Technologies Beginning the Space Age

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Introduction:

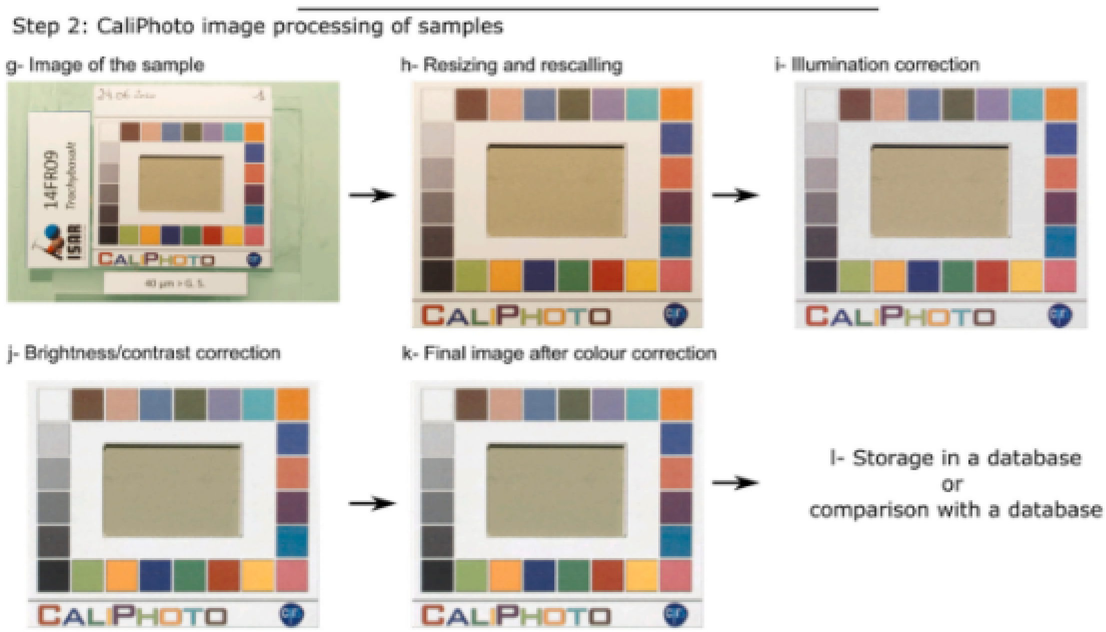
The Human race has always been exploratory. 60,000 years ago our ancestors migrated out of Africa into Europe and Asia, and through land bridges to the Americas and Australi [6]a. Later in the late 1400s, humans would re-connect the world in an effort to find wealth reconnecting Afro-Eurasia to the Americas [7]. The reconnection of the land masses on earth granted the empires and nations that capitalized on this opportunity immense wealth. This catapulted their people to later dominate the world, but it was not all moral. The domination exploited the people of the Americas killing off 90% of the native population through war but mainly disease [7]. Recently, humanity has begun a new age of exploration that is possibly the most influential one in human history: the exploration of space.

Currently, there are many restraints in space exploration. Retrieving and Analyzing materials is one of the many problems. It remains incredibly prevalent due to the lack of mobility that technology enables us to explore on other planets making it hard to retrieve and analyze materials. This remains an important process. This process is required to plan additional manned missions. The vastness of space remains a large problem because of the relatively slow speed at which spacecraft can reach; however, the greatest problem is cost in monetary means and resources. Scientists are working tirelessly to make space exploration more sustainable. It can positively impact the Grand Challenges area of sustainability by improving space analyzing methods, planning missions more efficiently, and increasing the efficiency of equipment to reduce size, increase speed, and productivity. But most importantly, they are working to curve costs to advance the human race into the cosmos.

Igneous Rock Identification:

During drilling on missions to the surface of Mars, materials are altered and piled on the surface to collect samples of said material. These materials are then analyzed to identify the composition of matter. The issue with this method is that the instruments and sensors doing the analysis need to be improved in their ability to accurately identify those materials. In 2021, scientists in Europe developed a solution to that problem. They developed cameras to read the RGB values of each pixel to analyze the composition of rock with up to a 90% accuracy rate [1].

Dr. Foucher, Bost, Guimbretiere, Courtois, Hickman-Lewis, Marceau, Martin, and Westall created a database of various different materials from Mars. They created the database by taking photos of the rocks crushed to different grains and running them through an image processing method called Caliphoto. From this method, they would determine the color of the material using RGB and take the average value between the grain sizes. They then created the database using those RGB values in addition to the revealed name of the material. Afterward, the group tested the database on the same samples under different lighting and determined the method to have a 90% accuracy rate [1].



The database is part of a system that works in three steps: taking the photo, processing the image, and running the RGB value through the database. The first step is self-explanatory; however, processing the image with the Caliphoto method developed by the group is more complicated. The process first includes resizing and rescaling the image to create a 1200px X 1020px image, then altering the lighting to remove the effect, then grayscale squares of the image are used to improve the brightness and contrast, and lastly, a reference image of the material is used to further correct the colors. The data is then compared to the image data in the database which results in it matching the sample image to the type of material. This process makes it easier to identify materials on the surface of planets with less equipment, so scientists and space enthusiasts can plan missions into space that are more sustainable[1].

Membrane Technologies:

Space Engineering is a field that focuses on solving logistical problems for deep space exploration. Space Engineers typically optimize spacecraft for long-term missions by minimizing the volume, mass, cost, and power consumption of spaceships. However, the field is changing with new technologies created by Dr. Bernardo, Dr. Iulianelli, Dr. Macedonio, and Dr. Drioli aided by The Institute of Membrane Technologies. New developments in membrane technologies make sub-optimal processes on spacecraft more efficient. This allows for more sustainable ways for water cleaning, fuel production, and gas separation while maintaining lightweight and scalable [2].

A challenge that membrane technologies can help with is recycling water. It does this in membrane bioreactors (MBR) to replace the original Convention Activated Sludge (CAS) process. The CAS process has two stages: first, oxygen is placed in a tank with the chemically treated water to promote microbe growth that produces a floc out of the original waste, then, the water is moved to a settling tank where the floc falls to the bottom. In an MBR, chemically treated water passes through a membrane that separates the solid material from the water. The MBR does not require a settling tank making it more compact [2].

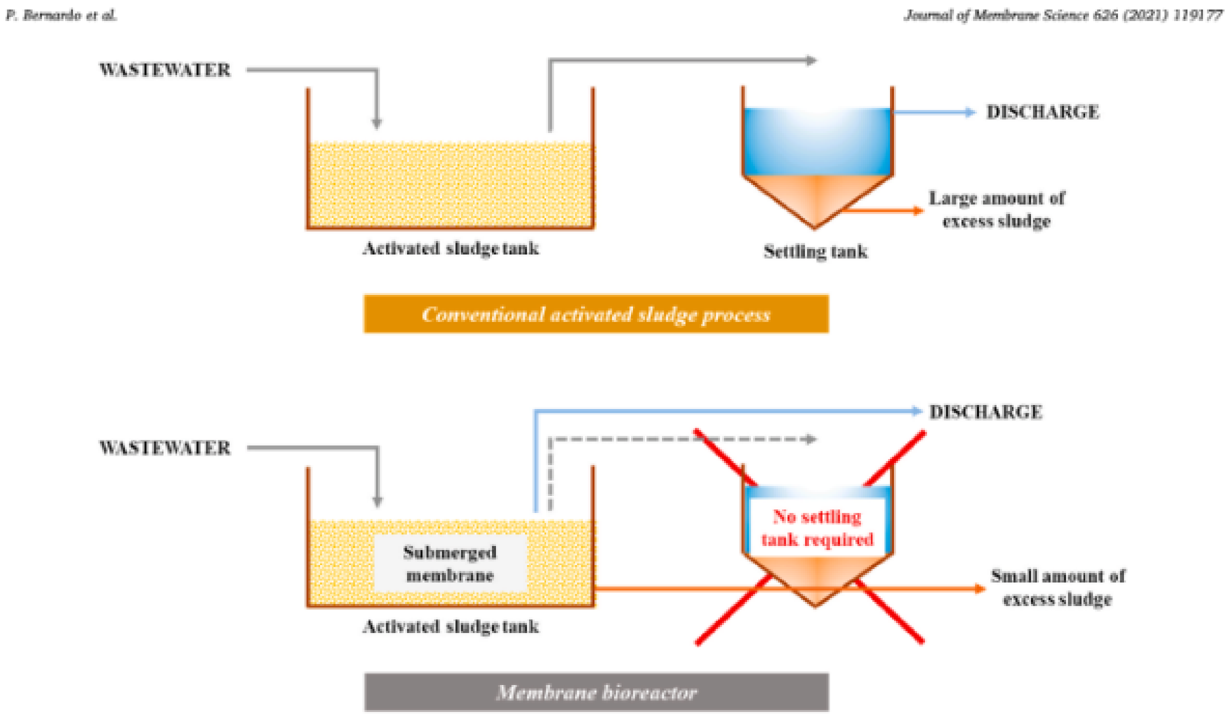


Fig. 3. Conventional activated sludge process vs membrane bioreactor.

Another challenge in spacecraft that these new membrane technologies could aid with is separating oxygen from Carbon Dioxide. The current system used in the ISS uses more power and is too massive for what is desired for long-term space travel; however, an electrochemical membrane could be a solution. The method works by moving carbon dioxide to the membrane with a carrier that is tightly bonded to it to aid in forcing it through the membrane. The carbon dioxide is then separated from the rest of the air when the carrier is oxidized through the membrane to lower its affinity towards carbon dioxide. The carrier is then diffused to the start, reduced, and placed back in the process. This improvement means that the process of cabin atmosphere maintenance requires less power making it more sustainable for long journeys. Separating CO_2 can also be used to create fuel from Carbon Dioxide Methanation [2].

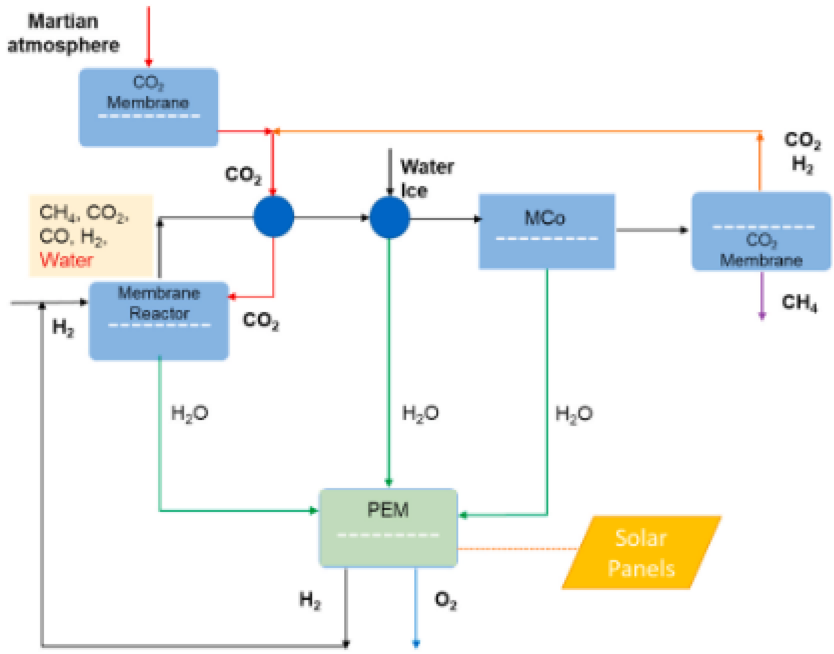
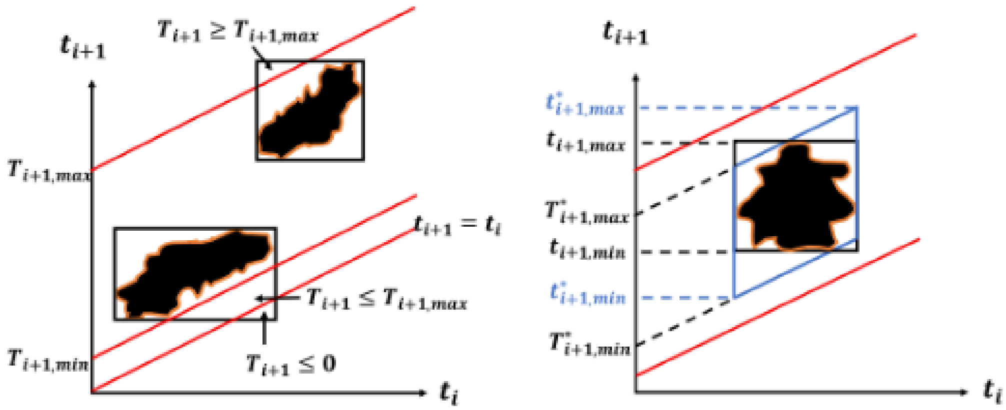


Fig. 18. Schematic of an integrated membrane cycle for CO_2 methanation and water electrolysis.

Finally, membranes can be used to separate water after the Carbon Dioxide Methanation. This process is required for a self-sufficient space colony due to the fact that it produces methane, for fuel, and water. The process can be enhanced by using a Membrane Reactor (MR) because it combines the reaction process with the separation process. It works by first reacting Carbon dioxide with hydrogen-producing Methane and Water then heat-resistant methanes separate the water vapor from the reactor letting it be used for other purposes [2].

Gravity-Assisted Launching:

With our current level of technology, it is incredibly inefficient to send space probes to the edges of our solar system. Our solar system's edge is located at 80 - 150 AU (AU is one earth's distance from the sun). Currently, for space travel, space agencies use metaheuristics algorithms to calculate space trajectories for optimal fuel consumption. To optimize the process even more, they prune the possible solutions using another algorithm called gravity assist space pruning (GASP). Moreover, the method is not practical for exploring the far reaches of the solar system because there are more variables associated with the extended flight time. In 2023, A team of scientists developed an algorithm that when applied can increase the flight speeds beyond that of the Voyager and Pioneer spacecrafts [3].



(a) rectangular solution space box bounds **(b)** rhombic solution space box bounds

Fig. 7 a, b Shortcomings of rectangle and rhombus in determining the solution space box bounds, respectively

Scientist Yuqi Song, Weiren Wu, Hang Hu, Mingpei Lin, Hui Wang, and Jinxiu Zhang created a space pruning function that further limits solutions provided by metaheuristics and refined by GASP. This algorithm makes traveling long distances throughout the solar system more time-efficient. They tested this algorithm by simulating a flight to the tail of the heliosphere with as many possible gravity assists from planets by receiving two from Earth, two from Venus, one from Jupiter, and one from Neptune before reaching the heliosphere's tail, which is the protective shield that protects the solar system from interstellar radiation. This process succeeds in proving the potential of the new method [3].

The method works with the metaheuristic algorithms, creating many local optimal values. The metaheuristic algorithms plot the solution in a 2D graph called a solution space. The GASP algorithm then comes and refines that solution space reducing the size of it in the 2D graph. Finally, a range of values is produced by overlaying a rhombus and square overtop of the original solution space. This creates a range of possible solutions that can be averaged to find a more accurate flight path [3]. This can enhance the fuel efficiency of spacecraft making it more sustainable and laying the groundwork for future generations to expand into the cosmos.

Intuitive Machines with ASU:

Originally beginning as NASA's Project M and then Project Morpheus, Intuitive Machines is a company that focuses on bridging the gap between humans and the moon [4]. As of 2021, the project received a grant of $ 41.2 million from NASA to explore the south pole of the moon. This mission objective is to analyze the craters on the surface and retrieve high-resolution images for studying and gathering data on the temperature of permanently shaded regions of the moon. The mission scientist lead is Mark Robinson of Arizona State

University's School of Earth and Space Exploration. He believes that the space exploration mission will "provide critical engineering information for designing larger-scale exploration over the next decade"[5].

The team at Intuitive Machines plans to launch their µNova spacecraft to gather information about the PSR zone. PSR are permanently shaded regions on the moon caused by the moon's lack of rotation. " µNova is a propulsive drone that deploys off of a Nova-C lander and hops across the lunar surface on the IM-2 mission" [4]. The Nova-C lander can cover up to 25km from the landing zone and hold a kilogram of analyzing equipment that they believe "may provide the critical science needed to sustain a human presence on the Moon." There is also an LX version of the µNova hopper that can hold an additional 7 kilograms of scientific equipment [4]. The data uncovered by this mission can lead to thoroughly planned missions. This can help minimize resource consumption making the process of space exploration more sustainable.

Societal Challenges:

If the positives of space exploration and colonization are so great, why are the efforts made so small? When the consequences of utilizing these technologies, developing missions, and sending humans into space are so great, what could hinder the expansion of this industry? Today's society, specifically in Western civilization, is plagued with grief from its past colonization phase. It recognizes the harm it has caused to many cultures around the world. Currently, society, for the most part, is working to correct the oppression it has caused to the subjects of their empires and the minorities that reside in their current state borders. The space industry faces resistance to growth because society is cautious not to make the same mistakes of the past.

One such mistake is the distribution of resources from the colonies. In the past, much of the profits went to aristocrats of the empires. Even though the countries were prosperous, the wealth rarely made it down to the lower class. One of the challenges of space travel is making sure the wealth benefits the whole of society rather than the wealthy elite. The failure to acknowledge this challenge can make the wealth gathered from space exploration void and cause internal violence. In 1789, the French ruling class failed to tackle this challenge [9], and it caused the overthrow of their government in the French Revolution [8]. This in turn led to the rise of Nepoleon and the Napoleonic Wars. Another example is the Russian Revolution when the Russian aristocrats failed to learn from the mistakes of the French. This caused the collapse of the Russian Empire.

Wealth distribution can also affect the inequity between countries. In Europe, The wealth gained inside countries like Great Britain, France, Austria, Prussia, and Russia allowed them to control and absorb countries that did not participate in colonization. Countries like Poland were wiped off the map by the more powerful countries of Prussia, Austria, and Russia. The Holy Roman Empire was dissolved by France. The Ottoman Empire was destroyed by France and Great Britain after World War I. The most major problem of space is making sure the wealth benefits everyone in society and the countries on the frontline of space exploration respect the sovereignty of smaller nations.

Today, society sees the mistakes made by these past empires. There are now many efforts to right the economic disparities and uplift the countries affected. Society has shifted to reject the imperial and unequal nature of its past, and the concept of space travel and colonization can repeat these mistakes. The concept of repeating the violence of the past pushes society away from space travel. However, society does not learn from the past. Society lives in the past. It fails to grow and take the lessons learned into the future. Until Western civilization moves on from the mistake of its past, there will be public dissent for space travel causing the process of expansion to be hindered.

Conclusion:

With the new technologies developed, space exploration has become much more sustainable. Planning for a new mission in space becomes easier with the new imaged-based igneous rock identification methods, and a proper moon exploration mission will be planned and carried out with the information gathered when the μNova mission occurs scanning the shaded regions of the moon for water. With modifications to the GASP system spacecraft travel speed can be enhanced to make moving from planet to planet faster and require fewer materials while membrane technologies from the Institute of Membrane Technologies will lessen the amount of materials required on spacecraft by limiting the size of important technological systems. As new technologies come out and continue to develop making space travel more accessible and allow for our species to reach the next age of exploration.

Currently, the human race is at a new beginning of an age. Our species has migrated to every major land mass with great migration and recontinued the earth with the European conquest of the Americas conquering our planet. Now, it is time our species expand beyond the bounds of our home world to become a species in the cosmos possibly being the first to do so. Like in the past, the first group to jump on the opportunity gained immense wealth and power. However, our race has grown learning from the past, so this time we can use the wealth gifted to us from the cosmos to better the lives of our fellow humans.

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