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FLYING OVER TITAN

The first mission to fly on another world gets the green light

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Flying over TITAN

Ezzy Pearson reports on NASA's Dragonfly, the first-ever science mission to fly on another world, which is set to soar over Saturn's largest moon in search of the elements of life

The Dragonfly octocopter is due to begin flying over Saturn's largest moon, Titan, in 2034

Titan, Saturn's largest moon, is a contradiction: a world that's remarkably Earth-like and profoundly alien at the same time. Like our own planet, the moon has a nitrogen-dominated atmosphere over a landscape of mountains, deserts and even seas. Only on Titan, the mountains aren't made from rock, but ice. And rather than water, in its rivers flows liquid methane.

Most captivating of all, the moon is rich with the organic chemicals that form the foundations of life on Earth. All this makes Titan an ideal place to investigate the evolution of the chemistry that makes our planet, and perhaps others too, habitable.

In April this year, NASA confirmed that it intends to send the Dragonfly mission on its way to the mysterious moon in July 2028. When it arrives in 2034, the spacecraft won't just roam on the moon's surface, it will also soar above it. Dragonfly will live up to its name, becoming the first-ever full science mission capable of flight in another world's atmosphere.

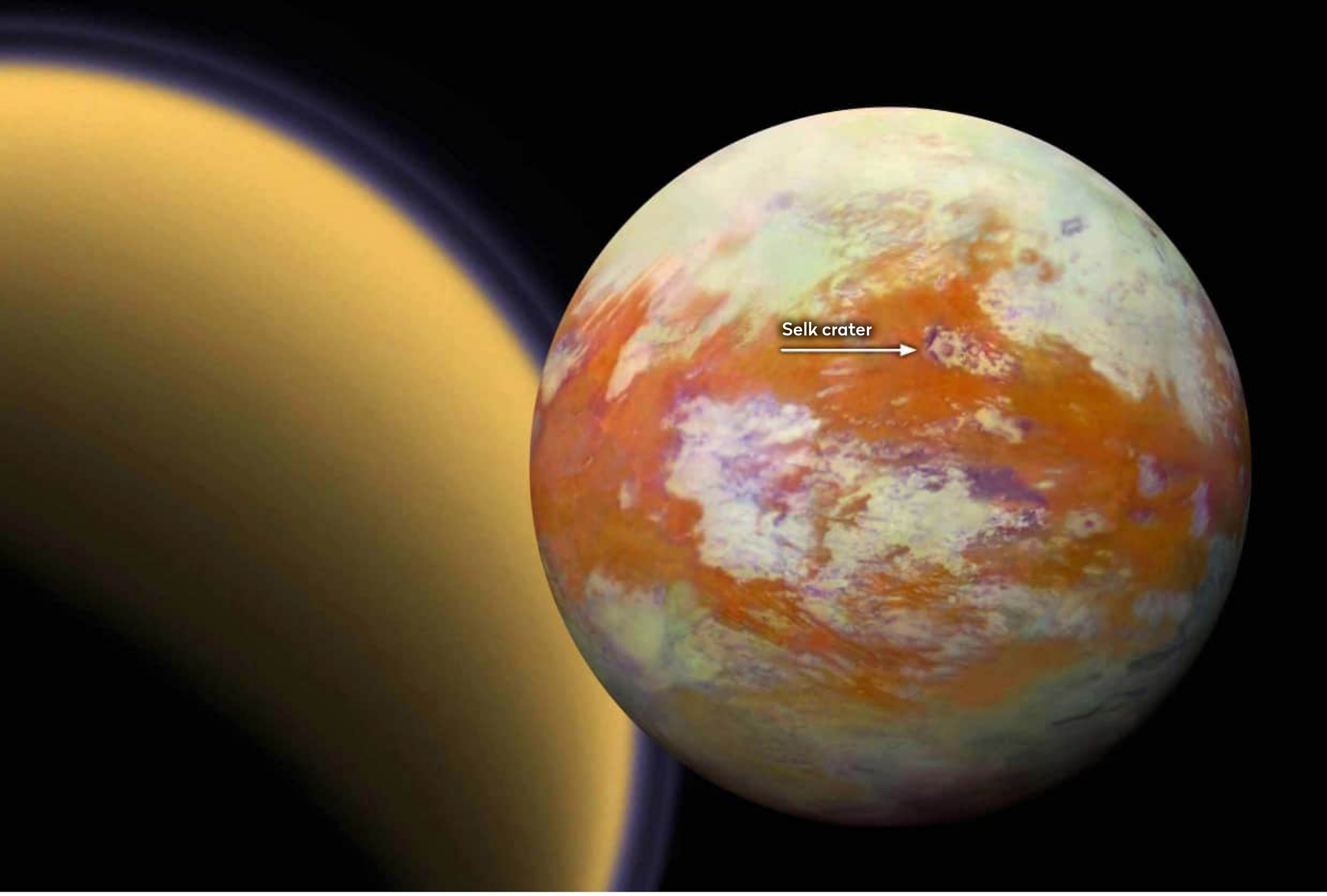
"Dragonfly is an octocopter – with four pairs of rotors – that will traverse to different sites on Titan by flying from place to place," says Zibi Turtle from Johns Hopkins University Applied Physics Laboratory and principal investigator of Dragonfly.

During its mission, Dragonfly will cover hundreds of kilometres. It will start its journey in the Shangri-La dune field, a desert just south of Titan's equator. From here it will hop from dune to dune, exploring a variety of landscapes and eventually making its way to the 80km-wide (50-mile) Selk impact crater.

Chemical quest

The spacecraft's mobility will allow it to reach the best spots to study Titan's unique chemistry. On Titan, methane serves a similar role to water on Earth – methane clouds fill the sky, pouring down methane rain into methane-filled lakes and rivers. It also serves as the starting point for much more complex molecules.

"The methane breaks down at the top of the atmosphere and recombines to form very large carbon molecules," says ▶



▶ Turtle. "These molecules fall out of the atmosphere onto the surface. Being an icy moon, Titan's surface is made of water ice. In places where the ice has melted, you have liquid water and complex carbon molecules together."

On Earth, the mixing of these carbon, or organic, molecules and water is part of the complex chain of chemistry that eventually gave rise to all biology. Unfortunately, the abundance of life on our own planet makes it impossible to study this chemistry outside a lab.

"Titan's basically been doing these chemistry experiments for thousands, maybe millions of years," explains Turtle. "We're picking up the results of those experiments."

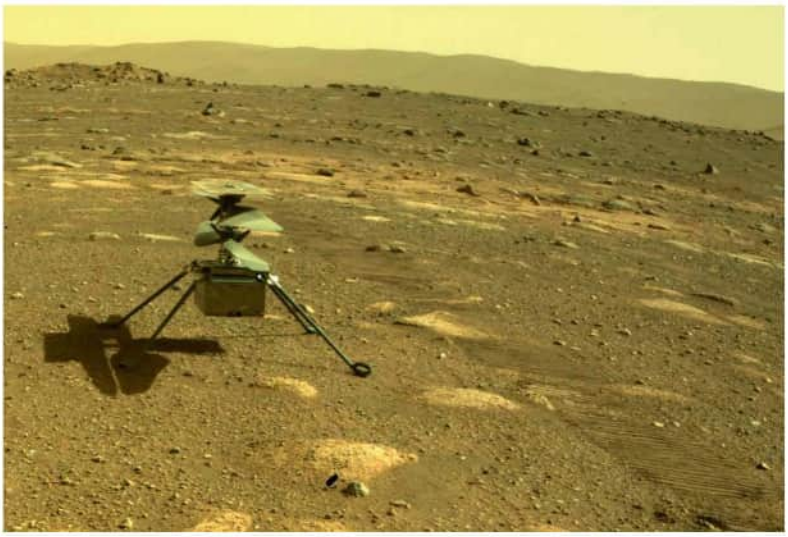
One area Dragonfly won't access is Titan's liquid water ocean, which lies deep under the moon's thick ice crust. If life has evolved on Titan, then it probably lives in this ocean. For that to have happened, the ocean water needs to have mixed with the surface organics. This could have occurred if a meteor impact punched through the crust. While at the Selk impact crater, Dragonfly will look for any signs of such an interaction.

All this helps build a better understanding of the habitability of Titan and, by extension, the habitability of other worlds like it. Currently, our frame of reference for where life can exist is limited to one planet: Earth.

"If [Titan] demonstrated the potential for habitability as well, that really expands the options around other planetary systems too," says Turtle. "Titan is a good exoplanet analogue in other ways too, as methane has been detected in several exoplanet atmospheres. Understanding the methane cycle will greatly help to better understand what might be happening on these worlds."

A flight-friendly moon

The thick atmosphere is also a vital tool for the mission, as it's what allows Dragonfly to get airborne. The only other craft to fly on another world is Ingenuity, a test spacecraft that flew on Mars in proximity to the Perseverance rover. Mars's thin atmosphere meant the rotors generated little lift and so Ingenuity had a mass of just 1.8kg (4lb). Dragonfly, meanwhile, will have a mass of 875kg and be the size of a car. Titan's surface pressure is 1.5 times that



▲ Dragonfly will explore dozens of promising locations before reaching Selk crater. Titan is shown in optical (left) and infrared (right)

▼ The (much smaller) Ingenuity on Mars. It proved that controlled flight on another planet is possible

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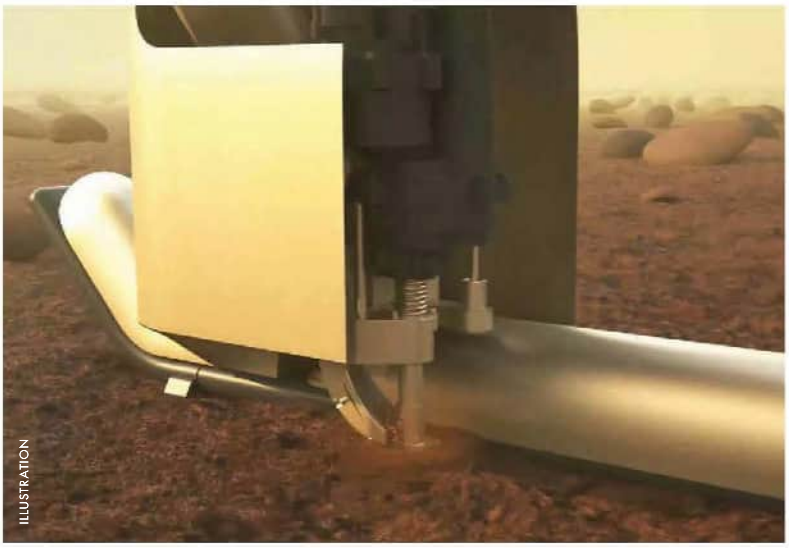


▲ **When it lands, Dragonfly will fire up DrACO (Drill for Acquisition of Complex Organics)**

of Earth, which makes rotors much more efficient at providing lift. This, combined with the fact that Titan's gravity is just 14 per cent of Earth's, allows Dragonfly to take to the air despite its size.

But while flight is integral to Dragonfly's mission, it will spend a good amount of time on the surface. One Titan day is around 16 Earth days and the team only plans to fly Dragonfly every other Titan day. The rest of the time, the octocopter will make surface measurements and communicate with Earth.

"We have an instrument suite that's designed to understand the chemistry that occurs before biology," says Turtle. "We have a drill, DrACO, that will break up the material and we can vacuum that up into a mass spectrometer [DraMS, which analyses what chemical compounds could be present]."

Dragonfly has another spectrometer, DraGNS, which will take a much broader look at the composition of the surface beneath the lander.

Clear for take-off

A suite of meteorology sensors, DraGMet, will monitor atmospheric temperature, pressure, methane humidity and wind speed. Weather is one area we know more about, thanks to the ESA Cassini mission, the Saturn orbiter that conducted 127 close fly-bys of Titan between 2004 and 2017, and even dropped off the Huygens probe to land on the moon's surface. By chance, these observations were one Saturn year (29 Earth years) before Dragonfly is due to land, meaning mission controllers know what weather to expect.

"Titan actually has a really calm atmosphere," says Turtle. "The atmosphere is dense and the years are long, so the temperature variations that drive Earth's dynamic weather are very small on Titan." ▶

Huygens images showed pebbles on a dried-up sand-like lake bed

Huygens on Titan

20 years ago, ESA's probe gave us our first close look at Titan

An artist's impression of the probe on Titan's surface

Long before Dragonfly, in 2005, another spacecraft set down on Titan. ESA's Huygens probe hitched a ride to the Saturn system on NASA's Cassini orbiter. Primarily designed as an atmospheric probe, Huygens descended towards Titan by parachute on 14 January, taking two hours, 27 minutes to reach the surface. Throughout the journey, it measured how the composition, temperature, pressure and air density varied with altitude.

These measurements will prove invaluable to the Dragonfly team as they try to ensure their own spacecraft safely makes it to the moon's surface.

Huygens took many images as it approached the surface, building a map of the terrain surrounding the probe's eventual landing site. The images revealed a sandy landscape scattered with rounded pebbles in what is now thought to be a dry lake bed.

The lander transmitted its findings to Cassini for 70 minutes, until the orbiter moved beyond the horizon, out of radio contact. Cassini relayed the data home, only for the mission team to discover that a coding error meant half of Huygens data hadn't been recorded!

Even so, the half that was saved revealed a fascinating world that planetary scientists have been itching to return to for the last two decades.

Protecting Titan

Preventing harm to alien life isn't NASA's only reason to keep Dragonfly clean...

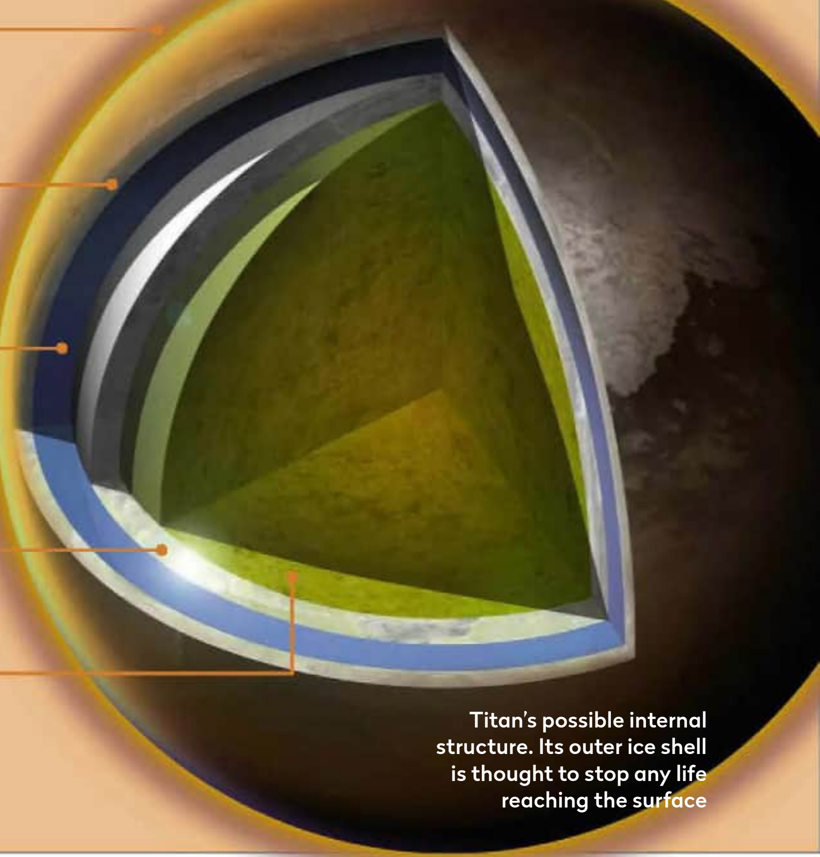
Given that investigating Titan's potential habitability is one of Dragonfly's primary goals, a major concern for the mission is planetary protection – that is, ensuring Dragonfly doesn't bring any biological stowaways from Earth to potentially contaminate Titan's environment.

Fortunately, there's little concern of harming any life that might exist on Titan. On Earth, no organism has ever been found reproducing at temperatures colder than –20ºC (–4ºF). Titan's –180ºC (–292ºF) temperature would kill, or at least deactivate, any microorganism on the spacecraft. And even if there is life on Titan, it would almost certainly be in the subsurface ocean, separated from Dragonfly by 100km (62 miles) of ice.

"Titan, like Ganymede, has a very deep interior water ocean," says Turtle. "It's not like Europa or Enceladus, where the ice shell is relatively thin. On Enceladus, we know there's transport between the ocean and the surface because there are jets erupting there. But on Titan, the requirements are less stringent."

The team will still take great caution to keep the spacecraft free of Earth biology to ensure that no biological contaminants impact its own measurements.

"You don't want to get all the way to Titan and find some cool carbon molecule and realise it came from the laboratory here on Earth," says Turtle.



Titan's possible internal structure. Its outer ice shell is thought to stop any life reaching the surface

▶ While on Earth it's not unusual to have a 10°C (50°F) swing from one week to the next, Titan doesn't change by more than 1°C (34°F), even from season to season. This makes the weather remarkably placid, meaning the Dragonfly team needn't worry about being grounded by storms.

Dragonfly will also be equipped with seismometers listening for 'titanquakes'. By analysing these, geologists will be able to precisely measure the thickness of Titan's crust, currently estimated at around 100km (62 miles) deep.

Finally, the spacecraft will be equipped with high-resolution cameras, DragonCams. During flights, these will image the surrounding landscape to scout for potential future landing sites and provide context for surface observations. While on the ground, the resolution will be great enough to make out individual sand grains. Unlike Earth's silica sand, Titan's is made of organic material – another of Titan's big mysteries.

"We know it's there, but we don't actually know how you form organic sand," says Turtle. Dragonfly is expected to reveal the answer.

One aspect of Titan's landscape the spacecraft won't investigate is the methane lakes and seas. These are all in the northern hemisphere, which will be in winter throughout Dragonfly's mission.

Training the tech for Titan

Currently, Dragonfly is undergoing its Critical Design Review, where every aspect of the spacecraft's design is tested. A half-scale test model has already undertaken over 700 test runs in wind tunnels to determine how much lift the rotors can generate. Meanwhile, a flying model has been taken to the Imperial Sand Dunes, California to test the software that controls Dragonfly.

"Titan is 70–90 lightminutes away, so everything has to be autonomous," says Turtle. "We've been putting a lot of work into developing and testing the systems so that Dragonfly can navigate and land [on its own]."

Arguably, the most difficult issue to surmount is the cold. Titan is around –180°C (–290°F), cold enough to make delicate hardware brittle and stop Dragonfly's electronics from working efficiently.

"It is almost unimaginably cold on Titan," says Turtle. "The lander is insulated to keep everything on the inside warm enough to function. Surprisingly, there

▲ A prototype is put through its paces over Imperial Sand Dunes in southern California

A half-scale model undergoes wind tunnel testing at NASA Langley Research Center

▶ Titan Chamber, where a test model is subjected to extreme temperatures and pressures

▼ Just some of the army of scientists and engineers developing the rotorcraft

are possible scenarios where it's so well insulated it could actually get too hot."

One of Dragonfly's best weapons to keep the cold at bay is actually its power source, a radio thermal generator (RTG) similar to those used on the Mars Perseverance and Curiosity rovers. RTGs convert heat given off by a brick of radioactive material into electricity and often serve a dual purpose as power source and heater.

Dragonfly's size and the extremity of the cold required NASA to build a huge new environmental test facility, the Titan Chamber. Measuring 4.5 metres (15ft) on all sides, the chamber can mimic the temperature and pressure conditions on Titan. For now, yet more test models are helping engineers plan how to best insulate the spacecraft. Eventually, the real Dragonfly will find its way into the chamber to ensure it can withstand whatever Titan will throw at it. Once the mission is underway, the chamber can be reconfigured to imitate other icy moons, such as Europa and Enceladus. Planetary explorers have already set their sights on exploring both moons in the future, missions that will no doubt build on the lessons being learned today.

There is still a long road ahead until Dragonfly reaches the launchpad, let alone Titan, but the spacecraft is well on its way towards floating through the skies above a distant alien moon.

Ezzy Pearson is *BBC Sky at Night Magazine*'s features editor. Her book *Robots in Space* is available through History Press