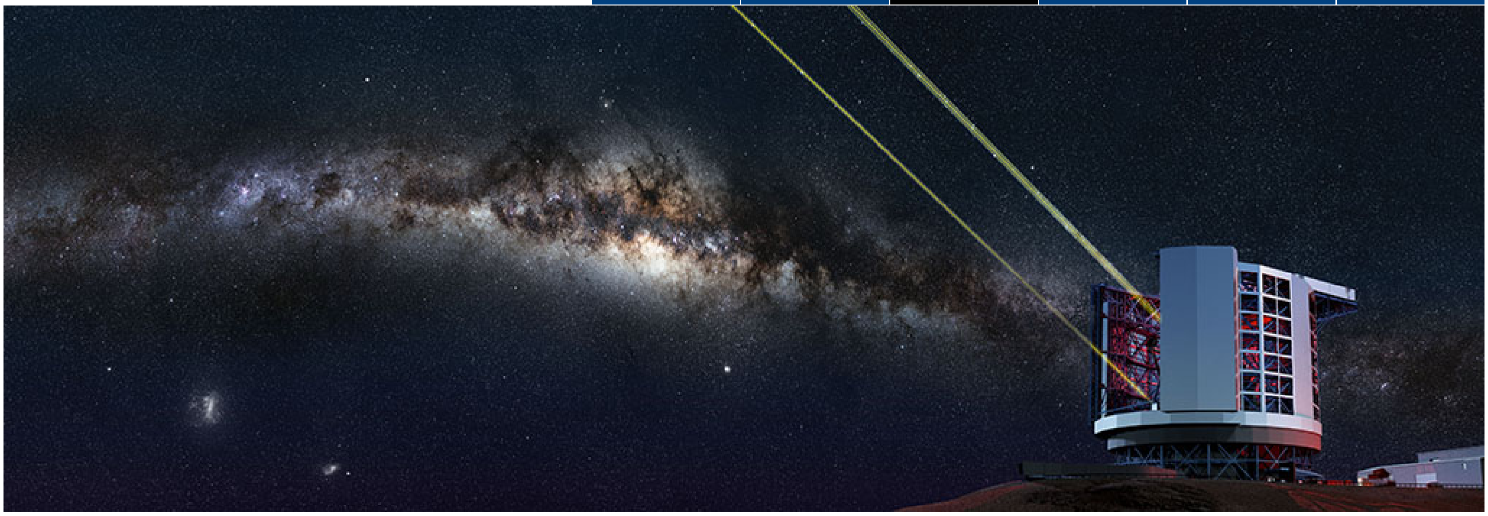

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DECEMBER 2018

POSTED ON DECEMBER 20, 2018

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WELCOME / GMTO'S YEAR IN REVIEW

We have had an exciting and productive year at GMTO. The year got off to a great start with the announcement in January that GMTO had secured the services of an international construction management company, WSP, to manage construction activities on the GMT site.

Then in mid-February, the Richard F. Caris Mirror Lab at the University of Arizona opened the furnace of GMT mirror 5, cast in the previous November, to reveal a perfect mirror blank. Following that, in early April, the mirror was lifted and the clean-out process was started.

In July, Conpax was selected to undertake the hard rock excavation work on the GMT site for the foundations for the telescope's enclosure and concrete pier. As you can read below, excavation is going well and is nearly complete after only five months of work.

In August, GMT's 2018 Science Book, describing the GMT's strengths and its potential for scientific discovery, was released. Then, in September, GMTO held its 6th Annual Community Science Meeting in Hawaii. Both involved scientists from across the U.S. and around the globe.

As 2018 progressed, there was more good news from the Mirror Lab – polishing of segment 2 was progressing fast. It is now only a few nanometers away from its final surface figure specification.

In October, GMTO undertook design reviews with the two telescope mount design vendors. In November, GMTO received their final proposals – a major project milestone. We expect to finalize a contract in early 2019.

In December, the G-CLEF spectrograph, being designed by the Smithsonian Astrophysical Observatory, passed its Critical Design Review, and in Arizona, the prototype mirror cell, under construction at CAID Industries, is rapidly taking shape. Read about both these milestones below.

As you can see, 2018 has been a very productive year for the project. With progress in all areas gaining pace we are excited to see what 2019 will bring.

– Dr. Patrick McCarthy
Vice President, GMTO

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PROGRESS ON SITE: EXCAVATION AND ELECTRICAL UPGRADES

View of site on December 13, 2018. In the foreground the utility tunnel is visible. Connected to the tunnel is the outer grade beam, denoting the edge of the enclosure. The inner excavations are for the telescope pier.

After just a few months of work, hard rock excavation on the GMT site in Chile is now nearly complete. At the time of writing, 4,370 cubic meters of rock had been removed from the summit in 348 dump trucks loads, putting the overall completion at 88%. The rock encountered by the Conpax excavation team was extremely hard, ideal for forming the foundation for a precision telescope.

The remaining work is expected to be completed by the end of January.

Along with the hard rock excavation, the site electrical power system has been upgraded, with a new power transformer being commissioned on the summit in early December. The power system at Support Site 2, where the residences are located, has also been upgraded and can now run completely on backup power when necessary.

The next contract to be let on site will be for installation of the GMT water and utility distribution systems. This contract will involve more total excavation volume than the hard rock package, although most of the material removed will be soil (as opposed to rock). The contract is expected to be let in early January, and the work will take about 8 months. It will involve installing a new water tank and piping throughout the site, including at the support sites.

At the summit, the next stage will be the pouring of concrete. This work is expected to begin in late 2019.

Don't forget, you can see what's happening on the site through our **webcam**.

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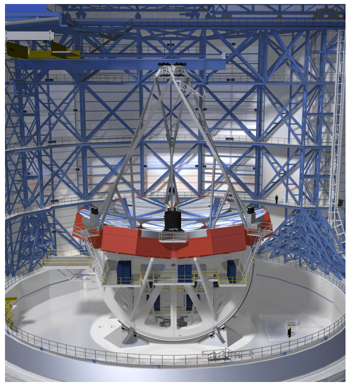
PROTOTYPE MIRROR CELL WELDMENT NEARING COMPLETION AT CAID INDUSTRIES

Barbara Fischer, Primary Mirror (M1) Subsystem Lead, gives us an update on the progress of the GMT prototype mirror cell under construction at **CAID Industries** in Tucson, Arizona.

When the GMT is operational, each of the telescope's seven giant mirrors will live on top of a "mirror cell". These seven mirror cells are part of the telescope mount, the precision machine that will secure all the optics and guide the telescope to look at different parts of the night sky.

The largest component of the individual mirror cells is the "weldment" – the steel enclosure that contains all the different support mechanisms the mirror requires to keep its shape. To verify the design of these support mechanisms, GMTO is creating a prototype mirror cell weldment.

Measuring approximately 8.6 m long, 10 m wide by 1.8 m tall, and weighing in at 22,700 kg (25 tons), the weldment was designed by engineers at GMTO. The contract is being



The GMT – the mirror cells are shown here in red.

led by Zaven Kechichian, GMTO Mechanical Engineering/Designer, and the weldment is being manufactured at CAID Industries in Arizona. Taking a year, production is expected to be complete in the first half of 2019.

The top plate of the weldment will resemble swiss cheese with over 500 holes of various sizes and shapes machined into it. Different kinds of support mechanisms will poke through these holes and attach to the back of a mirror. There will also be approximately 1,800 ventilation holes in the top plate to allow cooling of the back surface and perimeter of the mirror.

Barbara Fischer and Zaven Kechichian inside the test cell weldment at CAID. Image by Damien Jemison.

The top plate of the prototype mirror cell weldment with some holes already machined into it. Image: CAID Industries.

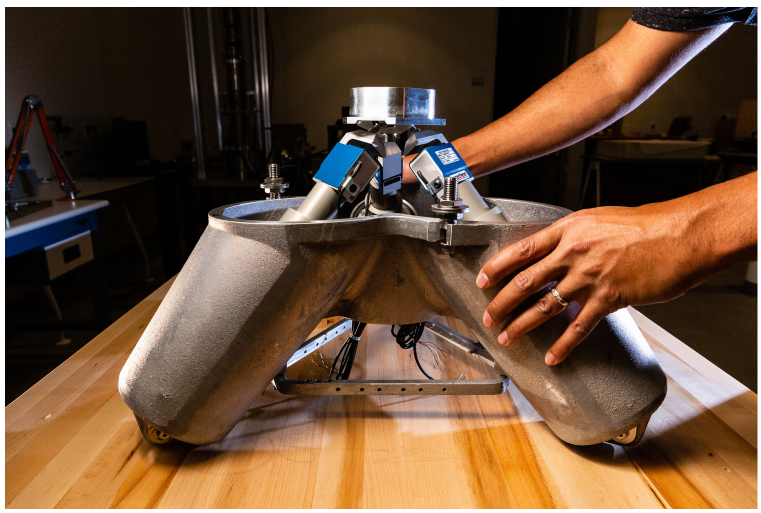
There are three kinds of supports for each mirror – static supports, single-axis and triple-axis force actuators, and positioning struts ("hardpoints"). These different supports will attach to the load spreaders or glass wedges bonded to the back of each mirror.

The static supports are about the size and shape of a coffee mug and are known as "wire baskets". These are what separate the mirror from the top of the cell and support the weight of the mirror while the telescope is offline. They are somewhat flexible (e.g. if you stand on one, it won't deform much); otherwise, they don't move, hence the name "static". Each off-axis mirror will need 332 static supports.

A triple actuator is a three-legged device, the size of a microwave oven, that makes force adjustments to support the weight of the mirror and overcome distortions due to gravity and temperature. The clever design of the triple actuator means that it can do its job in all

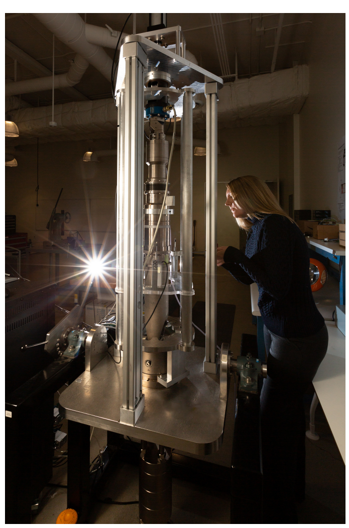
Static support, also known as a wire basket. Image by Damien Jemison.

orientations of the mirror, including when the telescope is pointed low in the sky and the mirrors are near-vertical. Each off-axis mirror will need 90 triple actuators along with another 80 single actuators.



Triple-axis force actuator. Image by Damien Jemison.

The hardpoints, known as hexapods, do the most work. These are long rods – about 4ft tall and three inches in diameter. Their job is to work with all the other hardpoints on all of the other mirrors to position the mirrors so they form a single optical surface. This is critical to achieving the scientific performance of the telescope. Each mirror segment will have 6 hardpoints – matching the number of degrees of freedom.



Barbara Fischer with a hardpoint, shown here mounted in the Hardpoint Test Stand. Image by Damien Jemison.

The purpose of creating the prototype mirror cell is to validate the active optics control system – how all of the above elements will work together – and to verify it is safe to use with one of GMT's precious mirrors. To take the first step, a mirror simulator will be used with the support system. Made of steel, it will simulate the size, center of gravity, and weight of a real mirror.

Validation of the prototype mirror cell is expected to begin in 2020. Once a real mirror is integrated with the prototype cell, it will be put under the Caris Mirror Lab's test tower for further verification.

Construction of a significant piece of steel hardware such as the prototype mirror cell weldment is a motivating milestone for the M1 team. With design and construction of prototypes of the support mechanisms also underway at GMTO, the M1 team expects to be very busy for the next few years.

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PROFILE: DR. DAE WOOK KIM, ASSISTANT PROFESSOR AT THE UNIVERSITY OF ARIZONA

Dr. Dae Wook Kim.

Dr. Dae Wook Kim is an assistant professor of optical sciences and astronomy at the University of Arizona. He received his Ph.D. degree in Optical Sciences from University of Arizona (UA) and bachelor's degree in Astronomy and Physics from Yonsei University. Dr. Kim works on the polishing and testing of GMT's primary mirror segments at the **Richard F. Caris Mirror Lab**. The second GMT segment is nearly complete – its current figure error is 25 nm rms (goal: 20 nm rms) with only the outer 2 cm left to finish.

Below Dr. Kim gives us some insight into his work on the GMT mirrors and his career to date.

Briefly describe your field of engineering.
Optical Engineering is a diverse field with a broad spectrum. I mostly work on research and development of various astronomical optics fabrication and testing technologies. At the other end of the spectrum, I work on designing and prototyping inspection gadgets for semiconductor wafer screening processes and augmented reality devices for human interface applications.

What is your role at the Richard F. Caris Mirror Lab?
As a Faculty member at UA in optical sciences and astronomy, I support the manufacturing process of the 8.4 m primary mirror segments for the Giant Magellan Telescope at the Richard F. Caris Mirror Lab. For the GMT, I develop adaptable fabrication technologies such as a polishing tool which simultaneously utilizes liquid-and-solid materials. I also investigate more accurate and robust measurement concepts in order to test the mirror's optical surface and guide the robotic polishing process.

Why did you want to get involved with working on the GMT mirrors?
The core motivation of the GMT project overlaps with my passion: exploring the cosmos beyond Earth, sharing the discoveries and knowledge with the world, answering some of the most fundamental questions, and serving our next generation through education. Also, as an optical engineer, it is a pleasure to contribute to the most powerful "camera" of my time – from the optical designer's point of view, the modern astronomical observatories are actually giant cameras.

How did you first get into your engineering career? What inspired you to choose this career?
I joined a camping trip to Mt. Graham near Tucson, Arizona in 2005. I was a visiting scholar from an astronomy graduate program in South Korea, and I still clearly remember two things from the trip. First, I was excited about cooking S'mores around the campfire for the first time in my life. Second, late at night, I had an opportunity to tour a nearby observatory under construction. I saw an amazing scientific instrument being assembled. It had two special and unique elements, its 8.4 m diameter mirrors: one mounted on the enormous opto-mechanical structure and another on the floor waiting to be installed. Everyone has their own unforgettable moment and that night was my lifetime bookmark. More than 10 years have passed, and the instrument a.k.a. Large Binocular Telescope is now fully operating, and I am a happy optical engineering scientist. Being there was the very real inspiration.

What has been your career path to date?
I often miss the two years I spent as a chef in the army. I dream of working in a nice kitchen, cooking a good meal, and serving guests. But I always wanted to work with students. Being a 'teacher', connecting my days with students' commitments to learning, their everlasting energies, unbiased potentials, and straightforward curiosities have been the best parts of my simple career. Right after my graduation, I started my career as a research scientist developing large optics fabrication and testing technologies. Years later I became an assistant professor of optical sciences and astronomy. Every day in my career, I read, write, investigate, communicate, study, and teach in my office and classrooms at the University of Arizona.

What has been your most rewarding career accomplishment to date?
I was truly happy when our team finally completed the very first 8.4 m primary mirror segment for the Giant Magellan Telescope. It was, and at the time of writing it still is, the largest and only 8.4 m off-axis optic in human history (until its twin, the second GMT segment, is completed in early 2019). I'm am always thankful to have been a part of such a meaningful mark.

What advice would you give to someone thinking about the same career?
If you think the cosmos and stars are beautiful, if you are curious about principles behind the scenes, if you like to design and build, and if you love to invent, please imagine your career in optical sciences.

Tell us about a non-science related talent that you have.
I love to cook and eat simple and local foods. I wish I could come up with a profound research topic combining astronomy, optics, and food.

What are you most looking forward to once the GMT is completed?
It will be exciting to discover something that we never saw or confirmed before, just like the first detection of gravitational waves in 2016 by LIGO. As a bonus, it will be great to see the iconic giant telescope materialize in front of us.

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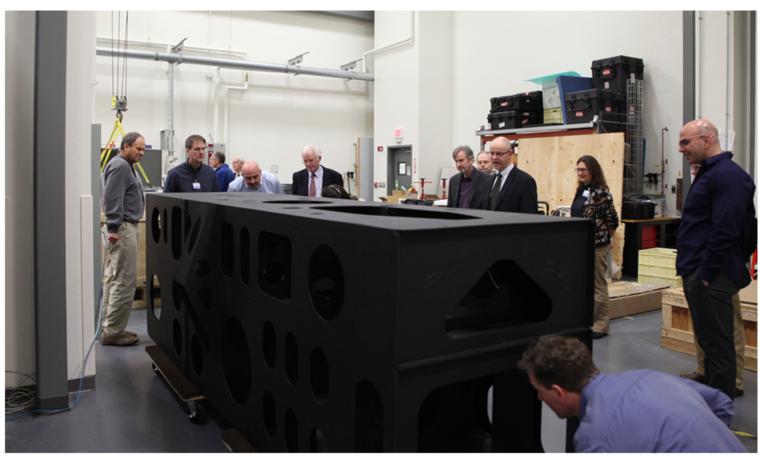
G-CLEF SPECTROGRAPH – CRITICAL DESIGN REVIEW

The **GMT-Consortium Large Earth Finder (G-CLEF)** is an instrument for the GMT being designed by scientists and engineers at the **Smithsonian Astrophysical Observatory** (SAO). G-CLEF is a high resolution, highly stable, fiber-fed visible-light Echelle spectrograph designed for precision radial velocity observations, investigations in stellar astrophysics, and studies of the intergalactic medium. It will be able to detect the motion of stars at the 10 cm/s level – i.e. walking pace – to determine the masses of their planets. It will also look for molecules such as oxygen in the atmospheres of exoplanets. It is expected to be the first science instrument delivered to the GMT.

The heart of G-CLEF is its spectrograph, a high precision, extremely stable optical device that will receive light from the GMT and turn it into scientific data. In early December, the spectrograph passed its Critical Design Review (CDR) after a meeting at SAO in Cambridge, MA. The review committee comprised seven well-respected experts from the US and Europe and was chaired by Dr. Ian Bryson (UK Astronomy Technology Centre, Royal Observatory). The committee heard presentations on topics such as requirements, design, compliance, safety, and budget/schedule.

In passing the spectrograph through its CDR, Dr. Bryson said, “The spectrograph design is excellent; the spectrograph will do you good science.” The final report from the committee is expected in January.

The next major reviews for G-CLEF are the software preliminary design review in late 2019 and the front-end instrument critical design review in early 2020.



Members of the review committee and guests inspect a full-scale model of the G-CLEF optical bench in the Smithsonian Astrophysical Observatory Lab in Cambridge, MA. Image credit: Joe Zajac.

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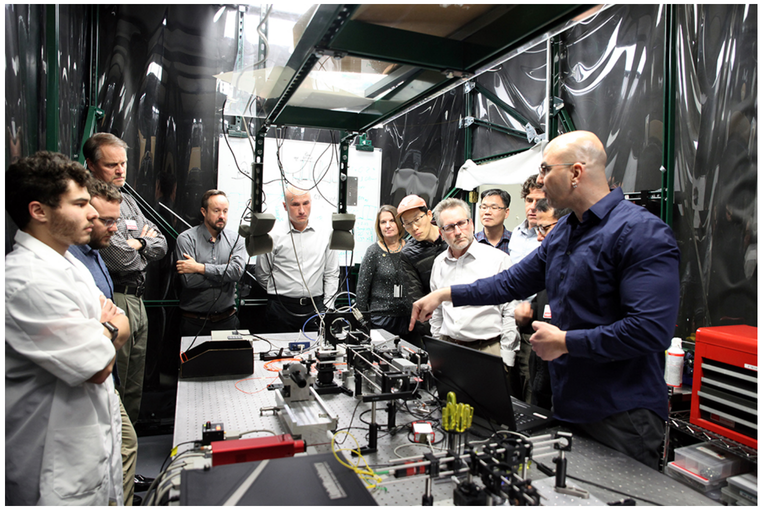
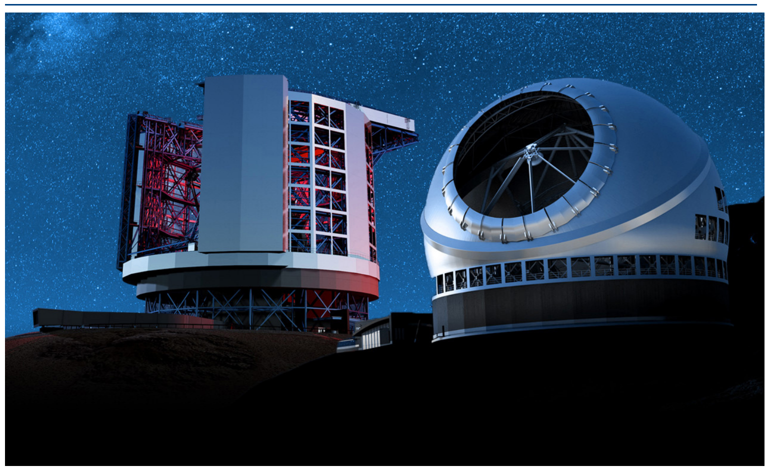


G-CLEF instrument scientist Sagi Ben-Ami shows the review committee and GMTO attendees a G-CLEF component prototype in SAO's lab facilities. Image credit: Joe Zajac.

The review committee and guests. G-CLEF Principal Investigator, Andrew Szentgyorgyi and G-CLEF Project Manager, Stuart McMuldroch are holding a model of the G-CLEF vacuum chamber. Image credit: Joe Zajac.

U.S. EXTREMELY LARGE TELESCOPE PROGRAM UPDATES



The National Science Foundation's National Optical Astronomy Observatory (NOAO), the Giant Magellan Telescope (GMT), and the Thirty Meter Telescope (TMT) are working collaboratively to develop a **U.S. Extremely Large Telescope (U.S. ELT) Program**.

The mission of the U.S. ELT Program is to strengthen scientific leadership by the U.S. community-at-large through access to extremely large telescopes in the Northern and Southern Hemispheres. This two-hemisphere system will provide the U.S. scientific community with greater and more diverse research opportunities than can be achieved with a single telescope, and hence more opportunities for leadership.

Key Science Program Meeting
The near-term goal of the U.S. ELT Program is to work with the U.S. research community to develop exemplar Key Science Programs (KSPs) within major research areas.

In November, NOAO hosted a meeting in Tucson, AZ for those participating in developing the KSPs. Dr. Rebecca Bernstein, GMT's Project Scientist, attended, and GMT instruments teams were represented.

KSP meeting – Tucson. Image credit: Michael Bolte.

American Astronomical Society Meeting
GMTO will be at the **233rd American Astronomical Society meeting** in January in Seattle. Here are the events we will be participating in.

The U.S. Extremely Large Telescope Program
Monday, January 7, 9:30am-11:30am in Room 4C-4
This session will feature presentations describing the objectives and structure of the U.S. ELT Program, as well as information about the TMT and GMT projects. There will be extensive discussion of Key Science Program (KSP) concepts that are being developed by community-based teams as a core component of the U.S. ELT Program. KSPs will address questions of fundamental scientific importance that require tens to hundreds of GMT and TMT nights and will follow open collaboration models that encourage broad, diverse participation by scientists throughout the U.S. research community. The session will include opportunities for audience discussion.

U.S. ELT Program: GMT & TMT Open House
Monday, January 7, 7:30pm-9:00pm in Room 4C-2
At this Open House, leadership of the two projects will present brief status updates. Open discussion will follow, and all members of the community are encouraged to participate. There will also be an opportunity for attendees to meet socially with key organizational, technical and scientific leadership of both TMT, GMT, and NOAO. Complimentary snacks and refreshments will be provided.

2018 GMT Science Book
The 2018 GMT Science Book is **now available for download** from our website. The book is divided into chapters describing the transformative impact that GMT will have on areas spanning observational astrophysics—from exoplanets around neighboring stars to the formation of the first, most distant stars, galaxies, and black holes in the universe. While we cannot predict all that GMT will do, this book represents a sample of the most interesting and transformative science that our community is planning to do with GMT.

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DR. MIGUEL ROTH RECEIVES ORDER OF BERNARDO O'HIGGINS

GMTO is delighted to announce that the Chilean Foreign Affairs Ministry has awarded the Order of Bernardo O'Higgins to Dr. Miguel Roth Fuchs, the Giant Magellan Telescope (GMTO) Representative in Chile, at a ceremony in Santiago.

The Order of Bernardo O'Higgins is the highest civilian honor awarded to non-Chilean citizens. This award was established in 1956 and is named after one of the founders of the Chilean Republic, General Bernardo O'Higgins. Dr. Roth received the award in recognition of his contribution to the development of astronomy in Chile, and for inspiring appreciation and knowledge of astronomy among students and people of all ages.

Read more in our **announcement**.

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Dr. Miguel Roth.