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NAYGN Mars Colony Essay Contest
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In the history of humanity, only twelve people have ever set foot on another celestial body, the Moon, which is only about 384,000 km from Earth [1]. By contrast, the only four rovers have been sent from Earth to traverse Mars, which is about 143 times further than the Moon. To send a crew and establish a self-sustaining colony on the surface of the red planet is a very daunting challenge. To maximize efficiency and resources, the crew will require an energy source that is immediately available upon landing in order to operate tools and other technologies for the purpose of building habitats, exploration, collecting water, growing food, and other essential activities for human life.

Mars has an atmosphere around 100 times thinner than Earth's, with an oxygen concentration of only about 1.6% [2]. The thin atmosphere is also ineffective to shield the surface of the planet from the sun's radiation and temperatures can drop down to -125 degrees Celsius [3]. As such, utilizing the spacecraft and its power source as the energy source for the first Mars habitat would be extremely efficient. An ambitious mission like a Mars colonization requires futuristic and innovative energy sources to meet this challenge, such as nuclear fusion power.

Although fusion power is not yet a reality, organizations and countries around the world are racing to become the first to produce magnetic confinement reactors that will produce net positive fusion reactions. Supposing that magnetic confinement fusion reactors such as tokamaks (Fig. 1) eventually achieve fusion ignition, the point where the fusion reaction is able to sustain itself, these apparatuses could hypothetically power the laser injectors of the electromagnetic propulsion system on the spacecraft, such as the Variable Specific Impulse Magnetoplasma Rocket (VASIMR) (Fig. 4) [8]. After powering the propulsion system, the tokamak could be disconnected to supply the energy needed to construct the Mars colony (Fig. 6).

Tokamaks are fusion reactors that harness the heat from fusion reactions produced in a toroidal vacuum chamber. When elements are super heated to temperatures of hundreds of millions of degrees Celsius, the element's atoms are stripped of their electrons, becoming free electrons and separate positively charged nuclei or ions. Normally, these positively charged ions would scatter away from each other, as two particles of the same charge will repel due to Coulomb forces. However, at such high temperatures, the positively charged nuclei are able to achieve speeds great enough to overcome the repulsive Coulomb forces separating them in order to fuse and create heavier elements [4]. Tokamaks use toroidal and poloidal superconductive magnetic coils to contain the plasma in a confined loop to keep the stream from hitting the walls of the reactor [5].

Tokamaks use two isotopes of hydrogen as plasma fuel, deuterium and tritium. Deuterium can be found in water, while tritium is scarce and radioactive, with a half-life of about 12.3 years [6]. However, tritium can be bred during the tokamak's operation by adding a lithium breeding blanket to the inside of the tokamak (Fig. 2) [7]. When heated to a temperature exceeding 100 million degrees Celsius, deuterium and tritium atoms will fuse, producing helium-4 nuclei, neutrons and a large amount of energy (Fig. 4) [4]. If the plasma is able to sustain its own fusion reactions, it is self sustaining, like the reactor on this hypothetical spacecraft. The constant energy produced by fusion is absorbed by the walls of the tokamak in the form of heat. A heat exchanger absorbs this energy, which a generator converts into electricity that can be used to power the neutron beam injectors that heat the plasma in the VASIMR system (Fig. 2) [11].

Any human requires four basic commodities in order to survive: air, water, food, and a habitable shelter. Therefore, the location of the first colony is also important to the mission. By landing and a region with a thick ice pack, the spacecraft can shut off the electromagnetic propulsion system and use the tokamak's energy to deploy a drill to bore down to the terrafirma and anchor the spacecraft down to a rocky subsurface. The displaced ice will provide the crew with a new source of deuterium and water to distil for drinking and growing food. Through electrolysis, the water can also be separated into oxygen to create breathable air. After the spaceship is secured, smaller rovers and boring machines powered by plutonium-283 RTGs, will be deployed. While some will be used to collect soil, ice, or debris for scientific research, others will continue mining the terrafirma to extract lithium to replenish the tokamak and create subterranean habitats for the crew. As they are below the surface, the habitats are also largely protected from any cosmic radiation and dust storms. Once the habitats are completed, oxygen and electricity from the tokamak can be diverted so the crew can begin life and research in the spacecraft and subterranean structures (Fig. 6).

In the first phases of development, the tokamak is the only energy source in the colony. This fusion reactor provides a consistent baseline power for the small community's electrical grid; therefore it is the colony's baseload energy source. However, as the small civilization expands, the Mars colonists engage in leisurely activities that require more energy. Intermittent energy sources, energy sources that are not continuous because of uncontrollable factors, mainly solar or wind power, are not possible on Mars [9]. The sun's rays are weak and unreliable on Mars, and frequent dust storms with speeds of over 100 km/hr would damage solar panels or wind turbines [10]. Instead, additional dispatchable energy sources, which are electrical power systems that can be turned on when demand peaks, such as geothermal energy, are much more reliable. With tokamaks supplying baseload energy, using geothermal energy as a dispatchable power source, and utilizing innovative technologies such as RTG powered exploration or mining rovers, radiation shielding with magnetic fields, and additive manufacturing, the Mars colony has the potential to sustain and become a successful community.

Figures:

Figure 1:

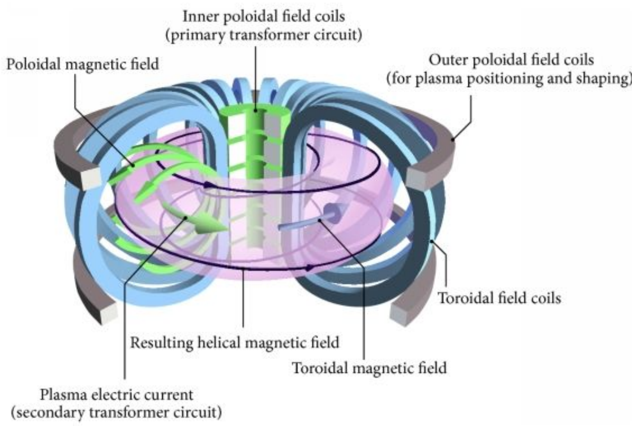


Figure 2:

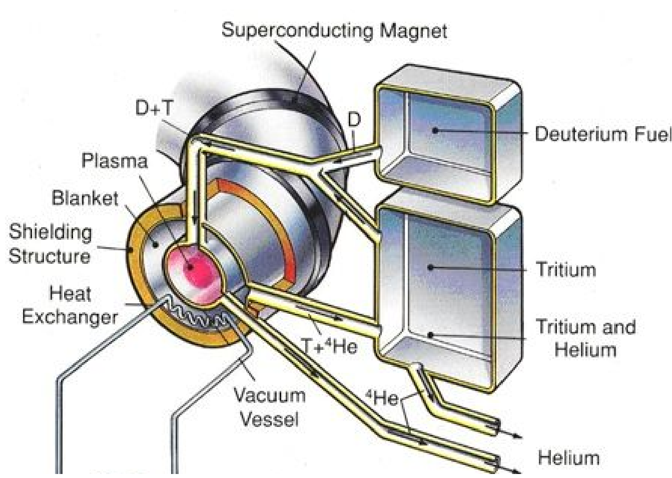


Figure 3:

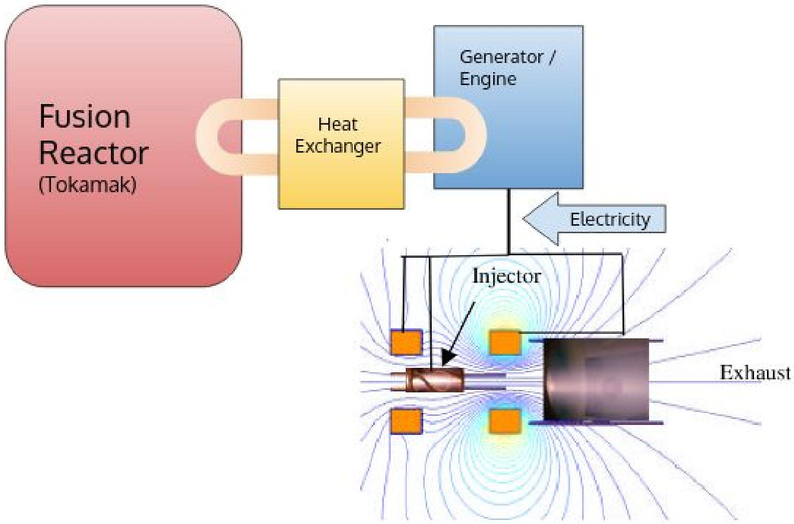


Figure 4:

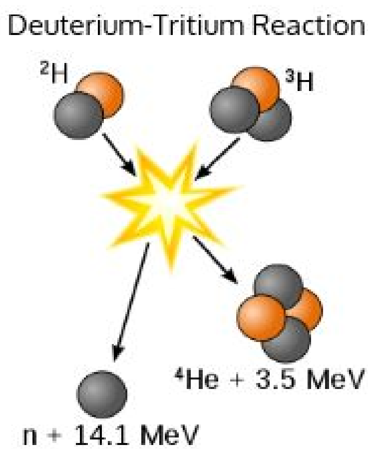


Figure 5:

The VASIMR electromagnetic propulsion system.

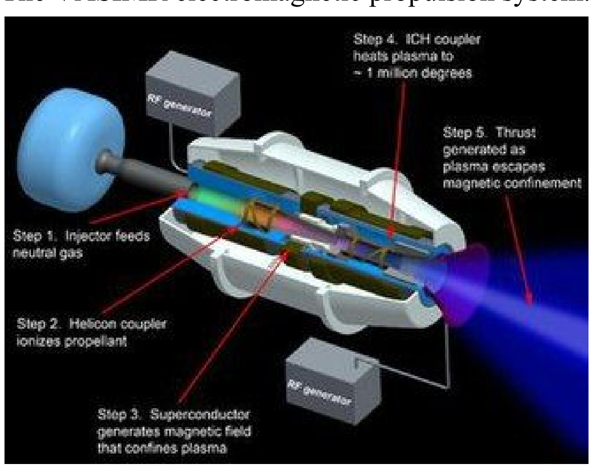
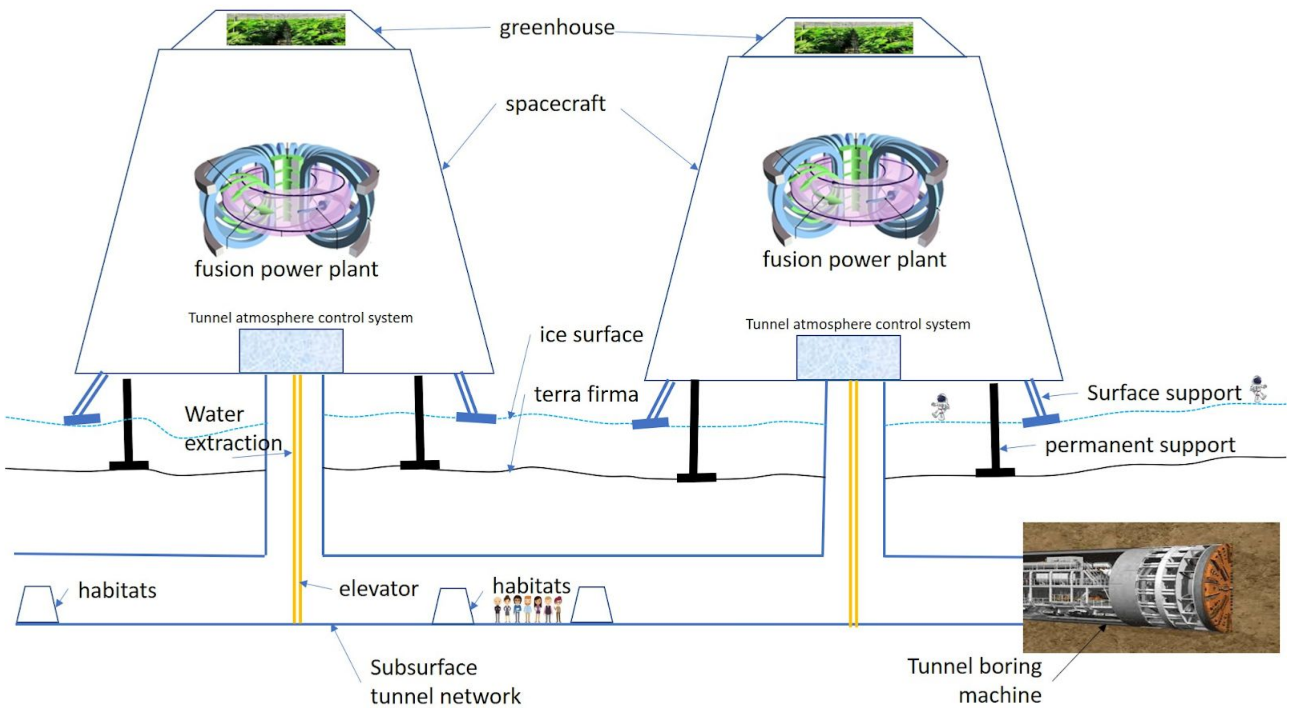


Figure 6: Proposed Habitat Design


greenhouse
spacecraft
fusion power plant
fusion power plant
Tunnel atmosphere control system
Tunnel atmosphere control system
ice surface
terra firma
Surface support
Water
extraction
permanent support
habitats
elevator
habitats
Subsurface
tunnel network
Tunnel boring
machine

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