A DRAGONFLY ON TITAN

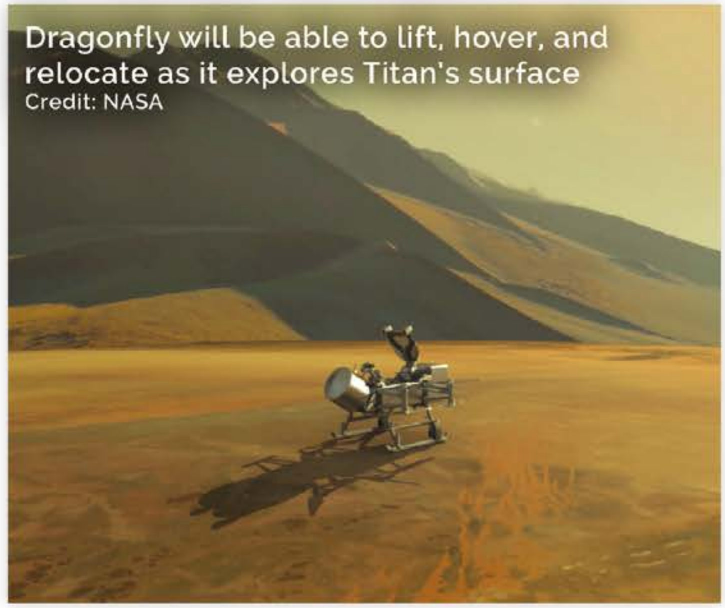
Jordan Strickler

Landing sequence for NASA's Dragonfly probe at Titan
Credit: NASA

The text was from Ken Hibbard's Johns Hopkins University Applied Physics Laboratory colleague Elizabeth "Zibi" Turtle, Principle Investigator on the Dragonfly mission. "Hey, when you have the chance, can you swing by my office?" As soon as Turtle, Mission Systems Engineer for the project, reached her office, she was on the phone with NASA. Shortly after ending the conversation, she called Doug Adams, Spacecraft Systems Engineer, who was boarding a flight out of Los Angeles International Airport.

"Zibi said, 'we won!'" laughs Adams while recounting the call. "I said, 'we won what?' It took five minutes of her convincing me that she wasn't pulling my leg." Dragonfly was going to Titan. The one-billion-dollar mission, which is slated to rocket toward Saturn's largest moon in 2026, will not be the first rotorcraft to visit an alien world—that distinction will be going to the Mars Helicopter, which will hitch a ride with the Mars 2020 rover. However, it will be the first time that a flying rotorcraft will undertake detailed scientific research.

Saturn's largest moon has long intrigued scientists with a chemical composition that is believed to mirror that of a primordial Earth. Researchers hope that the samples evaluated by Dragonfly will help them to understand the chemical environment which gave rise to life on Earth, as well as determine the potential



Dragonfly will be able to lift, hover, and relocate as it explores Titan's surface
Credit: NASA

habitability of Titan today. The probe will also search for any signs of microbial life.

Titan is located approximately 760,000 miles (1,223,100 kilometers) from Saturn and is the planet's largest satellite. The Dragonfly mission will be the most detailed exploration ever undertaken there. The moon was previously visited by the two Voyager spacecraft in 1979 and 1980; however, the dense atmosphere obscured the surface at visible wavelengths. In 1994, the Hubble Space Telescope imaged the moon at longer near-infrared wavelengths, revealing bright and dark regions on the surface.

The real details remained a mystery until Cassini made its visit a decade later. Using radar and imaging at near-infrared wavelengths, the orbiter was able to glimpse below the hazy atmosphere. In more than 100 flybys, it mapped much of Titan's surface and was able to make detailed studies of its atmosphere, as well as providing evidence of a global, salty ocean below the moon's icy crust. With Cassini came the European Space Agency's Huygens probe, which parachuted to Titan's surface in 2005, measured its winds and atmosphere, and imaged a small area of the surface in close-up detail.

Cassini showed us that Titan's surface has lakes, rivers, and even seas of liquid ethane and methane, as well as vast expanses of what appear to be sand dunes, but are probably composed largely of granular organic particles. Its climate is such that methane can form clouds and rain, as the moon's atmosphere is four times denser than Earth's and its gravity is approximately one-seventh that of our planet, which means Titan's raindrops fall much slower. Rainfall on Titan is rare, however—it may be hundreds of years between showers at a given location. Due to the fact that it is so far from the sun, Titan's surface temperature hovers around a chilly 290 degrees Fahrenheit (179 degrees Celsius below zero). Its surface pressure is also 50 percent higher than Earth's, perfect for a rotorcraft such as Dragonfly.

Titan's atmosphere is composed of around 95 percent nitrogen with about five percent methane. When exposed to sunlight, those methane and nitrogen molecules are split apart by ultraviolet light and recombine to form a variety of complex organic compounds. Organic molecules are the building blocks for life as we know it, and their presence on Titan (and possible compounds they could form) is promising.

"Titan is a really fascinating place," says Turtle. "It's the only moon that has a dense atmosphere. It's surprisingly Earth-like, which is intriguing. [Titan] was always this really mysterious place and one of the things that was fascinating is that it was revealed to have very Earth-like processes in the atmosphere and on the surface. It's also chemically very much like our own early planet, and it gives us the opportunity to study the pre-biotic chemistry that took place before biology developed here. We don't necessarily have the opportunity to study that here on Earth."

The ten-foot (three meters) long Dragonfly rotorcraft will land in dune fields near Titan's equator. From there, it will use its eight rotors to traverse dozens of sites across Titan's surface,

The Dragonfly team testing an early prototype
Credit: NASA

taking samples and performing analysis. "We know from the measurements of the upper atmosphere that there are very complex organic molecules," explains Turtle, "So we want to understand how these molecules have interacted on the surface, especially if they've been able to be in contact with liquid water."

As the probe enters the moon's atmosphere, a drogue parachute will open at Mach 1.5 and slow Dragonfly for approximately 90 minutes until it reaches an altitude of two miles (just under four kilometers). Then the main parachute will deploy, followed by heat shield separation so that Dragonfly can acquire the ground with its range sensing instruments. In all entry, descent, and landing (EDL) should take about two hours. "The atmosphere is very thick," says Adams. "We have a sequence where we do a direct entry into the atmosphere and we deploy a drogue parachute in conditions very similar to Mars as far as the supersonic deployment, and that's not an accident. Interestingly, it takes about six minutes to get to those conditions after we encounter the atmosphere and that's about the same time as the entire EDL on Mars, so it is much slower."

Initially plans for Dragonfly called for a flotation ring that would allow the craft to land on one of Titan's lakes. However, a more conventional box-with-skids layout soon emerged after it was decided that the areas between the dunes would be the focus of the mission. Besides offering a flat landing spot, the dunes could offer a wealth of information. "On Titan, the dunes are made of sand-sized particles, as one might expect, but the sand is [probably] organic," said Turtle. "We don't know how you form organic sand-sized particles, so that is one mystery. If there are different types of reactions going on, it will all be collected between these dunes, and we'll be able to get measurements of sand and it will be very widely sourced."

For robotic spacecraft, energy is everything. Titan is roughly 886 million miles (1.4 billion kilometers) from the sun, and at that distance solar energy is approximately 100 times weaker than on Earth. Additionally, the hazy atmosphere diminishes light by a factor of 10, so solar panels were ruled out and a nuclear power supply was chosen instead. "We use all of the waste heat from the MMRTG (multi-mission radioisotope thermoelectric generator) to keep the internal element of the lander warm in the cold environment," Hibbard said. "Then we use the RTG (radioisotope thermoelectric generator) as a large charge source for a battery and most of the activities are done off the battery. That way we have thermal power that will sustain us for the surface lifetime."

Unlike the Mars rovers (which spend a lot of time on the move), Dragonfly would be stationary most of the time, conducting experiments, transmitting data, and charging. "We'll be communicating with Dragonfly so we'll tell it where its initial landing site is, and in the longer term, we are going to work toward a large crater that is to the north of the initial landing site," Turtle said. "That's because in the impact cratering process, liquid water will be formed when the target is melted because Titan's crust is made of water-ice and that is melted during the impact. So the impact crater is potentially a good location for the organic material to have mixed with water."

Thanks to Dragonfly's dual-quadcopter design and the thick atmosphere and low gravity, the drone should be able to fly at least 90 miles (145 kilometers), more distance than was covered by all of the Mars rovers combined. Dragonfly will also be able navigate rugged terrain much faster and with less risk of damage than driving across the surface.

Data collected from the mission will allow researchers to assess the chance of Titan's habitability and see how far its chemistry has advanced toward something potentially biotic. Evaluation of the samples will attempt to pick up traces of water- or hydrocarbon-based life. Mass spectrometry will reveal atmospheric and soil composition, and gamma-ray spectrometry will be used to probe into the chemical composition of the shallow sub-surface. A suite of meteorology and geophysics sensors will record wind, pressure, temperature, and seismic activity, as well as a host of other factors. Finally, eight different cameras will let scientists peer at the nature of the moon's surface. These cameras will provide for forward and downward as well as ground and in-flight pictures. A microscopic imager aboard can inspect the surface material down to a sand-grain scale, while panoramic cameras will be able to survey sites in detail after landing.

"The primary objective is to understand the chemistry on Titan," said Turtle. "We know that all of the necessary ingredients for life as we know it are, or have been, present on the surface. There is this really rich photochemistry at the top of Titan's atmosphere; all of those organics fall out onto the surface where they have the opportunity to interact with each other and potentially interact with liquid water at sites of impact craters or possible volcanoes. So we know that all of those elements have been there for potentially millions of years and what we want to understand is what happens when you put all of these things together in this kind of environment. What kind of chemistry do you get? The reason we proposed a mobile vehicle is similar to the reasons that we send rovers to Mars—we want to be able to make measurements in parts of Titan that have had different histories. We also want to go where the materials have interacted in different ways so that we can get a sense of the chemistry ... and how complex the organic synthesis gets."

Although the announcement was months ago, the news is still registering with much of the team. "Getting the green light is hard to put it into words," says Hibbard. "The shock is part of it. You're hearing them tell you that your project was selected, but there is a part of you that still doesn't quite believe it. There is an element of exhilaration and jubilation because you've worked so hard for something and to have it actually happen was almost difficult to imagine. Now, it's like 'wow, now we actually have to go do this.'"

The Dragonfly prototype goes through its paces
Credit: NASA