AURORA

Mapping for Mars rovers: Former UAF grad student has an out-of-this-world job

By Rod Boyce

Fred Calef stands in front of the high bay at the Spacecraft Assembly Facility, with a view into the clean room with the Perseverance rover (upside down) in the background. Photos courtesy of Fred Calef and NASA.

Like thousands of people nowadays, Fred Calef ’10 has been working remotely. Nothing can stop the making of Mars maps, especially when there’s a newly arrived NASA rover on the surface needing directions.

“It wasn’t unusual for me to be making maps for the rovers from my local coffee shop,” Calef said two days before NASA's latest rover was to arrive on Mars. “Why make the hour drive into Pasadena when I can get the work done now? We’ve certainly trained and planned for working remotely. Since the rover lives on Mars, we’re used to working on other planets’ time periods, so we’ll be great when the rover lands.”

Calef, a former graduate student of the University of Alaska Fairbanks, is the lead map person on NASA’s Perseverance rover mission. He works for NASA’s Jet Propulsion Laboratory in Southern California.

Being a mapmaker means he’s part of a small team that uses data from the Perseverance rover to create a map of where it’s been and, when requested by the rover’s science team, where it’s going on its search for signs of ancient microbial life on Mars. Mapmaking was also key for getting the rover safely over to the Martian “airfield,” where it successfully unloaded the small Ingenuity helicopter for the historic first controlled flight on another planet.

“We do make maps of where the rover is after every drive. In fact, it’s our job to localize where the rover is every time it moves,” Calef said by email March 3, just under two weeks after Perseverance landed on Mars.

Tracks reveal the route of the Perseverance's first drive on the surface of Mars.

"Now, the rover does give us a hint by saying how far it thinks it drove (how many times the wheels turned) and in what direction. When it stops driving, it takes pictures that we use to figure out where we are. So, we make maps of where the rover is in addition to maps showing where science was done (i.e., what rock did we take a picture of, which rock we zapped with our laser, etc.)."

Calef and the two map team members he works with also add data to a web-based mapping tool — "kind of like Google Maps," he wrote —that lets science team members

make their own maps and highlight areas where they think the rover should go next.

“We also make maps on request from science team members or make new map layers to support the rover drivers to find the safest places to drive,” he wrote.

Calef and his team don’t just serve the needs of the Perseverance science team. They also make maps for the public and for science publications. They have created an online map through which anyone can track the rover’s explorations.

Always the scientist

Calef is a California native but attended high school in Massachusetts — Quincy High School, known as “Home of the Presidents.” He obtained a bachelor’s degree in Earth science from the University of Massachusetts Boston and a master’s in geological sciences from Ohio University. He came to UAF and earned his doctorate in 2010.

What got him interested in space and science? His grandfather.

“My grandfather was a big influence growing up. He would take me into the woods and pick up a rock and describe how it was formed and what the Earth looked like when it was around,” Calef writes on a biography page on the website of NASA’s Mars Exploration Program. “The ability to learn something new from observation made science something I wanted to pursue.

“For space, I love that every day we see a new view never seen by anyone ever before! That exploration spirit drove me to search the solar system and Mars in particular for what mysteries it contains.”

Calef knew at a young age that he wanted to be a scientist. It just wasn’t clear what type of science he would be studying, he wrote in answer to a question on the NASA webpage that asked, “When you were in elementary school, what did you want to be when you grew up?”

> *“The ability to learn something new from observation made science something I wanted to pursue.”*

“A scientist! Though I didn’t quite know what kind of scientist,” he wrote. “My interests ranged from paleontology (who doesn’t love dinosaurs!) to primates to

lasers (the first book I remember getting from the library in 2nd grade was on lasers and masers).”

Photo caption: Calef visits the Mars yard at the Jet Propulsion Laboratory.

Looking back, he sees the roadmap that led to his work at the Jet Propulsion Laboratory. And he sees something in common among the various places he has worked along the way.

“My work background has been diverse, from state transportation planning, local government support, digitizing voting precincts, studying acid mine drainage, evaluating coal resources, and environmental remediation,” he wrote on the NASA website. “The thread tying it all

together was mapping. That one technical skill was honed in all those jobs, which I now apply to Mars exploration."

What about non-science and non-work? The NASA website asked him to share any hobbies.

"I really like martial arts (aikido) and writing poetry," he wrote. "Both allow me to explore something away from the highly technical work I do with something more physical and creative."

An earthbound Martian

Mars is getting to be like an old friend for the mapping specialist, who did his doctoral work at UAF's Geophysical Institute.

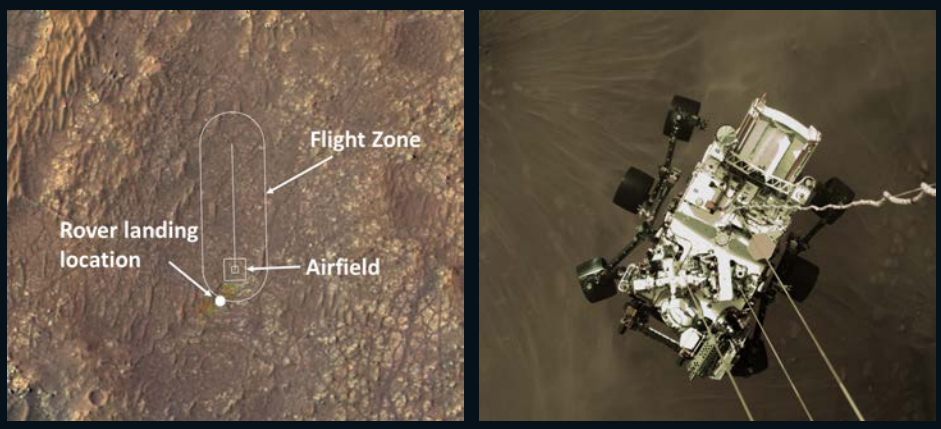
Perseverance's touchdown on Mars was the third Martian landing Calef has supported, the others being the Curiosity rover, which arrived on Mars in August 2012, and the InSight lander, which reached the surface of the planet in November 2018.

He has also been involved with the Opportunity rover, which landed on Mars in January 2004, long before he

joined the Jet Propulsion Laboratory, and continued operating until June 2018.

He was nervous in a telephone interview from his California home 45 hours before Perseverance's scheduled landing.

"You know, it's always good to know that it worked well once," he said.



Left: An image shows the rover landing site and the airfield. Right: Perseverance lands on Mars.

"If you're not nervous, there's something wrong," he said. "But I think a lot of the nerves now are making sure that I can deliver to the science team and engineers the maps that they need and less about the landing. It definitely is nerve-racking, but I'm mostly excited about that."

At UAF, and while working as a graduate student under the guidance of planetary science professor Robert Herrick at the Geophysical Institute, Calef dove into the Martian surface.

With Herrick and the Geophysical Institute's Virgil "Buck" Sharpton as co-authors, Calef wrote a paper titled "Geomorphic analysis of small rayed craters on Mars: Examining primary versus secondary impacts." The paper appeared in the Journal of Geophysical Research in October 2009.

In December 2010 he published his Ph.D. thesis, titled "Investigating the retention of bright and dark ejecta from small rayed craters on Mars."

More Mars research papers followed.

In 2010 Calef landed at NASA's Jet Propulsion Laboratory, heaven for a Mars scientist.

"I was brought here to develop the landing site-based maps that were used to test land the Curiosity rover on — in a computer modeling statistical sense, because the rovers are big and they're expensive and you only get one

chance to land safely on the planet. So I developed those maps."

During that time he also did a little work with the Mars exploration rover Opportunity, helping to take photos from the surface that were then used for driving the rover around. Most of his work, though, remained with preparing Curiosity's landing maps.

About four months out from Perseverance's planned landing, lead project scientist John Grotzinger asked Calef to join the mission as "Keeper of the Maps."

"This is a new position for a person purely dedicated to mapping for the mission, providing base maps and helping locate places where the rover has driven and rocks that we've analyzed," Calef said. "And generally helping the science team get this spatial aspect to the mission. Where are things? Where did we do things and why is this here? How tall is that cliff?"

Working with a subject that is on average 140 million miles from Earth certainly presents numerous challenges. One of them affects the daily schedule of the rover team back here on Earth in a big way.

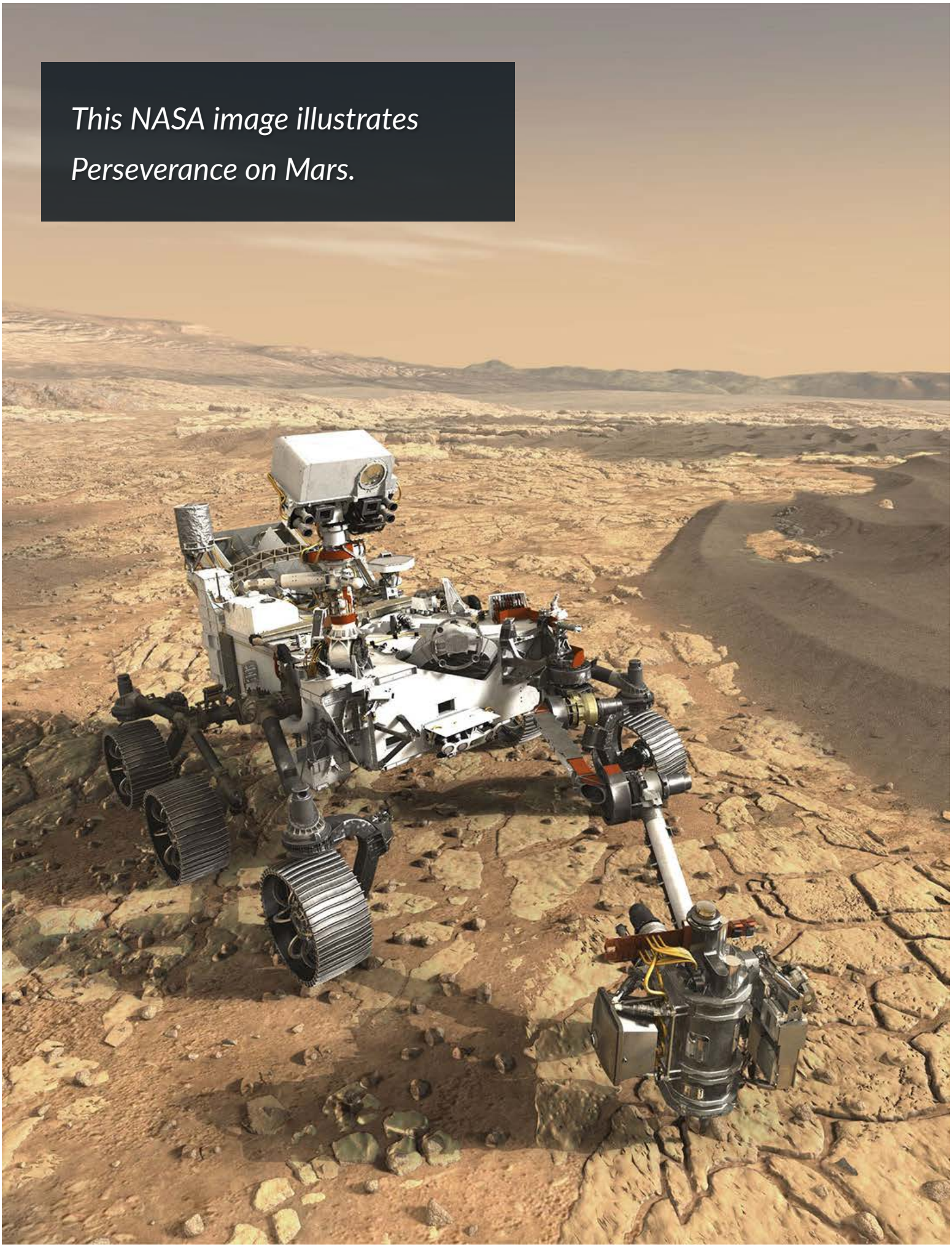
That's because a day on Mars equates to one Earth day plus 37 Earth minutes.

"In general, there's a large team of 100-plus individuals who need to coordinate to make sure the rover is healthy, figure out what science we're going to do for the next day, write the programs to make the rover do what we want it to do, and write documents (and make maps) detailing everything we're doing and want to do," Calef wrote in the March 3 email after the Perseverance landing.

That means meetings. Lots of them.

"Now take all these meetings and rotate them roughly 40 minutes forward every day. I started my 'morning' at 10:30 p.m. today," he wrote. "Tomorrow it will be approximately 11:30 p.m. Then a bit after midnight the next day, etc. This is the notorious 'Mars Time,' which we'll live on for the next 90 days."

"I'm about halfway through my shift tonight," he wrote in the email, which arrived at 1:16 a.m. Alaska time. "Going to go put in some new place names for features around the rover."



This NASA image illustrates Perseverance on Mars.

Why reach for Mars?

Mars is the planet of choice for studying right now. It's the hot item on the planetary menu.

Spacecraft from the U.S., China and the United Arab Emirates all reached Mars in February 2021 in an acceleration of exploration.

So why do we need to study Mars?

Calef lists a couple of reasons, starting with how studying Mars can teach us about Earth.

"One of the big problems, like studying how Earth came to be, is that there aren't many very old rocks like when the Earth was first formed — things that are 2, 2 1/2, 3, 4 billion years old," he said. "A lot of those rocks have been destroyed or become highly reworked (smushed and remelted) on Earth."

Scientists do have ancient rocks to look at, but those don't reveal nearly as much as the researchers would like.

“It’s like trying to read a book that’s gone through the shredder,” he said.

Mars provides the opportunity to look into Earth’s past.

“Because it’s smaller, around 3 billion years ago the planet just cools off faster and then everything kind of stops,” Calef said. “It’s locked into this time period of early Earth 4 to 3 billion years ago, which is also what we know from Earth is the foundation of when life starts to evolve from evidence we find on Earth.

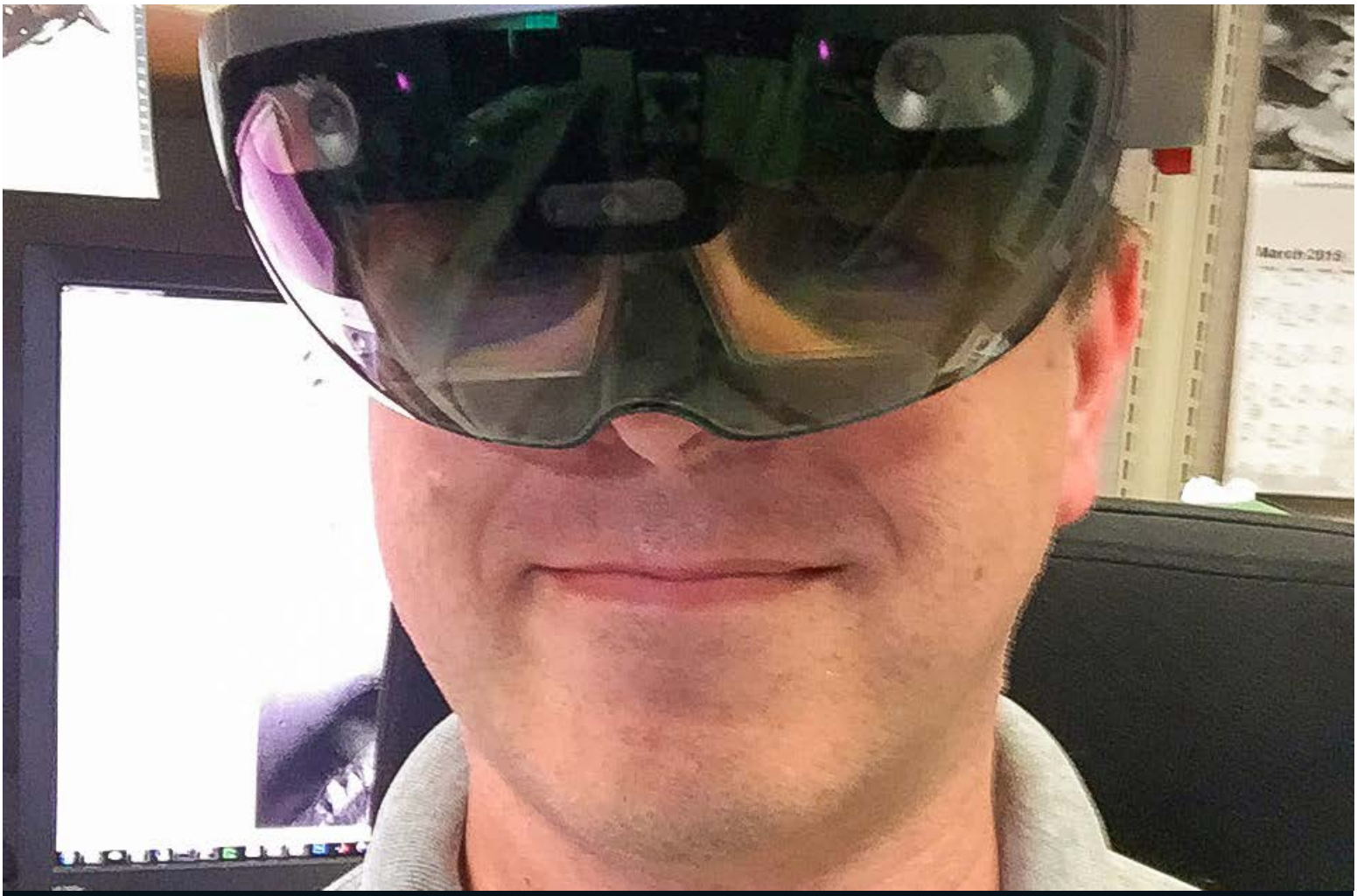


Photo caption: Calef wears a Hololens, which "lets us see Mars in 3D."

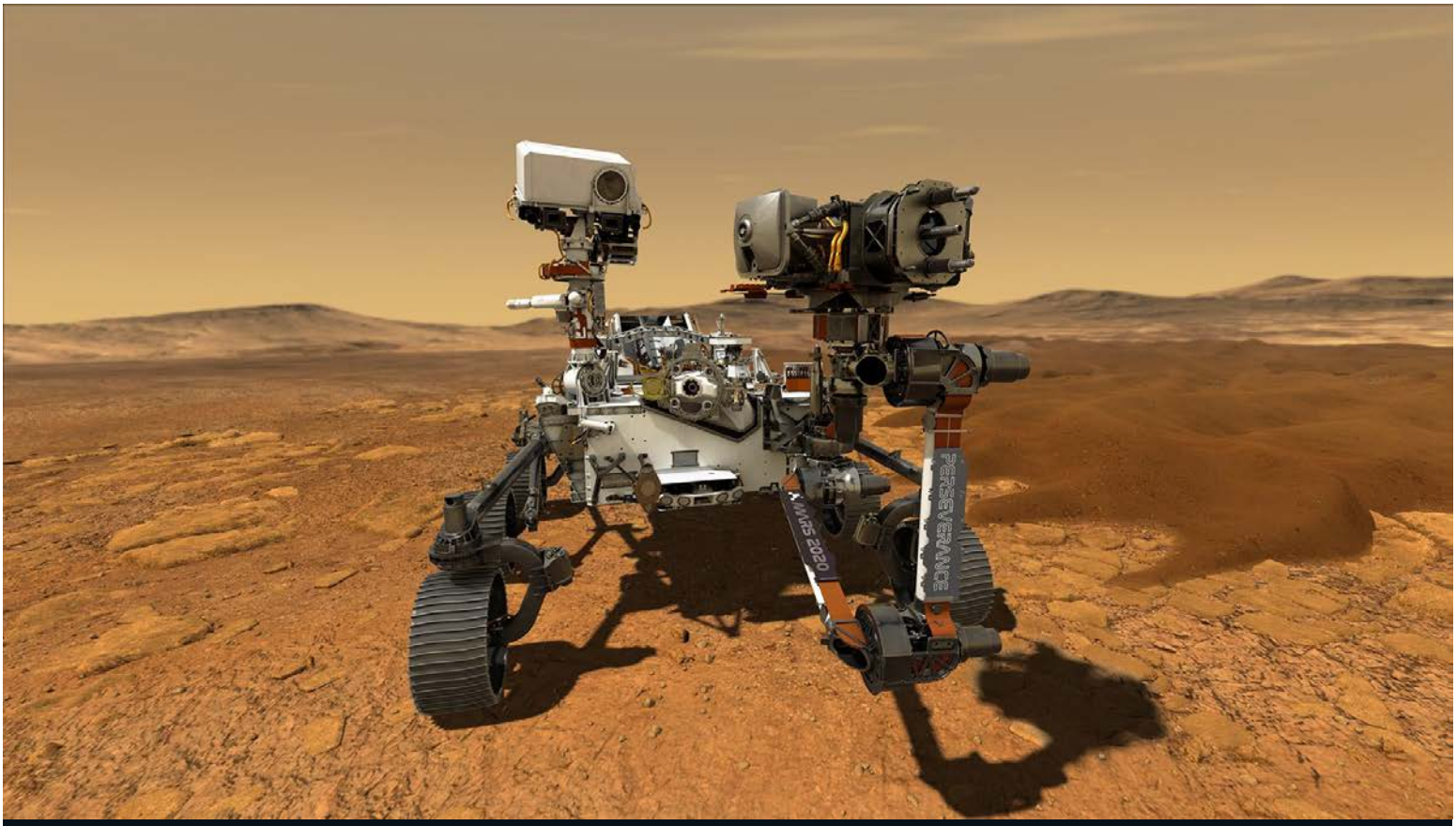
"We're trying to answer fundamental questions like, 'How does life develop on a planet, and does it develop everywhere?' I think NASA, in general, has always been looking at that goal, but we're getting real close to actually having the answer," he said.

Another reason for exploring Mars? It can benefit your daily life on Earth.

“To send something to anywhere off the planet, to any planet, to Mars, to Venus, to Jupiter, it has to be small, it has to be energy efficient, and it has to use materials that are incredibly durable and rugged — all the hallmarks of useful materials that we can then use on Earth to make life better,” he said.

“Everyone has a cellphone, right? And it has a camera. You can talk to people on the other side of the planet. You have batteries that last for over a day on this little phone that’s portable. All those are basically things that used to be the size of a house and now you can fit in your pocket,” he said.

“And that’s all about space. We take big things, we make them small and efficient and powerful, but with less power. Our technology development for space really feeds right back into developing new technology and materials that we can use on Earth.”



Perseverance travels the surface of Mars in this NASA illustration.