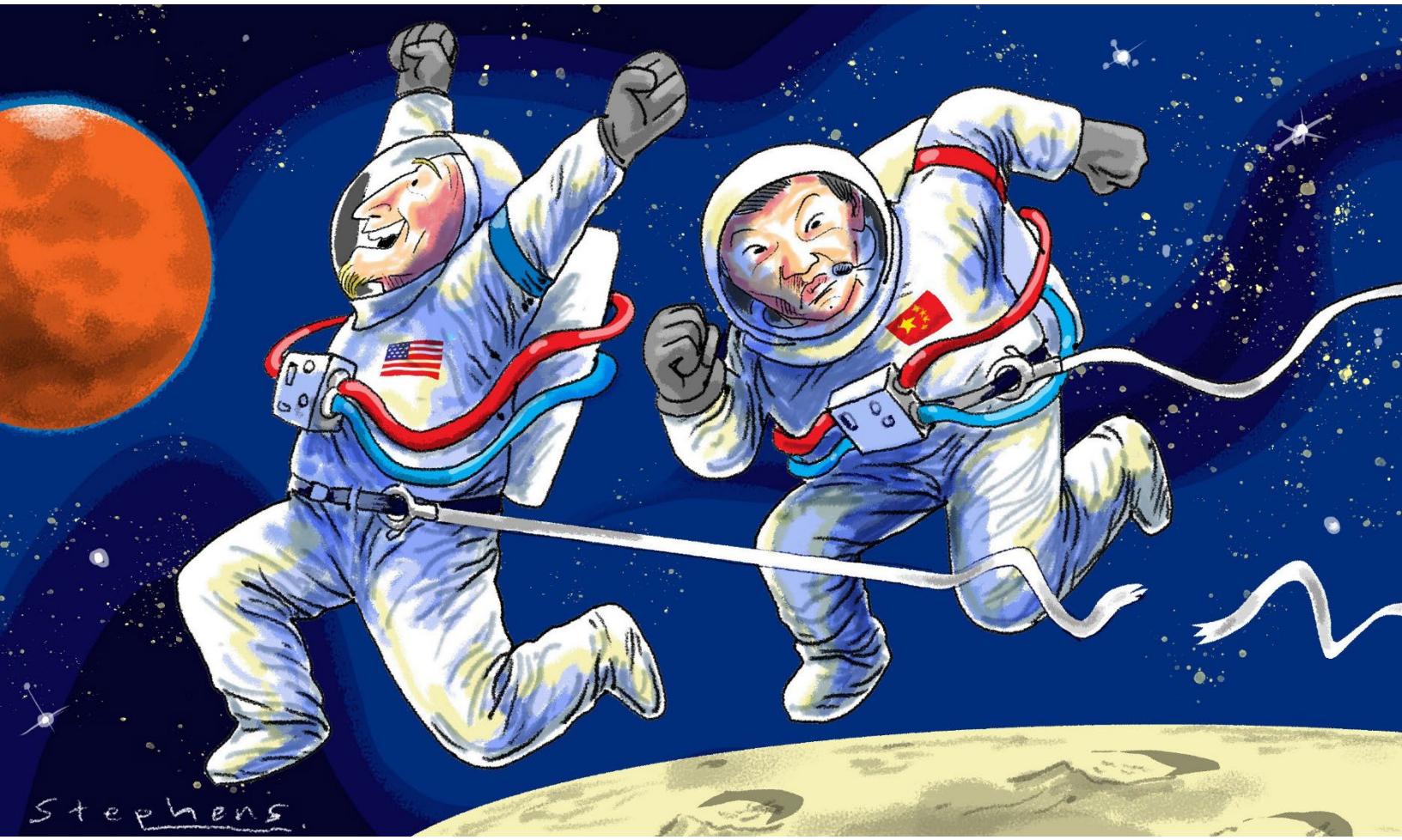
RACE TO THE MOON... AGAIN?



INTRODUCTION

Over the course of history, the moon has served a plethora of roles, the most essential being in timekeeping, as well as providing the only form of light during the night. It has acted as a
“cultural mirror” to our beliefs, being interpreted in almost every culture either as a god or as a planet, something too far to fully comprehend. The moon became a romantic symbol of past artists, a never ending source of inspiration and amazement. Even today, as you look up at the night sky, you’re certain your eyes will eventually meet earth’s satellite. The moon has been here since the beginning of humanity, it makes sense for people to want to conquer it.

That is exactly what we did 50 years ago. Now, it seems, we want to do it again. But why? How did we get to the moon in the first place? Why was it so important for us to achieve this milestone? Why did we stop our crewed missions? Most importantly, why are we interested in going back?

PAST MISSIONS

Closely after the end of world war two, as the cold war started to heat up, the world's largest superpowers entered a race which would bring leaps in technological advancements - the space race had begun. Although Russia had early success with Sputnik one, being the first successful satellite launch, on October 4th 1957, it would be the USA to successfully land the first astronaut on the moon, only 12 years later. By 1961, a few months after Yuri Gagarin became the first man in space, president John F. Kennedy committed to the goal of landing a man on the moon by the end of the decade, giving the start to the now famous Apollo program.

It was not until 1967 that the first Apollo mission got underway, and unfortunately it ended in disaster with 3 astronauts losing their lives. This would be followed by three uncrewed missions, and only in October of 1968 would astronauts get back on Apollo missions with the successful flight of Apollo 7.

Apollo 7 was the first crewed space flight, with three astronauts spending a total of 10 days 20 hours and 9 minutes in space, completing 163 orbits of the earth. A few months later Apollo 8 brought the first flight around the moon. Apollo 9 was a test for the lunar module in space, followed by Apollo 10 in May 1969, it being a full rehearsal for the first moon landing. By this stage, in the span of less than a year 12 astronauts had successfully been part of Apollo missions to space, and NASA was ready to take the next big step. On July 16, 1969, Apollo 11 launched from Cape Canaveral with three astronauts aboard: Neil Amstrong, Adwin Aldrin, and Michael Collins. Four days later, Neil Armstrong became the first man to successfully walk on the moon, famously saying: “That’s one small step for man, one giant leap for mankind”. Just like that, in the span of a decade NASA had managed to put a man on the moon.

Apollo 12 was the next mission, and interestingly enough, as a part of the experiments conducted, one deliberately crashed the lunar ascend stage back on the surface in order to measure the shock wave through seismic equipment left behind. For all the wrong reasons, Apollo 13 is one of the better known missions. Two days after liftoff, an oxygen tank exploded; however, thanks to the ingenuity of the team back on earth as well as the hard work of the astronauts, the spacecraft made it safely back to earth. Nonetheless, the lunar landing was aborted. Apollo 14, after delays due to investigations into the previous mission, landed on the lunar highlands in July 1971. The following three and last Apollo missions were characterized by the presence of the lunar rover which greatly extended the reach of the missions. With Apollo 17 landing back on earth on December 19, 1972, came the end of the Apollo missions, and of the human presence on the moon.

Why did we stop going to the moon?

As described above, the last manned moon mission was the Apollo 17 mission that took place in December 1972. Since then, no human has touched the lunar surface. But why? The main reason was money: as soon as Kennedy's goal of landing on the moon was achieved, NASA faced large funding cuts, making the last three planned Apollo missions (Apollo 18-20) untenable. Research-based missions were not seen as important and, in addition, public support declined tremendously. Furthermore, as the Cold War ended, the Strategic Arms Limitations Talks (SALT) decided to drastically reduce missile production, including the ones used for space travel.

PRESENT MISSIONS

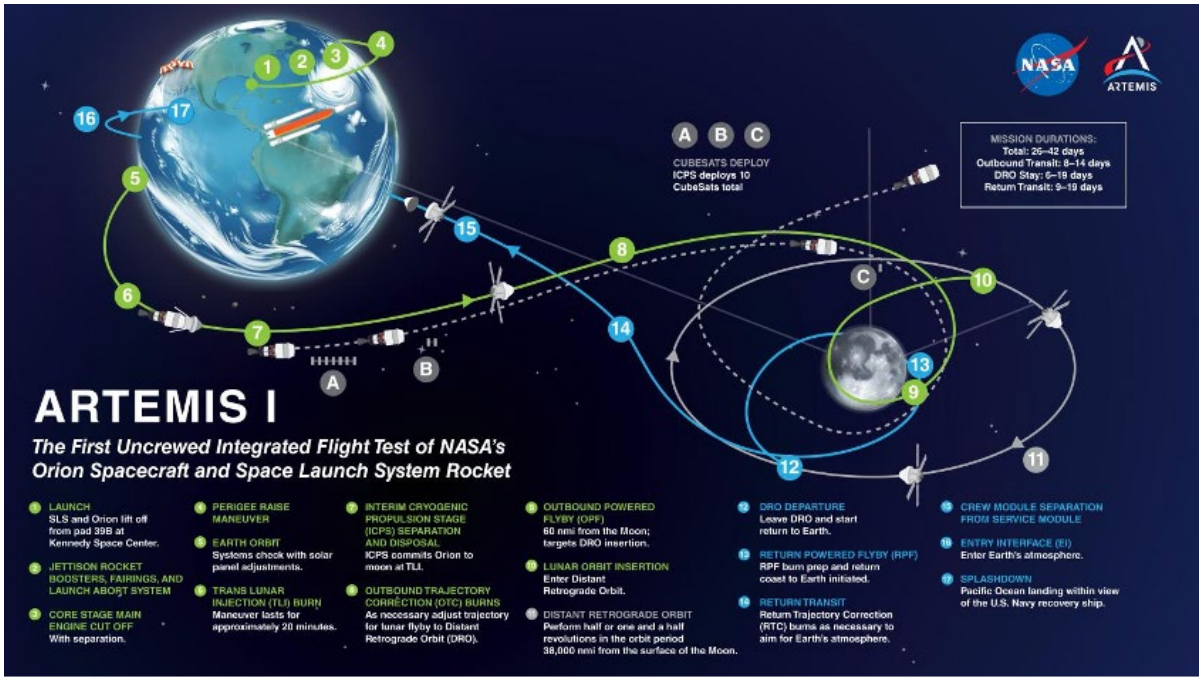
After having understood the most important manned moon missions of the past and why we stopped going there, the next part of this report is dedicated to learning more about the most important present missions that have the goal to finally take mankind back to the moon. In addition, we also want to elaborate on why we are actually going to the moon again. We will focus on the Artemis missions, which are highly relevant at the moment, but we will also touch on other important ongoing missions.

Artemis missions:

The Artemis missions are a three-step effort to land humans on the moon again, in the middle of this decade. Next to some important objectives of the missions themselves, which will be described in more detail below, they shall also lay the foundation for future manned missions to Mars.

In the Artemis program, there are three separate missions currently planned:

Artemis 1 will be an uncrewed test flight around and beyond the moon that was launched only last week (November 16, 2022) from Kennedy Space Centre in Florida. The mission serves as an extensive test of the Space Launch System (world's most powerful rocket) and the Orion module (the spacecraft that will carry the astronauts in future missions). Once in space, the Orion module will detach and begin its journey, taking in an orbit at 100 km above the lunar surface before continuing to go approximately 64,000 km beyond the moon. The planned course of the mission is depicted in the following picture:



The estimated length of the Artemis 1 mission is 26 days. Afterwards, the Orion module will splash down in the Pacific Ocean, near California. Next to extensive tests of the material before the first crewed flight, there will also be a range of scientific and technological experiments onboard that will take place in deep space. Their main purpose is to expand lunar knowledge and shed light on deep space radiation.

Artemis 2 will then be a crewed flight around and beyond the moon, which will take humans the farthest they have ever been in space. The mission will take between 8 to 10 days and will include a four-person crew. The main goal is to collect valuable flight test data.

Finally, Artemis 3 will be the mission that will land humans on the moon again after more than 50 years. Four astronauts will board the Orion module, dock with the Lunar Gateway and remain in space for 30 days. The Lunar Gateway is a planned small space station orbiting the moon, designed to be a flexible platform for missions to the moon and beyond. Two of the crew members will then fly down to the lunar surface, more specifically, the moon's south pole, which is an area previously unvisited by humans. The two astronauts are expected to spend a week exploring the surface and performing a variety of scientific studies.

Work on Artemis 1 started in 2017 and the mission successfully launched after 5 years of preparation on November 16, 2022. Artemis 2 is expected to launch no earlier than 2024, while Artemis 3 is not expected to take place sooner than 2025. As NASA inspector General Paul Martin stated, it is not unlikely that the crewed lunar landing will slip to 2026 at the earliest.

But why is NASA going back to the moon in the first place?

Unlike for the Apollo missions, the goal of the Artemis missions is now to go to the moon and "stay there". NASA and its partners are investigating the possibility of establishing bases both in lunar orbit and on the lunar surface, which would allow to extend trips to weeks and possibly months. Other key objectives of the Artemis missions are shown below:

Equality	First woman and first person of color on the moon
Technology	Testing the new technologies that are designed to pave the way for future deep-space missions
Partnerships	Large-scale collaboration with commercial companies like SpaceX and Boeing
Knowledge	More knowledge about the moon and more advanced technologies will allow to retrieve samples more strategically than during the Apollo era
Resources	Discovery of water on the moon and potential deposits of rare minerals hold promise for both scientific and economic exploration and exploitation

Last but not least, the technology and research developed and the experience gained during the Artemis missions can also be expected to serve as basis for a future crewed mission to Mars. However, one also needs to acknowledge that, while the journey to the moon takes three days, reaching Mars is a far lengthier and more complicated goal. The role of Artemis could rather be to lay the foundation for building a lunar settlement and economy; still, we will eventually send humans to Mars in the far future.

What is coming after Artemis 1-3?

Although NASA currently focused on the Artemis missions 1 to 3, they have already awarded contracts for boosters on rockets up to Artemis 13. If the Artemis missions prove to be successful, NASA has ambitions for further crewed missions on an

annual basis, which could have the goal to start establishing a base on the lunar surface. This base could then be used as a staging post on the journey to Mars.

Although the Artemis missions are of most relevance at the moment, there are also a few other organizations that plan manned flights to the moon in the 2020s. After the launch of Artemis 1 in November 2022, the next important launch date will be that of the dearMoon project, which is planned for 2023. The project carried out by SpaceX and financed by Japanese billionaire Yusaku Maezawa is a space tourism and art project: Maezawa and eight other civilians, accompanied by 1-2 other crew members, will make use of a SpaceX Starship spacecraft to fly around the moon. The selected passengers will be accomplished artists, since Maezawa hopes that the flight inspires them in their creation of novel art. The tour is expected to take 6 days; if successful, this flight could tremendously accelerate space tourism activities.

While the dearMoon project is a private spaceflight, also the national space agencies of Russia and China are working on noticeable crewed moon missions: Russian Roscosmos astronauts are planned to fly around the moon aboard the Oryol spacecraft in 2029. The first uncrewed test flight of the spacecraft around the moon is planned for 2028. The Chinese Crewed Lunar Mission goes even a step further and plans to put a pair of astronauts on the moon for a 6-hour stay in 2030.

FUTURE MISSIONS

While past missions were a success in the eyes of the public, they have also had a significant impact on the scientific world - studying the findings of the missions has shifted our perspectives about our origins as it has shed light on the circumstances that led to the extinction of dinosaurs 65 million years ago, allowing the subsequent rise of mammals. Moreover, these discoveries have given experts a better understanding of collisions of solid bodies: scientists now believe that impacts are responsible for a majority of extinction events in the history of life on Earth.

Now that we have understood what the most important past and current missions achieved, we want to give a broader outlook on the future of the field. In short, what's next?

The answer, like everything regarding space, is uncertain. However, here's what we know so far: over the next couple of years, at least four international robotic missions will focus on the moon, mapping the terrain at an unparalleled quality. Through technological advancements, we will also soft-land the moon and explore the mysterious polar regions - we'll examine the unusual environment there and gather more information in order to facilitate future crewed missions.

Eventually, people will return to the moon. The goal will be to learn how to use earth's satellite to support the growing spacefaring capability, that is having vehicles capable of traveling beyond earth's atmosphere. We hope to acquire the skills and develop the technologies essential for

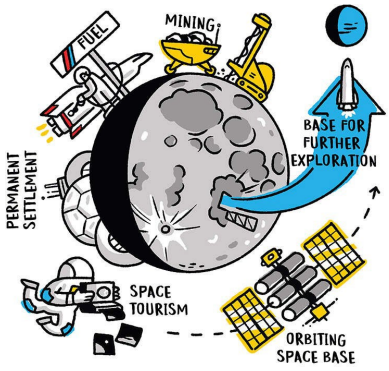
living and working in space, to start experimenting prolonged stays that will ultimately open the solar system for human exploration.

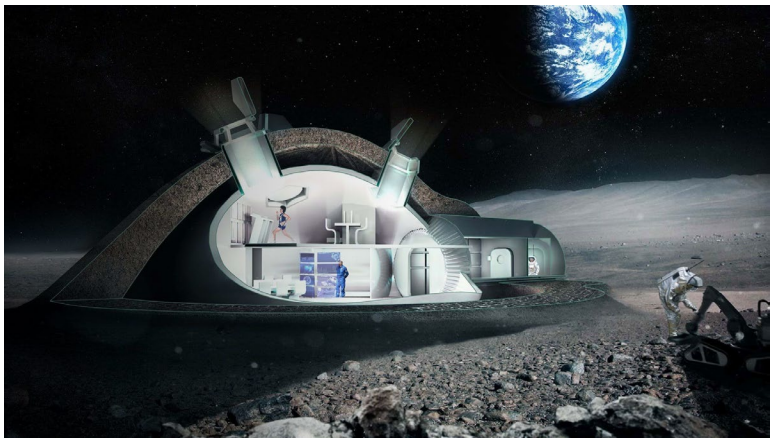
With all these exciting prospects in mind, future lunar missions will provide new insights into our origins and into how the universe works. The most famous past discovery in this sense was made by NASA'S Lunar Reconnaissance Orbiter (LRO), in 2019, when it uncovered evidence of water in the form of ice in the rocks at the moon's north pole. Recently images from the same LRO have revealed places where the sun shines 96% of the time, which would prove ideal for the placement of a lunar base, as solar panels would never experience total darkness for more than a 24-hour period of time.

Additionally, NASA has been testing what the daily life of humans on the moon would feel like, including the infamous work commute. In the volcanic landscape of northern Arizona, less than 40 miles from the Grand Canyon, NASA is trying out a prototype for a lunar rover that will accompany the astronauts on Artemis on their journey to the satellite. The vehicle is rolling along on six independently rotating wheels and is designed to take humans to "scientific sites of interest". It is comparable in size with a family van, yet it is supposed to allow astronauts to work multiple days away from the home base. Marc Reagan, the program mission manager described the rover's role in lunar exploration: "the vehicle will have to keep the crew warm, keep electronics cool, carry solar panels for recharging, have compartments for the crew to eat and sleep and be able to automatically drive itself to meet astronauts at various locations". This "entire life support" will enable humans to collect probes and to conduct extensive scientific projects, which will eventually lead to new discoveries.

What else is waiting to be unearthed? Well, we have yet to understand the effects of deep-space travel on astronauts, to assess whether space radiation shielding is effective and to see how humans react to working in space for extended time periods. Moreover, we'd have to artificially reproduce earth's environment: the things like fresh air, water and food that we take for granted become problematic when thinking about the lunar surface. The moon's conditions are unfavorable for permanent settlement, but scientists are constantly looking for solutions. Some of the hardships astronauts will face include: space radiation, from which we're protected on earth thanks to the planet's magnetic field, dust that erodes space suits and temperature fluctuations, from -170 Celsius at night to -100 Celsius over the course of a lunar day. Also, construction will prove difficult: while on earth we're used to accounting for the force of gravity, on the satellite we'll have to keep buildings from exploding due to their pressurized structure.

The moon could serve as a base for further exploration - astronauts may even be able to fuel up for their Mars trip with their lunar rocket fuel. People could choose to spend their holiday at an orbiting space base or even in a permanent settlement on Earth's satellite. Space tourism could finally become tangible - there are already some startup companies planning to offer expeditions on or around the moon, estimated to start anywhere from 2023 to 2043. Two main types of lunar tourism would be available: flyby in a circumlunar trajectory and lunar landing. Don't get excited just yet! While space tourism will be accessible to the public, its costs will be too high for a normal person: for a circumlunar flyby, Space Adventures is charging $150 million per seat, including ground-base training. On the more expensive side, the Golden Spike Company is charging $750 million per seat for future lunar landing.





All these sound inspiring, but one is inclined to ask: humans are on the moon, what's after that?Mars? Possibly. Probably. Who knows?

CONCLUSION

To put it simply, humanity is going back to the moon in order to extend our horizons, both scientifically, technologically and literally. We have always been driven by curiosity, by intellectual development and by the possibility of something new, of something perhaps better. We're engrossed in a constant search for knowledge, one that we've decided to take into space, farther than it has ever previously been.

The implications of such a goal are endless and inspiring; in truth, we don't know what the future holds. We don't know what we'll discover, what we'll achieve, or how far the lunar expeditions will take us. We hope for a permanent settlement, for an orbiting space base, for moon-made rocket fuel, for space tourism and even for space mining, but we have multiple hardships to overcome until then. Our brightest minds are working on achieving everything stated before -sooner or later, our goals will materialize in one form or another.

Returning to the lunar surface will be the next “small step” that will give rise to the future, very distant, giant leap for mankind.

SOURCES

1. https://www.rmg.co.uk/stories/topics/nasa-moon-mission-artemis-program-launch-date
2. https://www.rmg.co.uk/stories/topics/why-did-we-stop-going-moon
3. https://en.wikipedia.org/wiki/DearMoon_project
4. https://www.autoevolution.com/news/russia-s-orel-spacecraft-aims-to-challenge-nasa-s-orion-to-the-moon-they-ll-need-luck-198840.html
5. https://spacenews.com/china-claims-progress-on-rockets-for-crewed-lunar-landings-and-moon-base
6. https://moon.nasa.gov/exploration/history
7. https://www.nytimes.com/2022/09/01/briefing/nasa-moon-mars-space-travel.html
8. https://www.iop.org/explore-physics/moon/what-next-for-humans-on-moon
9. https://www.pbs.org/newshour/science/3-things-nasa-is-testing-for-its-future-moon-base-camp