LASP SPACE
Laboratory for Atmospheric and Space Physics
University of Colorado **Boulder**
Issue 15 • July 2021

Features: **The knowledge partnership • Defining a mission in only 100 days • EMM drives advancements • The science of Hope**

Special Issue: The Emirates Mars Mission

LASP partnered with the UAE's Mohammed bin Rashid Space Centre (MBRSC) in 2014 to develop the Emirates Mars Mission (EMM). The Lab collaborated with Emirati managers, engineers, scientists, and mission operators to develop, build, and operate the mission's Hope spacecraft. LASP, with MBRSC, Arizona State University, and the Space Sciences Lab at UC Berkeley, developed and built its three scientific instruments: Emirates Mars Ultraviolet Spectrograph (EMUS), Emirates eXploration Imager (EXI), and Emirates Mars InfraRed Spectrometer (EMIRS). EMM launched from Japan on July 19, 2020 and went into orbit around Mars on February 9, 2021.

Courtesy Emirates Mars Mission

Letter from the director

Dan Baker

Before the COVID-19 pandemic, few might have imagined that the third World War would be waged against a microscopic foe. While humans found a shared imperative in this fight, another unifying, and much more positive, scientific target emerged: Mars.

On July 19, 2020, the UAE, along with LASP and other partners, launched a remarkable spacecraft toward Mars. The Hope Probe went into orbit around the Red Planet on February 9, 2021 in

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IN FOCUS

EMM: The knowledge partnership

Mike McGrath

When a team from Dubai approached LASP in 2014 and asked, "Do you have ideas for a mission to Mars?," the Lab enthusiastically responded with a proposal. What evolved was more than LASP imagined: a knowledge partnership with the UAE to facilitate the sharing of technical and scientific information that allowed us to co-design and launch a mission to Mars.

I was asked recently, "How was the overall experience?" and responded with many positive emotions. EMM proved to be much more than two partners, working side-by-side, to develop a spacecraft and suite of instruments to go to another planet. With more than 450 international team members, we learned that culture matters. Language matters. Personal and professional motivations matter.

The mission provided a view of a country growing its capabilities on the edge of what's possible. It revealed a non-media view of an Islamic culture that was

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Letter from the director, continued

time to celebrate the UAE's founding 50 years ago, and was soon joined by NASA's Perseverance Rover and China's Tianwen-1 missions.

Along with its innovative payload, the Hope Probe carries with it the aspirations of a new generation of young Arabs who see in the mission the hope for a better and more peaceful future, not only for the UAE, but for the entire Middle East.

The exploration of space is a shared dream. Citizens from many countries cheer this multinational advance toward furthering our understanding of Mars and hope the coordinated exploration of another planet will inspire an era of peaceful cooperation on our home planet as well.

Mike McGrath visiting the Emirates Institution for Advanced Science and Technology (EIAST) in Dubai to discuss the EMM status in July 2014. Left to right: Ibrahim Al Qasim, Mike McGrath, Omran Sharaf, Suhail al Dhafri. *(Courtesy EIAST)*

enlightening. The Emiratis delighted us with their care and generosity. EMM brought new experiences for both cultures, from partnering with universities and other governments to enjoying new food, activities, and friendships—all during the challenges of a global pandemic. The knowledge partnership prospered well beyond anything LASP had envisioned.

So how was it? For many at LASP, it was a once-in-a-lifetime experience. For hundreds of Emiratis, it was the attainment of tacit knowledge of deep-space mission development and its challenges, and also the exquisite feeling of success—all while inspiring Emirati youth to reach for the impossible. *For me...it was wonderful!*

Mike McGrath is a senior advisor to LASP and EMM.

Defining a planetary mission in only 100 days

Pete Withnell

Of the roughly 6,000 spacecraft currently in operation, only 250 were sent beyond Earth's orbit into the solar system. Defining a planetary mission is rare, so it typically takes a year or more for the vision to evolve into reality. The EMM program was defined, start to finish, in only 100 days. In that time, an international team was formed to establish the mission's scientific goals, determine the orbit plan, set achievable engineering requirements, assess

Co-designing and launching the Hope Probe forged a unique knowledge partnership. Group photo of the original EMM team members from the US and UAE after the critical design review in Dubai, UAE in 2017. *(Courtesy MBRSC)*

LASP's funded missions

In development
- DALI/EDA
- ESCAPE SMEX
- Libera EVC-1
- Solaris MIDEX
- IMAP IDEX
- LSITP/L-CIRiS and LuSEE
- CANVAS CubeSat
- VISORS NSF CubeSat

Design and fabrication
- CLARREO Pathfinder
- INSPIRESat-4
- IXPE SMEX
- TSIS-2
- SPRITE CubeSat
- AEPEX CubeSat

Assembly and environmental testing
- Europa Clipper/SUDA
- GOES-T/EXIS, GOES-U/EXIS
- INSPIRESat-1/DAXSS
- CIRBE CubeSat
- CTIM CubeSat
- CUTE CubeSat

In orbit—prime mission
- EMM
- TSIS-1
- Parker Solar Probe
- GOES-16/EXIS
- GOES-17/EXIS
- CSIM CubeSat

In orbit—extended mission
- GOLD
- AIM
- MMS
- SDO/EVE
- THEMIS and ARTEMIS
- TIMED/SEE
- New Horizons/SDC
- MAVEN

For more information on current missions, as well as full instrument and mission names, visit http://lasp.colorado.edu.

technology needs, and make build/buy decisions that ultimately set the mission's schedule and funding.

The mission was inherently ambitious. But the technology to achieve the objectives was readily available, so every effort was made to design the spacecraft using commercially available, high-heritage components. To hit the ground running, a team with decades of experience in interplanetary spacecraft engineering was hired. The outcome of those early, extraordinary efforts held together for all seven years of development and operations, meeting EMM's objectives on time and within budget. The tight timeline forced us to be innovative, but the mission's overall success suggested an intriguing thought: that the rapid-definition approach is not only achievable, but also advantageous.

Pete Withnell is the LASP program manager for EMM.

EMM drives LASP technical advancements

Nic Ferrington

EMM engineers prepare the Hope Probe for environmental testing in LASP's new thermal vacuum chamber. *(Courtesy Emirates Mars Mission)*

EMM's ambitious and unique mission requirements gave rise to numerous advancements at LASP.

The Lab's novel partnership with the UAE meant team members were distributed across the globe. This situation necessitated improvements to program management and systems-engineering processes to accommodate Discovery-class mission development with our international partners. LASP gained expertise by designing the Astrolabe bus for deep-space, interplanetary travel. The new bus includes high-accuracy pointing, increased data volume accommodation, and autonomous operations.

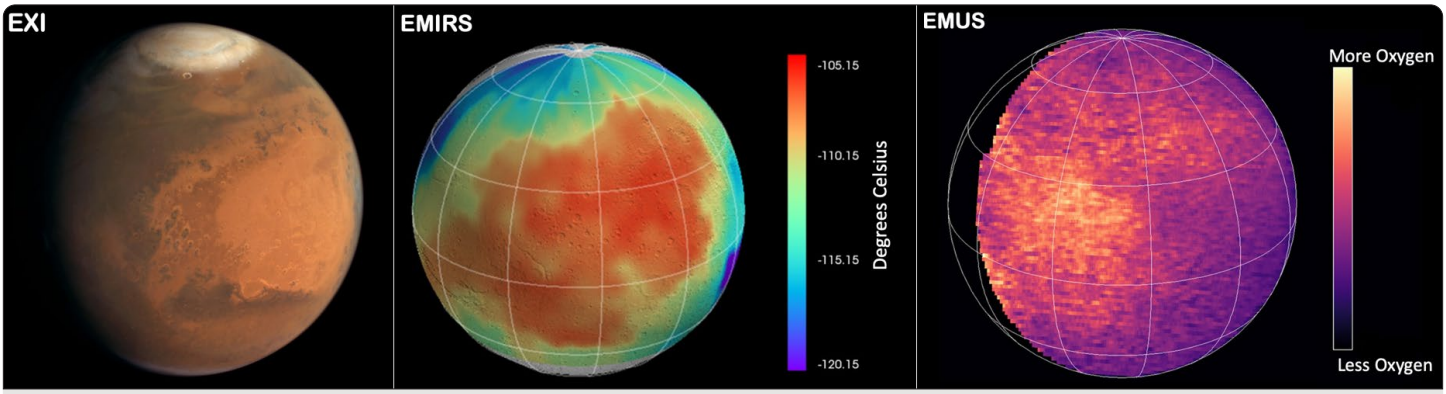
EMM was the second mission to make use of LASP's new class 10,000 high-bay cleanroom and recently updated vacuum chamber, which allowed program engineers to conduct on-site thermal, shock, and acoustic testing for this SUV-sized spacecraft. In addition, organizing the transportation of Hope to Japan, coordinating with a new launch-vehicle provider, and navigating Japan's launch-site procedures took LASP's international relations proficiency to the next level. The Lab also enhanced its mission operations capabilities to coordinate between operations centers on opposite sides of the Earth, in Colorado and the UAE.

LASP's technical advances were many throughout the EMM mission, but the partnership with the UAE team was the most rewarding of all.

Nic Ferrington is the head of LASP's Systems Engineering Department and the EMM mission systems engineer.

The science of Hope

Justin Deighan



All three instruments simultaneously observed the Terra Arabia region of the planet on the morning of May 24, 2021. The EXI image shows the bright dust on the surface. EMIRS mapped the temperature of the atmosphere, tracking how it warmed up over the morning. EMUS mapped the distribution of atomic oxygen in the planet's atmosphere, showing a dense patch emerging from the nightside into the day. *(Courtesy Emirates Mars Mission)*

The scientific goals of Hope are to provide a complete picture of the lower and upper Martian atmosphere and how they are connected. Unique to the mission is its large orbit, which provides a weather satellite-style view of the Martian atmosphere, enabling observations of nearly every location on the planet at all times of day, every nine days.

To achieve these goals, Hope carries three scientific instruments: EXI obtains images of the ozone column, dust, and water ice; EMIRS measures temperature, water vapor, dust, and water ice in the lower atmosphere; and EMUS measures the global characteristics and variability of hydrogen and oxygen in the upper atmosphere to understand atmospheric escape. The international, multi-disciplinary science team synthesizes these observations to understand the holistic behavior of the Martian atmosphere and reconstruct how the planet evolved from having widespread liquid surface water early in its history to being the dry, cold desert that exists today.

Justin Deighan is a LASP research scientist and the EMM deputy science lead.

The students of EMM

Heather Reed

LASP has a long history of training the next generation of space professionals in all aspects of space exploration. The EMM international collaboration afforded a unique component to the learning experience for the students who supported the mission. Emirati Noora Alsaeed came to LASP under the MBRSC Research for Undergraduate (REU) program and is now a PhD candidate at CU with a research focus on Mars.

In addition, five early-career UAE engineers received their Master of Science degrees in aerospace engineering while supporting the mission, including Mohsen Al Awadhi, who is now the primary mission systems engineer for Hope. Jack Mayden, an American student, supported the mission as an entry-level systems engineer and was recently hired by the Jet Propulsion Laboratory after graduation.

Noora Alsaeed

Heather Reed is a LASP engineering program manager and the EMM instrument payload manager.

LASP INNER SPACE

LASP mission & technical stats

- LASP operates 3 satellites.
- LASP operates 142 instruments on 20 spacecraft.

LASP staff stats

(April 22, 2021)

Scientific researchers	85
Tenure-track faculty	26
Visiting faculty	3
Professionals	364
Graduate students	47
Undergraduate students	114
Total	**639**
Affiliates	193
Open positions	14

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Achievement awards

The 2020 recipients of the Charles A. Barth Scholarship for CU undergraduates in space research were Ethan Ayari, Benjamin Johnston, and Madison Ace Stratton. Recipients of the John T. Gosling Endowed Fellowship for CU graduate students in solar-terrestrial physics were Andrea Hughes, Ann Marie Mahon, and Ben Hogan. These LASP scholarships were awarded in fall 2020.

Cora Randall, LASP scientist and professor in the Atmospheric and Oceanic Studies Department, was named one of 12 Distinguished CU Professors for 2020. This is the highest honor awarded to faculty and recognizes those who "demonstrate exemplary performance in research or creative work, a record of excellence in classroom teaching and supervision of individual learning, and outstanding service to the profession, the university and its affiliates".

Fran Bagenal, LASP's assistant director of the Department of Planetary Science, was elected to the 2021 class of the National Academy of Sciences. This high and rare honor is bestowed to scientists worldwide in recognition of their distinguished and continuing achievements in original research. Bagenal joins a class of 120 elected members—59 of whom are women, the most elected in a single year.

LASP solar and stellar researcher Dmitry Vorobiev was named a 2020 NASA Nancy Grace Roman Technology Fellow for Early Career Researchers. This prestigious research grant recognizes those with innovative ideas to advance astrophysics flight programs and technology and includes start-up funding for lab development and idea incubation.

Distinguished visitors

LASP Director Dan Baker hosted several special guests virtually in his space policy class this spring at CU Boulder. Thomas Zurbuchen, associate administrator of NASA, and NASA senior policy analyst Laura Delgado Lopez spoke to the students. They discussed organization and management changes within NASA's Science Mission Directorate as well as broad policy issues confronting the agency today.

U.S. Congressman Ed Perlmutter also visited to discuss his roles in Congress, including serving as a member of the House Science Committee. He and Jeff O'Neil, the Congressman's Deputy Chief of Staff for Policy, talked about how their office approaches policy issues, gathers feedback, and pursues legislation, and highlighted the recent PROSWIFT Act for space weather, which Rep. Perlmutter sponsored. President Trump signed this act into law in October 2020.