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'From Early Earth to Mars' Biosphere 2 Digital Twinning Project Awarded Big Idea Challenge Grant

Today

By Laine Kowalski, The University of Arizona Office of Research and Partnerships

At Biosphere 2, the "From Early Earth to Mars" Big Idea Challenge winning project unites experts across five disciplines, including information science, to explore and predict how life can inhabit and transform planets.



Scott Saleska, director of the LEO Survey and lead of the BIC "From Early Earth to Mars" project, inspects the living crust atop one of the LEO hillslopes at Biosphere 2.

Photo by Kris Hanning, Office of Research and Partnerships.

The University of Arizona's [Biosphere 2](https://biosphere2.org/) (<https://biosphere2.org/>) has long captured the public's imagination as a site where researchers can study physical systems at scale. It is also a powerful, 21st-century testbed for planetary futures, where scientists can engage with some of the most profound questions of our time: How does life transform a planet? How can we restore what has been damaged on Earth? And what will it take to build a habitable future on Earth and on new worlds? These questions are at the forefront of a new era of terraformation science.

"'Terraformation' had its origins in the mid-1900s in both science and science fiction, with the word deriving from Terra, the Roman goddess of Earth, capturing the idea that whole planets could be transformed to become Earth-like and livable for humans, plants and animals," said [Scott Saleska](https://eeb.arizona.edu/person/scott-saleska) (<https://eeb.arizona.edu/person/scott-saleska>), professor of ecology and evolutionary biology in the U of A [College of Science](https://science.arizona.edu) (<https://science.arizona.edu>). "When we say 'landscape terraformation,' though, we mean to make it into a practical science by emphasizing that much of planetary terraformation actually starts at landscape scales or smaller, scales at which we can conduct experiments here on Earth today."

Saleska is leading a new project, “From Early Earth to Mars: Advancing an Integrated 'Landscape Terraformation Science' of How Life Transforms Planets with a Multi-scale Collaboratory Digital Twinning of Biosphere 2.” It is [one of six projects selected \(https://news.arizona.edu/news/six-teams-selected-awardees-inaugural-university-arizona-big-idea-challenge\)](https://news.arizona.edu/news/six-teams-selected-awardees-inaugural-university-arizona-big-idea-challenge) as winners of the inaugural Big Idea Challenge.



An outside view of the LEO Survey's three experimental hillslopes at Biosphere 2.

Photo by Kris Hanning, Office of Research and Partnerships.

The team’s big idea, in the broadest terms, is making Mars habitable while keeping Earth livable, by aiming to understand and predict how life can transform barren landscapes into habitable environments through landscape terraformation. The project will advance the capacity to terraform other planets and will be relevant here on Earth, by informing international policies and pressing environmental challenges such as restoring degraded landscapes and solving climate change.

“The Big Idea Challenge was created to spark transdisciplinary collaborations capable of tackling questions that cannot be solved by individual or small teams alone and sparking new frontiers of research at the university with high potential for future extramural funding,” said **Tomás Díaz de la Rubia**, senior vice president for research and partnerships at the University of Arizona. “The ‘From Early Earth to Mars’ team embodies the

spirit of convergent research by bringing together experts across natural science fields, including ecology, microbiology, hydrology and geochemistry, as well as humanities. Combining these fields all together with artificial intelligence will enable us to explore how life, technology and environment intertwine to transform the future of planetary science.”

Key project leaders include Scott Saleska (Department Ecology and Evolutionary Biology), **Jennifer L. Croissant** (<https://sociology.arizona.edu/person/jennifer-croissant>) (School of Sociology), **Cristian Román** ([/person/cristian-roman](https://person/cristian-roman)) (College of Information Science), **Solange Duhamel** (<https://mcb.arizona.edu/person/solange-duhamel>) (Department of Molecular and Cellular Biology) and **Ken McAllister** (<https://pah.arizona.edu/people/mesmer>) (College of Humanities).

At the core of the project is the **Landscape Evolution Observatory (LEO)** (<https://biosphere2.org/research/research-initiatives/landscape-evolution-observatory-leo>), a trio of massive experimental hillslopes inside Biosphere 2 that together constitute the world’s largest laboratory experiment in the interdisciplinary earth sciences.

LEO allows researchers to monitor how bare rock gradually evolves into biologically active terrain in real time. Each hillslope is wired and plumbed with more than 1,800 sensors and samplers and is built from one million pounds of crushed basalt rock extracted from a volcanic crater in northern Arizona.

Saleska has led LEO for several years, observing how water flow and climate conditions impact biological growth on the three hillslopes. The crushed basalt sits in three 30 meter-length trays, angled at about 10 degrees in a climate-controlled environment. Water is delivered to the slopes as rain and is then filtered and processed within the soil of LEO. There, it catalyzes both soil-forming chemical reactions and the growth of early forms of microbial and plant life.



Moss, plants and microbial growth on top of the basalt hillslopes demonstrate preliminary landscape terraformation.

Photo by Kris Hanning, Office of Research and Partnerships.

Since construction began about a decade ago, LEO has already revealed how life “finds a way,” according to Saleska. Cyanobacterial crusts, or microscopic photosynthetic organisms capable of fixing nitrogen, have spontaneously colonized the basalt, paving the way for mosses that seasonally blanket the slopes. This living crust demonstrates, in miniature, the same planetary-scale transformation that early Earth experienced when ancient cyanobacteria evolved to oxygenate the planet’s atmosphere billions of years ago.

The next stage for LEO is to introduce species of nitrogen-fixing vascular plants with roots and hydraulic systems that move water from soil to leaves—processes critical for fully developed ecosystems.

This experimental system provides the physical foundation for the Big Idea Challenge team to develop a digital twin of LEO—a dynamic, AI-powered computational model that mirrors LEO’s evolving landscapes.

As data streams in from LEO’s sensor networks, the digital twin will update simultaneously, enabling researchers to model virtual scenarios and run hypothetical experiments. These simulations will help predict how microbial

communities, plants and water flows interact to create fertile soil, manage carbon and sustain ecosystems on Earth and other planets over time.

“Creating a digital twin is the key for translating everything we learn in the experimental system of LEO to the real world,” Saleska said. “That is our goal, to create virtual representations of how we think the real world will respond to changes or interventions, so that we can better predict real risks and outcomes.”

Insights from LEO could inform efforts to rehabilitate mining sites, restore landscapes after wildfires and even improve agricultural sustainability.

The team also plans to create small-scale versions of LEO, or mini LEOs, that will simulate Mars’ atmospheric and soil conditions. The objective is for LEO’s digital twin to eventually encompass a Mars-like environment, as well, enabling experiments that assess risks and evaluate strategies for designing sustainable life-support systems to colonize and terraform other planets. By modeling how soil, microbes and ecosystems develop from scratch, scientists could better anticipate the challenges of building habitable landscapes on Mars.

One key experiment the team is proposing will tackle what Saleska calls “The Matt Damon Problem.” In the movie “The Martian,” the actor plays a stranded astronaut who grows potatoes on Mars to survive. In reality, Martian soils contain toxic perchlorates that would kill Earth plants. The team plans to test whether a combination of water and perchlorate-reducing bacteria—also found in the Atacama Desert in northern Chile—can detoxify Mars-like soil inside the mini-LEO chambers that experimentally simulate the Red Planet’s environment.

Moreover, the project would help inform international policies and treaties around planetary protection. By studying terraformation in controlled environments and in virtual analog worlds, researchers can explore the promise and risks of engineering ecosystems at planetary scales, informing global terraforming standards and regulations for Earth and for future colonies on potential new worlds.

Ultimately, “From Early Earth to Mars” is more than just a single study.

“The entire project is really a \$100 million idea,” Saleska said. “We’re utilizing the Big Idea Challenge proposal to get the seeds of this vision firmly planted so that we are able to acquire those larger amounts of funds further down

the line to make it all possible.”

Big Idea Challenge

The Big Idea Challenge is administered by the [U of A Office of Research Partnerships](https://research.arizona.edu/) (<https://research.arizona.edu/>) with support from the [U of A Research Development Services](https://research.arizona.edu/development) (<https://research.arizona.edu/development>) and Lewis-Burke Associates. After a competitive pitch event, six teams were selected to receive \$250,000 over two years and strategic guidance to support transformative research that seeks novel solutions to grand challenges. The winning teams are pursuing research in the strategic areas of data, information systems and artificial intelligence; defense and national security; energy and environmental sustainability; the future of health and biomedical sciences; the human experience; and space sciences.

Experts

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