THE JOURNEY OF AN IDEA:
FROM NATURE TO MARTIAN ROTORCRAFT

How nature inspired NASA's Ingenuity

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NATURE AS A TECHNOLOGY LAB

With billions of species flying, crawling, walking, and swimming, nature offers mankind the best sources for research and development projects. An operational biodiversity that has been sustainable and functional for more than 3.8 billion years has proven the sustainability of the mechanisms used by modern living beings.

Man, always curious about his surroundings, could not help himself from mimicking what he sees in his surroundings and seeking inspiration from the organic systems found in nature to deal with his own problems.

Surely, as man had a better comprehension of how macro and micro world operate; the engineering and technology went further.

Today, nature continues to inspire scientists. And now, scientists are studying the insect flight, particularly that of bees, to create better airborne vehicles for space exploration activities. And Ingenuity, the Mars' first rotorcraft, is one such engineering dream which came true.

THE MECHANISMS BEHIND THE BEE FLIGHT

In order to understand the conditions inspired the design of Ingenuity, one must have a deeper look into mechanisms used by bees during flight.

Bees are some of the nature's most awe-striking flight machines. They are able to hover with a surprisingly small amount of flight equipment such as the wings, thorax and flight muscles. Yet, they make the best out of what they have in the most efficient way with the use of aerodynamics and mathematics. Considering their oldest fossilized sample is 100 million years old; their flight mechanisms are also highly sustainable (Poinar Jr, 2020).

Because of their optimized flight technique, they have been creatures appealing to scientists for centuries. Naturally, engineers who wish to increase the flight quality of their machines have been studying bees to find a solution to their questions.

Although they have been inspiring engineers' designs for centuries; the way bees fly is far different than man-made vehicles do. Bees use different mechanisms and principles to fly long distances. First, unlike aeroplanes and gliders, their wings are not steady but in constant motion. This motion called flapping creates a turbulence effect bringing about a vortex with a potential to provide considerable lift (Savage, 2015). However, these vortices are not enough on their own. They need to be supported with some complex mathematical calculations on their wings. The wing angle is really what makes the difference. A change in the angle of wings can cause bees to stall and the vortices prevent them from stalling during a long-haul flight. It is this very combination of geometry and aerodynamics in aerial locomotion is what keeps bees on constant flight mode (Nabawy and Crowther, 2017).

In addition to changing the angle of their abdomen depending on the change of wind energy between their head and tail; these tiny creatures also make use of optic flow to optimize their flight efficiency by expanding the power of reaction to the variations in velocity resulting from the turbulence during a flight (Taylor, Luu, Ball and Srinivasan, 2013). They need to take their optimization techniques even further especially when carrying a load such as pollen or nectar. In order to overcome the problem of carrying an extra load on their back from foraging; bees expand their load capacity and any physiological restriction of their flight muscles through some exceptional kinematics (Altshuler, 2005).

Bees do not only use their wings for long distance flight. They also create wing movements to ventilate their hives known as fanning. Their aerial locomotion facilitates a lift and thrust based on the aerodynamic principles of inertia and vortex (Junge, 2007).

Understanding and studying all these mechanisms behind the bee flight is quite important to design hovering and flying vehicles for space exploration in extra-terrestrial environments.

THE THIN AIR AND GRAVITY

There are various factors affecting the flight quality. The altitude is one of these criteria with an impact on the smoothness, speed, and efficiency of the flight. For instance, modern planes cannot fly above 50 km as the air density is too low to create enough buoyancy for planes and balloons at this altitude. As one flies higher in the atmosphere, the air becomes thinner. Hence, the altitude for space satellites is rarely below 150 km as the air is thick enough to cause overheating and excessive drifting. Rockets are the only vehicles able to fly in mesosphere although this flight only lasts for minutes (Azadi et., 2021)

In other words, air thickness is a factor one cannot ignore if he is eager to fly on another planet. The Red Planet has an atmosphere made of carbon dioxide, nitrogen, argon, and oxygen, which makes it 100 times thinner than the Earth's atmosphere (ESA, 2019).

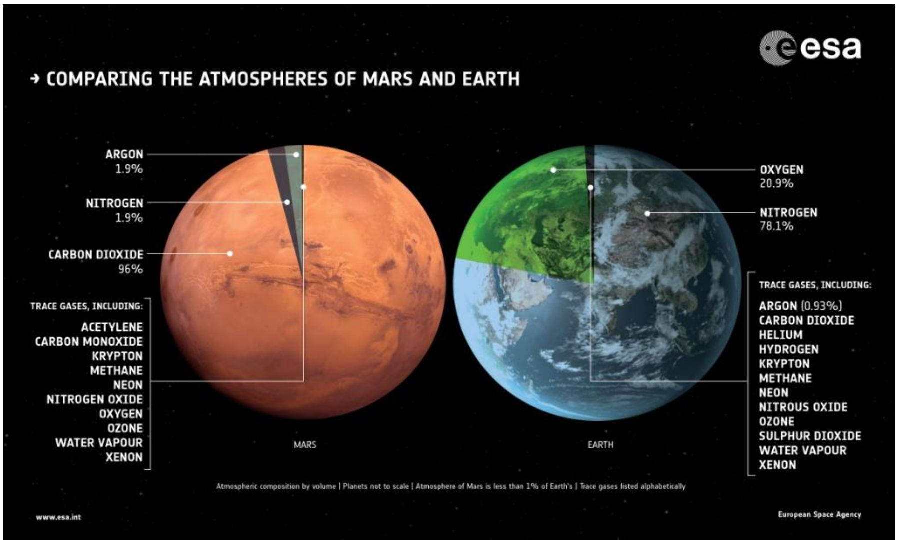
The distance between Earth and Mars is about 225 million kilometres (Biswal M et al., 2020). Mars has a very thin atmosphere of some 6 mbar, made of CO2 (Scherf and Lammer, 2021). The atmospheric composition of our planet and the Red planet is shown in the table below. And as it is clearly seen from the chart that there is less gravity on Mars.

Table 1. Characteristics of Earth and Mars

	EARTH	MARS
Atmospheric Composition	78% N_2, 21% O_2, 1% OTHER	96% CO_2, < 2% Ar, < 2% N_2, <1% OTHER
Force of Gravity (Weight)	100 Ibs ON EARTH	38 Ibs ON MARS (62,5% LESS GRAVITY)

Source: (Musk, 2017: 47).

Figure 1. Comparing the atmospheres of Mars and Earth



Source: (ESA, 2018).

The Red Planet has an atmospheric volume of less than 1% of the Earth, which is far thinner. The two planets have different atmospheric compositions. The Earth has a nitrogen and oxygen rich atmosphere whereas the atmosphere of the Red Planet is rich in carbon dioxide (ESA, 2018). This thin air makes it difficult for the aircrafts to take off once they land.

HOW INGENUITY FLIES

As Mars' atmosphere cannot provide enough lift for an aircraft; it requires ingenuity to design an aircraft to fly on the Red Planet. Bee-inspired robots designed by Stanford engineers are what gave Bob Balaram the inspiration he was looking for. He thought a smaller (0.5 m) and a lighter (1.8kg) vehicle design was supposed to fly much more easily on the Red Planet in theory. Yet, the vehicle still needed support for the lift-off. Two sets of blades were added to the vehicle, with a rotating speed of 10 times faster than Earth (Betz, 2020). This speed would compensate for the low density and would help the rotorcraft sustain its dynamic pressure.

This genius concept became successful, and Ingenuity has landed on the Red Planet. Now, it is scheduled to test its flight and lift-off skills. If the rotorcraft successfully flies there, it will enable scientists to capture low-altitude views for the first time (Poo, 2020).

CONCLUSION

Man’s eagerness to fly and to discover new places from the bee’s or bird’s eyeshot has led to the creation of splendid designs since the dawn of civilization. Considering that man’s purpose in the colonization of the Red Planet is to explore the unknown; it offers a great vantage point. Aircrafts that can fly at high speed or at any speed will save time, cost, and energy for the researchers.

If the rotorcraft’s design can successfully take off, it can help engineers to improve the aircraft technology even further. Successful airborne vehicles not only will speed up the exploration and colonization process, but they will also contribute to the development of transportation technologies for the colonized residents of the Red Planet.

Nature will continue to inspire aircraft designs. The way Alpine bombus bees fly may offer a potential for future spacecrafts. These tiny creatures are great at flying at higher altitudes and making use of thin air through a special flapping technique to generate a lift-off (Dillion and Dudley, 2014). These living beings may offer a solution to the lifting problem for future concepts.

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