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The Trojan Initiative: A Proposal For A Research Settlement On 2011 HM_{102} and A Framework for Future Settlement on Asteroids

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ABSTRACT

Humankind has yearned for hundreds of thousands of years to explore and truly understand the dynamics of our enigmatic universe. However, we have often been limited by our hindsight here on Earth, or the limitations of human travel to further destinations. Having the ability to send humans to deep space would arguably set us millions of years ahead in our scientific understanding of various physical processes, including insight on some of the key mysteries that we still face. Perhaps a settlement further away from the Sun, Earth, and limiting optical resolution could provide us with greater ability to collect more meaningful data through our telescopes or other instruments. Moreover, one of the most significant abilities of such a settlement could be slightly easier access to sites of research within our own solar system that could be essential in the forthcoming years, such as Jupiter, Titan, the Kuiper Belt, and some Oort Cloud objects. Here we describe a unique option and set of goals to pursue and achieve just that via a mission to an L5 Trojan asteroid of Neptune, 2011 HM_{102}. In this paper, we propose a number of possible challenges presented by traveling to the base, modeling its layout, maintaining the presence of life, and opportunities for research on the asteroid as well as possible solutions to these challenges.

We begin our journey by outlining some motivations for creating a settlement on the asteroid, then outline a few key technological goals that must be achieved before we are capable of efficiently sending a colony of people to the settlement. We describe materials necessary for its construction as well as a novel mechanism for artificial gravity utilizing the Roche limit of the asteroid and multiple applications of quark-gluon plasma. From there we explore more aspects of settlement design, including key considerations for the layout of our settlement, sources of power, and protection from high-energy radiation from sources such as galactic cosmic rays. Then, we embark on a detailed discussion on the measures needed to maintain life on the settlement, such as hydroponic crop growth, a cycle for water recovery and oxygen generation, temperature maintenance, and air purification. Some remarks on the sustainability of life on the settlement follow, as well as some recommendations for entertainment, social life, economics, and governmental systems on the settlement.

Keywords: 2011 HM_{102}, trojan asteroid, settlement, space exploration

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REASON FOR SETTLING

Outlined by Briana Chen

Our primary reason for settling is due to the large amount of research opportunities from our position on 2011 HM_{102}. The distance from the Sun is one of the most important aspects of this settlement. This would allow for less solar interference when analyzing radiation data, which is a persistent problem on Earth and even on nearby planets and objects such as Mars and the Moon.

Since our settlement focuses on one of Neptune's trojans, settlers would also be able to study Neptune's environment. This is one of the better places to choose as there is not a potentially hazardous orbit, with trojan asteroids having a 1:1 mean-motion resonance as a planet— essentially, it has the exact same orbital period as the planet, which is considerably stable (*2011 HM102: A new companion for Neptune*, n.d.). It has remained in this resonant configuration with Neptune for at least a billion years, so this companionship is likely to ensure stability even further in the future, a good indication for a long-term settlement such as ours would be.

Another reason for settling on a Neptune trojan would be to discover a greater population of trojans. For example, Jupiter is known to have around a million objects in its Trojan swarms, and this means that Neptune must also have a considerable number of trojans and trojan-like objects surrounding it. These objects are difficult to find, but by settling on one of them, we would likely be able to better detect other similar objects due to our close proximity.

Specifically, we chose 2011 HM_{102} because it has the highest inclination out of other known Neptune trojans (29.4 degrees) and is also very bright. It has comparable brightness to Jupiter's largest L5 trojan Patroclus, which really has so much brightness only because it is a binary. Thus, by settling on the possibly largest L5 Trojan in our solar system, settlers would be able to study its unique properties in further detail (*2011 HM102: A new companion for Neptune*, n.d.).

The placement of our settlement allows the settlers to directly see the center of the Milky Way, providing a newfound way of studying its supermassive black hole. In this direct line of sight, the settlers would likely be able to discover new data and emissions from the black hole.

Overall, the most important aspect of this settlement is to conduct novel research on the lesser known aspects of our galaxy.

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POPULATION

Outlined by Geetika Chitturi

The population of the Trojan Initiative settlement would consist of 150 scientists and researchers trained in space travel. These 150 settlers would be a diverse group of qualified people from all over Earth. When a settler wishes to leave the settlement, finishes their research on the settlement, or must travel back to Earth for medical or legal reasons, they would be transported back to Earth and another scientist or researcher would be transported to the settlement to join the Trojan Initiative, keeping the population of the settlement at 150 settlers at all times.

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TRAVEL TO SETTLEMENT

Outlined by Archit Kalra

A Quark-gluon Plasma-based model for an Antimatter Engine for Propulsion towards the target asteroid

Given the relatively far distance to the asteroid from Earth, it is imperative that the means of traveling to and back from the base are faster than current ones. This is especially imperative since in the case of an emergency, it could take years to actually send help with conventional engines. We propose the creation of an antimatter engine slightly different from current models which could serve as a way to travel between the Earth and the asteroid.

The need for modifications to current models primarily manifests itself in that there is an extremely limited amount of antimatter that we have been able to produce so far, and it remains a challenge to efficiently store it using current ion traps. One of the best solutions to this issue is a novel mechanism that would incorporate a material that could hadronize and produce matter-antimatter pairs by itself. Namely, quark-gluon plasma, a substance nearly as primordial as the universe itself, could facilitate our travel to the final frontier. Using extremely high temperatures and with the help of a particle accelerator, we can create quark-gluon plasma and store it in a way such that cooling small amounts of it sequentially can create matter-antimatter pairs and generate large amounts of energy (Rafelski, 2015).

So far, there has been limited interest in using quark-gluon plasma to help us travel into space, primarily because it would appear to be a bogus idea to rely on a substance that has lasted for seconds in the few times it has been successfully created, but there are some ways in which we can optimize its production and storage. Here we will go on a brief tangent to discuss some of the current advances in quark-gluon plasma production and ways in which it can be stored and repurposed to accomplish our goal.

Current methods of quark-gluon plasma production generally involve colliding heavy ions at relativistic speeds (Nayak, 2019), but the amounts of plasma that are actually produced hadronize relatively quickly (pun intended). Granted, this is primarily to create substance to study and analyze the properties of rather than optimize for engineering. To improve the efficiency of this process, we propose further research on the creation of a decelerator capable of decelerating and stabilizing quark-gluon plasmas, which is no doubt an immensely difficult task. However, if it is done, the possibilities for study as well as genuine application of quark-gluon plasmas would be enormous. Once such a decelerator is active, it could help produce and ultimately trap quark-gluon plasmas that can be sequentially cooled to produce annihilating pairs.

Although the concept in itself of creating a large amount of quark-gluon plasma and expecting the model to succeed perfectly without causing massive explosions may be far-fetched at first thought, there are some possible measures that could drastically increase our confidence in such a venture, specifically in terms of ultrahigh temperature ion traps that can trap and store the quark gluon plasma and allow it to be filtered out in extremely small amounts to condense and annihilate. Some of the most reputable ion trap models to date have been pioneered by Penning, Malmberg, and other revolutionary scientists (Dubin & O’Neil, 1999); these are not intended for quark-gluon plasmas, but remodeling and retesting the potential

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for such traps to efficiently store them at high temperatures could change our perspective of this issue and allow us to achieve the goal of antimatter engines.

As previously mentioned, there is the issue of high temperatures as well. Quark-gluon plasma was produced on Earth at temperatures upwards of 4 trillion degrees Celsius, the hottest temperature ever achieved on the planet (Brookhaven National Laboratory, 2010). To circumvent the issue of having to expend an enormous amount of energy to get an energy source, we propose an intuitive maneuver. The energy produced by annihilation can be used to power two separate processes: the thrust of the rocket engine as well as the heating of the quark-gluon plasma apparatus. Initially, there will need to be an external source that could power the trap in order to store the plasma at the high temperatures required, but once some of the plasma slowly flows through and exits into a separate annihilation chamber, some of the energy released can return in a feedback loop to continue the process until there is no more thrust needed, when the gates can be modulated such that a very limited amount is used to self-power the storage of the quark-gluon plasma.

Despite some of the possible inefficiencies in isolating the quark-gluon plasma and cooling it bit-by-bit for annihilation, antimatter is indisputably one of the most powerful power sources for space propulsion (NASA, 2006). The potential for reaching relativistic speeds with such an engine is enormous, and having novel mechanisms involving quark-gluon plasmas could have hitherto-unimaginable implications as well as possibilities.

Similar modeling can be used to easily power the space settlement itself using quark-gluon plasmas and matter-antimatter annihilation.

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SETTLEMENT MATERIALS

Outlined by Raghav Sriram

The primary challenge of building settlements is not finding technology advanced to get the job done: Instead, the primary challenge is getting enough resources and materials that can be used to build the settlement itself.

Materials to Build Structure

The components of our space settlement are simple, yet serve complex purposes. To give strength to the structure, in order to withstand storms and below zero temperatures, we will use silicon carbide, Ti-Al Alloys, and Polyamide Fibers such as Kevlar. PVC and Nickel Magnesium Alloy are for cooling and heating pipes. To protect against corrosion our structure will be coated by a layer of Aluminium Oxynitride and Indium Tin Oxide. For internal life support components, piping and frameworks will be developed via carbon nanotubes and Boron Nitride Nanotubes. Additionally, BoPet will be used as the main component of astronautical suits and equipment due to its high tensile strength, chemical and dimensional stability, and electrical insulation properties (Gale, 2016). Additionally, suits will be suited with MLI to protect against radiation.

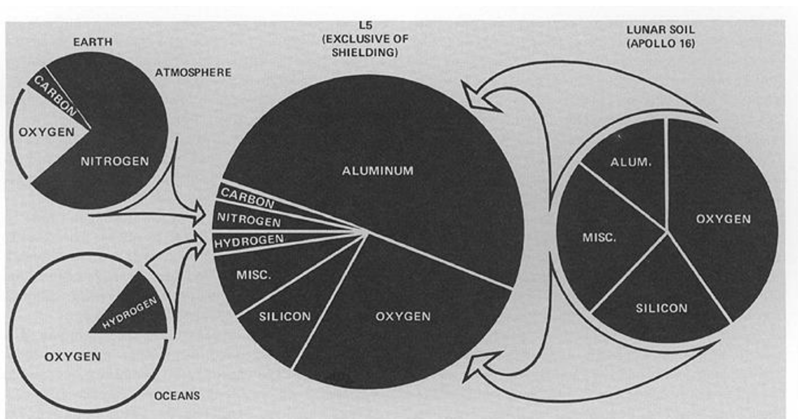

Figure 4-10.– *"Sources of Materials" pie chart of resources and their locations relative to L_5.*

(Cloh, 2017)

Laser Mining

A likely first manufacturing project for our settlement would be using lasers to cut shapes out of existing rock on HM_{102}. Shipping solar-powered lasers to use our asteroid as the building blocks of our settlement is a viable and cost-effective solution. At the first stages of our settlement, essentially, the most effective approach is assembling our laser cut-out blocks into a sphere, installing a docking portal, and wrapping the entire settlement in plastic in order to keep it together and air-tight. Once applying thick coats of paint and epoxy to the interior of the structure, thus creating a simple but easy to make initial settlement structure prior to our final structural ring.

Recycling Trash

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Expired missions such as the Apollo Missions, often drop their technological waste into Earth's orbits. There is no reason why key components, panels, and structural members from completed missions such as these should not be migrated to a re-assembly point for the 2011 HM_{102} mission.

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SETTLEMENT DESIGN

A Model for the Simulation of Artificial Gravity

Outlined by Archit Kalra

This segment does involve a considerable amount of approximations at the moment, but primarily serves as an example for the construction of an adaptive artificial gravity apparatus that can emulate normal conditions as they are on Earth.

For the sake of comparison to Earth, we can calculate the gravitational acceleration on 2011 HM_{102}. However, we will need to make an approximation of the density of the object to derive a rough metric for the mass first. The density ρ of the Trojan would likely be near 1.5 g/cm^3, especially due to the high icy compositions of many asteroids in the area as well as a decent partial composition of rocks and metals such as iron. Given this, coupled with the observed radius R of the object (100 km), we find that a rough mass M of 2011 HM_{102} is

$$M = \frac{4}{3}\pi R^3 \rho$$
$$= 6.28 \times 10^{18} \text{ kg}$$

Since the gravitational acceleration is $a = \frac{GM}{r^2}$, we find that the gravitational acceleration is $a = 0.0419\, m/s^2 = 4.27 * 10^{-3} g$. This is clearly lower than the Earth's gravitational acceleration by multiple orders of magnitude. However, since current systems of artificial gravity generally involve invoking a centrifugal force that would simulate a gravitational force for people who are facing inwards relative to the center (essentially "upside down"), our settlement must also be oriented in a way such that there is a simulant of gravity, albeit in the opposite direction (upside down).

We propose the implementation of a magnetic ring-based artificial gravity system that can increase the rotation rate of the asteroid about an axis and induce a centrifugal force that can attract objects to the floor of the settlement. This is arguably far more beneficial than having an artificial gravity system solely act on the settlement structure itself because even slight mistakes in traveling on the asteroid surface itself could cause a person or an object to reach escape velocity and travel away from it. The presence of an artificial gravity device that can encompass the entire asteroid would prevent such issues from occurring.

To actually create this ring and activate it, we propose a novel mechanism that involves releasing an ultra-dense core before landing on the asteroid. This ultra-dense core would orbit the asteroid and contain multiple piezoelectric segments that would fragment upon approaching the Roche limit of the asteroid. The sheer force of fragmentation would activate and induce a magnetic field that could be coordinated by multiple segments derived from the core and force the asteroid to rotate faster. A quantitative approach to this follows:

$$d \approx 2.44R\left(\frac{\rho_M}{\rho_m}\right)^{1/3}$$

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Solving for ρ_m, we get $\rho_m = \rho_M \frac{14.53R^3}{d^3} = \frac{2.1795*10^7}{d^3}$

If the magnetic ring is d = 110 km above the center of the asteroid (10 km above the surface if we maintain its approximation as a sphere), there will still be sufficient gravitational attraction to the asteroid. With this metric, we find the density of the satellite in order for it to be torn apart must be 21795 g/cm^3 =22 kg/cm^3. This is clearly extraorbitant, but theoretically can be achieved by yet again incorporating some of the wondrous properties of quark-gluon plasma and uniquely using it as an "adhesive agent" to bind parts of the artificial gravity device together and increase the density of the combined device to the desired value.

As previously discussed, we can theoretically produce quark-gluon plasma at high levels and store it using the novel trap mechanism as discussed previously in our discussion of antimatter engines. The plasma would not only act as a way to increase the density of the object and allow for it to break apart, but also, in a controlled cooling process, power the magnetic fields of the satellite by forming matter-antimatter pairs that can annihilate, as mentioned in the section on the antimatter engine.

Here we introduce a brief model for a possible unit structure for a magnetic field-generating device that would accomplish this. To induce a magnetic field, we can add an electromagnet into a cubic structure that can be remotely activated or inactivated by controlling the rate of cooling of the quark-gluon plasma and subsequent annihilation of matter-antimatter pairs. The primary issue in this design is how exactly we can limit the amount of quark-gluon plasma that can be cooled at a particular time so that we can modulate the amount of energy released and have a greater efficiency in powering the device as well as ensure that all of the plasma does not form matter-antimatter pairs immediately. Thus, there must be a heat cylinder magnetic trap that can store the plasma at high temperatures as well as a pore that is remotely operated such that a limited amount can be released and cooled as necessary.

We can approximate that the mass of such a unit (without the quark-gluon plasma) may be 1-2 kg (1.5 kg for the sake of calculation) and the volume about 200 cm^3; with 100 units, we have about 150 kg and 20,000 cm^3 of volume. However, to achieve the desired density so that the object can break up in the Roche limit and have the artificial gravity effect, we must add ~286 kg of mass without changing the volume. Following an approximate metric that quark-gluon plasma has a density of 40 billion tons per cubic centimeter (Mrówczyński, 1999), we can achieve this since 286 kg of it adds $7.88 * 10^{-12}$ cm^3 of volume to the material! There is the slight matter of actually storing the quark-gluon plasma at extremely high temperatures to prevent it from condensing, but this can easily be done within the unit cells themselves so it does not add additional volume to the device.

Once these unit cells break apart and form a ring around the asteroid, the electromagnets can be remotely activated and create separate magnetic fields that can interact with the metallic asteroid and create a torque. In approximate terms, the torque can cause a centrifugal force to build up and generate artificial gravity close to g as desired.

As a consideration, it is important to note that this is based on the hope that there are few adverse effects associated with our design, but with the understanding that they will likely come up at some point in time.

Chiefly, these complications could include but are not limited to possible perturbations to the asteroid's orbit around the Sun or issues with our magnetic field if the asteroid ends up being more chondric or less metal-heavy. There must be more detail in these calculations, and it would be fantastic to have an exploratory mission to the asteroid that can gather some more detail on the demographics such as its composition before sending this device in preparation for the settlement.

Layout of Structure

Outlined by Briana Chen

This settlement is shaped similar to a torus, and the circumference around the asteroid will be the Trojan Initiative settlement.

To begin with, there will be windows for conducting research, as well as designated areas for said research. Sectioning out areas for research will help distinguish living areas from work, similar to that of Earth. The heat melt compactor (see "Sustainability of Base") will be located in this area so that the residents may conduct research on how effectively it functions (in terms of how trash is compacted).

The living areas will consist of all necessary resources for the population. Residents will share a large dining area, similar to a school cafeteria. There will also be doctor's offices located on both sides of the living area in case of any medical needs. The government will conjourn in the community area, and outside of the designated locations (as shown in the diagram), the people will be free to decide where they wish to live within the living space boundaries. In addition, the living areas will be flanked on both sides by farming areas and technical rooms, for management of electrical and temperature control systems.

When we refer to antimatter storage within the diagram, we are discussing quark-gluon plasma, which must be stored within the settlement. Thus, it is on the opposite end of the living area to hopefully lessen any possible dangers. The same idea was employed with the generators, where none were placed within the actual living area. A docking area was placed next to the antimatter engine for ease of transfer.

In terms of transportation, there will be multiple biking spaces for people to deposit their bikes as well as the motorized track going around the settlement. Since the generators will take up a significant amount of space, they will also be spaced out around the settlement, just like the transportation.

Two cell towers will be placed on opposite ends of the settlement to ensure communication will remain possible from any point in the Trojan Initiative. The radio system will be controlled within the technical rooms as well.

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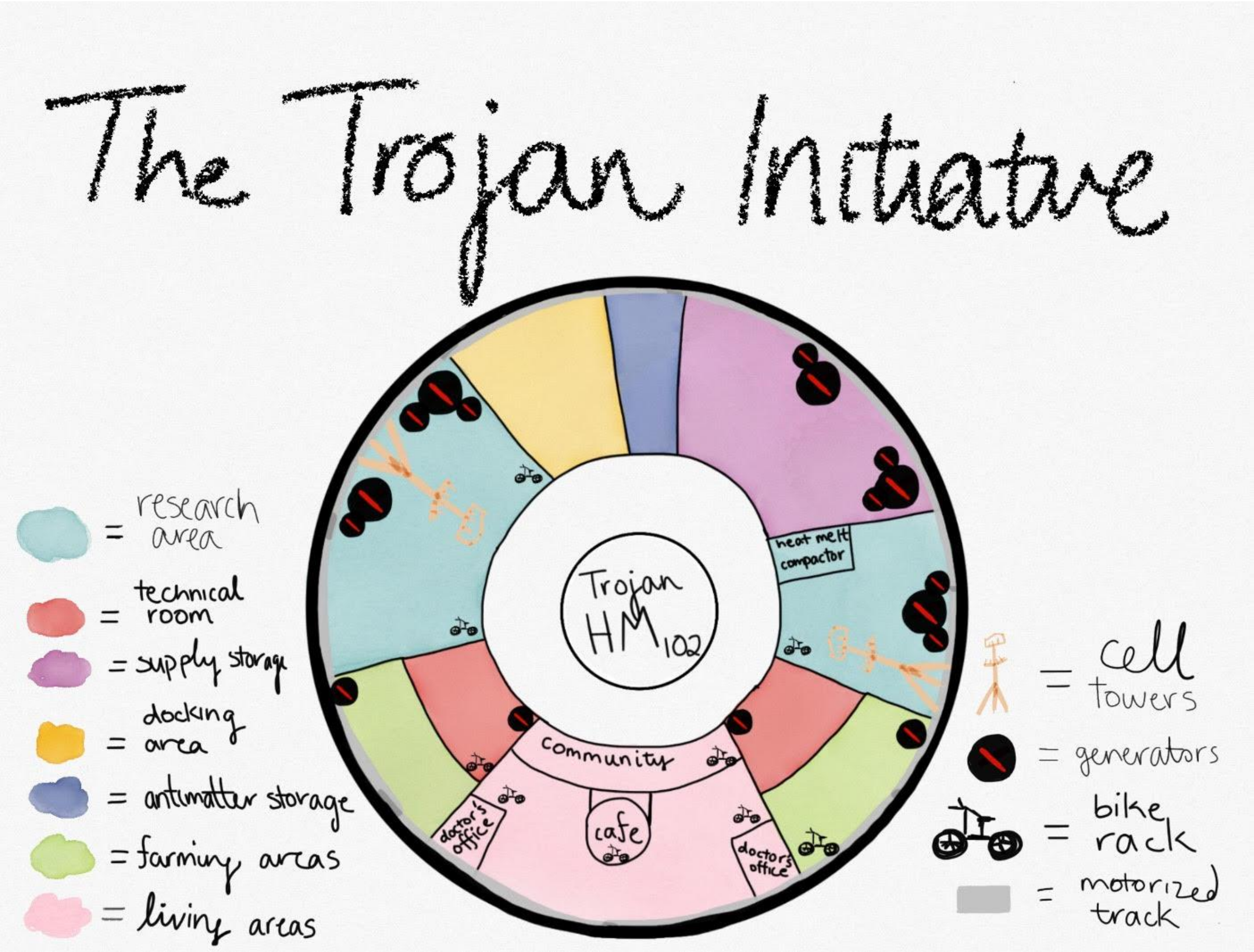
See below for a detailed illustration of the Trojan Initiative settlement's layout:



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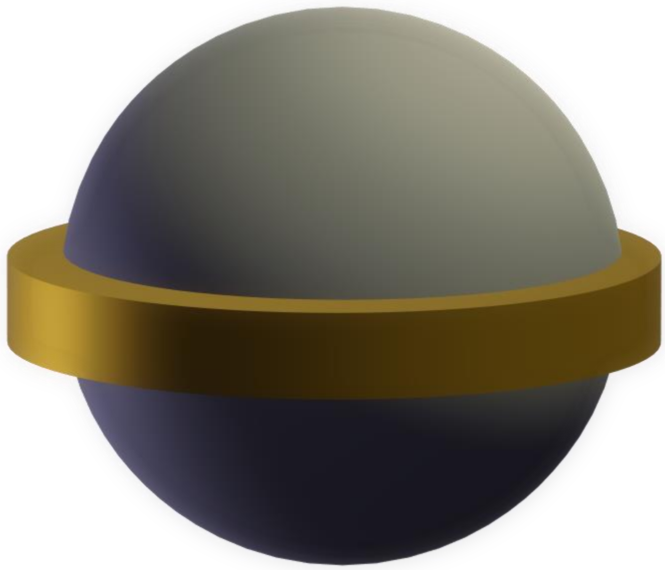
See below for a model resembling the Trojan Initiative settlement:



POWER SOURCES

Outlined by Geetika Chitturi

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Americium-241 Advanced Stirling Radioisotope Generators

Powering the settlement on 2011 HM_{102} would pose a challenge as the trojan is too far from the Sun to enable the capture of an adequate amount of solar energy to be converted into the amount of power needed on the settlement. To avoid dependency on the Sun as a power source, we propose the use of Americium-241 Advanced Stirling Radioisotope Generators (ASRGs).

ASRGs utilize the thermodynamic concept of Stirling cycles to generate power. Two closed cylinders inside the ASRG contain small pistons and companion displacers suspended in helium gas, which prevents the pistons and their displacers from grazing the side of the cylinders (Advanced Stirling Radioisotope Generator (ASRG), 2013). The cylinders, each known as a converter, are aligned end-to-end near the center of the ASRG to help cancel out the small vibrations that result from the pistons being synchronized (*Advanced Stirling Radioisotope Generator (ASRG),* 2013). The thermal energy emitted from the Americium-241 decay is converted into kinetic energy that moves the pistons and the corresponding displacers back and forth at a speed of over 100 times per second (*Advanced Stirling Radioisotope Generator (ASRG),* 2013). Due to being magnetized, the pistons are able to oscillate between coils of wire (*Advanced Stirling Radioisotope Generator (ASRG),* 2013). This oscillation allows the associated displacers to rapidly force the helium gas from the heated end of the cylinders near the Americium decay to the cooler ends near a passive cooler, causing the gas to expand and contract respectively, which sends the pistons through the coils of wire (*Advanced Stirling Radioisotope Generator (ASRG),* 2013). Through the principle of Faraday's Law, these actions allow for an alternating current to be generated. A controller connected to the ASRG is then able to convert the energy into 130 watts of direct current for each unit of voltage that can be used (*Advanced Stirling Radioisotope Generator (ASRG),* 2013).

Traditionally, ASRGs employ Plutonium-238 as the acting radioisotope. However, we decided we would use Americium-241 because it is much easier to acquire, has a longer half-life, and has less potential for causing harm due to emitting less radiation. While 1 pound of Plutonium-238 is estimated to cost around 4,000,000 dollars per pound (Pentland, 2015), Americium-241 costs around 680,388.60 dollars per pound (Hore-Lacy, 2014), making it almost 6 times cheaper. This is largely due to the fact that Americium-241 can be produced from the beta-decay of Plutonium-241 and the large storages of Plutonium-241 globally undergoing beta-decay imply that a large amount of Americium-241 is available to use. On the other hand, Plutonium-238 is produced by Neptunium-237 undergoing irradiation, a process that is difficult and time-consuming. Although Americium-241 is less efficient than Plutonium-238, the availability of it outweighs the potential efficiency drawbacks.

Lithium-Ion Batteries

Lithium-ion batteries would be used as a portable power source. Lithium-ion batteries are much more lightweight and efficient than other battery alternatives. Lithium-ion batteries also would not need to be conditioned, meaning that they would not have to be fully discharged before charging or fully charged before discharging to be able to function, unlike other batteries. Currently, lithium-ion batteries developed for use in space typically have a lifespan of around 10 years (*Batteries in Space*, 2019).

Lithium-ion batteries provide power through a chemical reaction that takes place inside the battery. When a lithium-ion battery is charging, lithium ions are released by the cathode of the battery and travel through a separator where they are received by the anode of the battery (*How does a lithium-ion battery work?*, 2017). When a lithium-ion battery is discharging, lithium ions are released by the anode of the battery and travel through a separator where they are received by the cathode of the battery, causing a flow of electrons to be generated (*How does a lithium-ion battery work?*, 2017).

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SHIELDING AND PROTECTION

Outlined by Briana Chen

The human body, in space, is afflicted particularly by space radiation. Without an atmosphere or planetary magnetic field, humans are susceptible to various levels of radiation in space, the most prevalent of which are galactic cosmic rays and solar energetic particles (Mars, 2021). From robotic missions to Mars, it has been suggested that an astronaut could be exposed to 700 times the radiation dosage of Earth (Scharf, 2019). In particular, magnetized plasma from the Sun's solar wind can break up DNA and can also cause cancer (*Magnetic shield could protect spacecraft*, 2017). More importantly, however, are galactic cosmic rays, which poses an immense challenge that we must shield our settlement from. These high-energy protons and heavy ions move so quickly that they get their electrons stripped away, and thus ionize atoms as they pass through, clearly posing a danger to the compositions in human bodies if they pass through them (*Space radiation shielding*). Moreover, when striking a spacecraft or astronaut, more particles can be produced such as neutrons. This secondary effect could accumulate to around 3 chest x-rays. One msV of space radiation can be received at once— in comparison, Earth inhabitants receive about 2 mSv each year (*Space radiation shielding*). Thus, as the majority of radiation danger comes from these rays and their resulting particles, we must especially work on protecting the interior and exterior of the spacecraft, particularly focusing on protecting areas of the spacecraft that are most densely populated.

It is crucial that we develop effective shielding from these particles. Research on animals shows that in space, the body will experience a greater risk for different health issues due to the differing levels of radiation compared to that on Earth (Mars, 2021). In particular, it can lead to long-term health consequences such as cancer and heart disease, an increased risk for these illnesses poses a problem for the future well-being of the Trojan population.

Solar wind from the sun becomes a serious issue outside of the Earth's magnetosphere, which shields these rays on longer flights (*Magnetic shield could protect spacecraft*, 2017). Thus, one option is to develop an artificial magnetosphere for the Trojan Initiative, which would model the protection that Earth has from radiation exposure. This would be done by using magnesium diboride superconducting magnets, which would be coiled within the Trojan Initiative and thereby create an artificial magnetic field (Wenz, 2017). However, this method is questionable as the strength of the magnetic field created may or may not be enough to combat high-energy particles in space. More tests will need to be done in order to make sure this method is a decently effective option.

As a result, we will need to focus on taking a more physical precaution, which is choosing an effective material for traditional radiation shielding. This involves absorbing radiation. Thus, the material chosen for the shielding would need to be able to deflect micrometeoroids, be easily shaped, and be durable as well as light (Dunbar). One option is reinforced polyethylene, which acts as both a shield that can protect from micrometeorite and a fabric that can be molded easily (Dunbar). The process of creating the reinforced polyethylene shield for a spacecraft has been described as such (Dunbar): After first creating a thick brick of reinforced polyethylene, a vacuum pump will remove air and bubbles from the material. With heat and pressure from an autoclave, which will heat the material to about 200 degrees Fahrenheit and place the "brick" under immense pressure, the brick will be bonded together through chemical reactions.

Afterwards, this brick will only weigh half as much as a piece of aluminum that same size (Dunbar). Due to its high hydrogen contents, polyethylene can block primary and secondary radiation more than metals like aluminum, which is promising news since it proves itself a more effective version of aluminum— a material that is most frequently used for spacecraft radiation shielding (*Space radiation shielding*).

The best option for using polyethylene is to use it in the interior, secondary, and outer layer of the Trojan Initiative. As stated before, although high energy particles may be initially prevented from entering a spacecraft, it could cause a secondary effect through particles like neutrons, which would simply be a slower form of dangerous radiation. To "damp out" the secondary particles' energy, a layer of shielding of polyethylene can be used. Because polyethylene has a high hydrogen content, it will be effective in absorbing energy in these collisions because the atomic nuclei will be similar in mass to the secondary neutron particles (Scharf, 2019).

Another material that can be used is lithium hydride. A 2019 study by Schuy and others found that lithium hydride can "attenuate radiation over distances 20% shorter than for polyethylene" (Scharf, 2019). However, lithium hydride is highly reactive to water in air (Scharf, 2019), which may prove a slight danger to the interior of the Trojan settlement. As a result, it may be best to use it on the exterior of the settlement.

Experiments could also be done by using lithium hydride to make lithium aluminum hydride. As an organic synthesis reagent, lithium aluminum hydride could release hydrogen by reacting with water (Scharf, 2019). With excess hydrogen, it can possibly react with carbon dioxide and undergo the Sabatier Reaction, thus forming water and methane. Once this water is filtered via the Water Process Assembly, it can be available for consumption (see more in "Water Recovery" in "Maintenance of Life"). As can be seen, this is another use for lithium hydride outside of radiation shielding, proving that it is a beneficial option for a Trojan settlement in more ways than one.

Other possibilities for additional radiation shielding involve the multi-layer insulation (MLI) discussed in "Maintenance of Livable Temperatures." As the plastic sheets are metal-coated, the metal will absorb some of the radiation. In addition, we would use the heat-compressed tiles discussed in the section "Sustainability of Settlement" as a form of radiation shielding within the interior since the plastic within the tiles deflects some radiation as well.

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MAINTENANCE OF LIFE

Outlined by Raghav Sriram

Designing and maintaining life in our habitat is an extremely complex, highly constrained task with many conflicting objectives. Our habitat must provide a living volume appropriate for the mission duration and all of the functions and consumables required to support the crew (e.g., a breathable atmosphere, clean water, food, a place to sleep, workstations to support crew tasks, etc.). As the creators of this settlement, we must ensure all of these systems are included and properly integrated while minimizing mass and cost. This is critical as habitats are often large, massive elements that must be pushed through most of a mission's propulsive maneuvers to support the crew. This large 'gear ratio' drives the design of launch vehicles and propulsion stages and often drives the overall cost and complexity of a mission. Therefore, the optimization of habitat designs is an important aspect of the development of any human space exploration mission, especially this one.

Life Requirements on Earth and in Space

Item	On Earth		In Space	
	kg per person per day[1]	gallons per person per day	kg per person per day[2]	gallons per person per day
Oxygen	0.84		0.84	
Drinking Water	10	2.64	1.62	0.43
Dried Food	1.77		1.77	
Water for Food	4	1.06	0.80	0.21

(NASA, 2014)

Importance of Growing Food

One could say being able to create a sustainable and long-lasting colony largely hinges on the ability to grow food in space, which is certainly no easy task. Cold temperatures, long night and day cycles, low atmospheric pressure, and low temperatures present on HM102 will make this task even more difficult. The cost of sending a pound (453 grams) of food, or anything for that matter, is estimated to cost $10,000. This cost means that we simply cannot build a sustainable colony in space without it being able to grow its own supplies. Thus, a self-sustainable alternative must be developed.

Sustainable Crop Growth

When developing a system for growing crops, there are numerous considerations to keep in mind. Firstly, crops produced must be high yielding and nutritious (CHO, protein, and fat). They must also have a high harvest index which is calculated by dividing the pounds of edible material by the total biomass of crops. Additionally, environmental settings and must be considered (Wheeler, 2015).

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In order to sustainably grow crops, we will be employing concepts and techniques learned from the Vegetable Production System, known as Veggie, which was a study conducted by NASA that helped study plant growth in microgravity environments. We will be utilizing hydroponics to grow our crops. Hydroponics is an efficient way to grow crops in outer space as it conserves water and nutrients, eliminates water stress, optimizes mineral nutrition, and facilitates harvesting (Wheeler, 2015).

Additionally, our settlement will employ an inflatable greenhouse suited with life support systems as another avenue of growing and cultivating crops. Essentially, the inflatable greenhouse will grow food as well as plants that create oxygen for life support systems via a process known as bioregenerative life support system. This will allow us to grow crops such as lettuce and cabbage (Frank, 1999).

(Wheeler, 2015)


(Wheeler, 2015)

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Field Crops Observations[1]

Crop	Productivity ($g\ DM\ m^{-2}\ d^{-1}$)	Photosynthetic Energy Conversion Efficiency [2] (%)
Tall Fescue	43	7.0 (UK)
Maize	40	6.8 (US)
Sudan Grass	52	6.0 (US)

CEA NASA Studies

Crop	Productivity ($g\ DM\ m^{-2}\ d^{-1}$)	Radiation Use Efficiency ($g\ DM\ mol^{-1}$ PAR)
Wheat	61	1.44 Utah State[3]
	130	0.67 Utah State[4]
Potato (12⇨24 h photoper.)	45	0.97 Univ. Wisc.[5]
(12 h photoper. only)	38	1.15 Univ. Wisc.[5]

[1] *D.O. Hall. 1976. FEBS Letters*
[2] *Original data based on total solar irradiance; table data reflect efficiency based on PAR (400-700 nm)*
[3] *Monje and Bugbee. 1998. Plant Cell Environ (estimated)*
[4] *Bugbee and Salisbury. 1988. Plant Physiol.*
[5] *From Wheeler, 2006. Potato Res. (assumes transplanting to increase PAR absorption).*

(Wheeler, 2015)

Water Recovery

It would be incredibly impractical, in terms of volume and cost, to completely stock our space settlement with water via space shuttle transport. With HM102 not having water readily available, as we know it, and not a grocery market on sight, we must come up with a way to create and recycle water for long periods of time (NASA, 2014).

The human body is two-thirds water and it has been estimated that nearly an octillion of 1027 water molecules flow through our bodies daily. Therefore, humans must consume sufficient amounts of water for the maintenance of life (NASA, 2014).

What we suggest is using a water recovery system that NASA is currently developing called that utilizes the Sabatier Reaction. Essentially, this water recovery system consists of a urine processor assembly (UPA) and a water process assembly (WPA). The UPA removes volatile components in urine using distillation where heat disinfection is used to prevent microbial growth. Urea is first stabilized chemically

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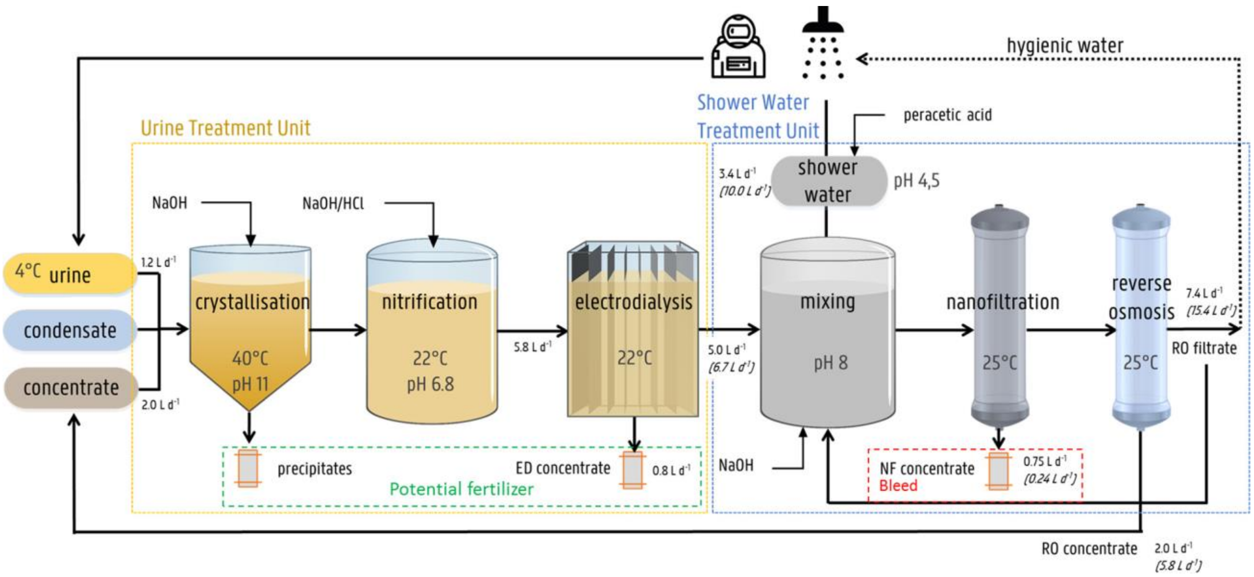
so that it does not turn into ammonia and volatilize with water. Less desirable and volatile components of urine remain as liquid brine which will then later be disposed of. Once urine is fully reclaimed, the urine distillate will be sent to the WPA for further processing. Our Water Processing Assembly will consist of an aeration basin, numerous filtration beds, a chlorination station, and a volatile removal assembly. The volatile removal assembly will remove small, volatile organic molecules such as methanol, ethanol, and isopropyl alcohol. These systems will work hand-to-hand on making what was once urine into potable water.



Urine Processor Assembly (URA)

Oxygen Recycling

On Earth, we often take the role plants play in the oxygen production/carbon dioxide removal process for granted. These processes are vital for creating the end-goal of a fully oxygenated ecosystem on HM102. The by-products of human metabolism, carbon dioxide, and water vapor present a challenge in terms of supplying oxygen and removing carbon dioxide (NASA, 2014).

The oxygen generator system we have developed will make use of electrolysis by combining water and electricity to reclaim hydrogen and oxygen ($2H_2O + \text{Electricity} \rightarrow 2H_2 + O_2$). However, this reaction produces a potential hazard as hydrogen is flammable. We can solve this issue by combining the Hydrogen produced from this reaction with the total exhaled carbon dioxide from the settlement to reclaim the lost water ($4H_2 + CO_2 \rightarrow 2H_2O + CH_4$), essentially creating an efficient recycling system. The methane produced from this reaction will be safely disposed outside of the settlement. This reaction is known as the Sabatier Reaction and will be crucial for other endeavors in our settlement. For example, we can use the methane created from this reaction as a source of propulsion fuel, further expanding the distance we can explore beyond our settlement. Additionally, the reclaimed water from this reaction will be passed through our aforementioned water processing assembly and can be filtered into drinking water or be added to the oxygen generator system to reclaim more oxygen and further progress the cycle.

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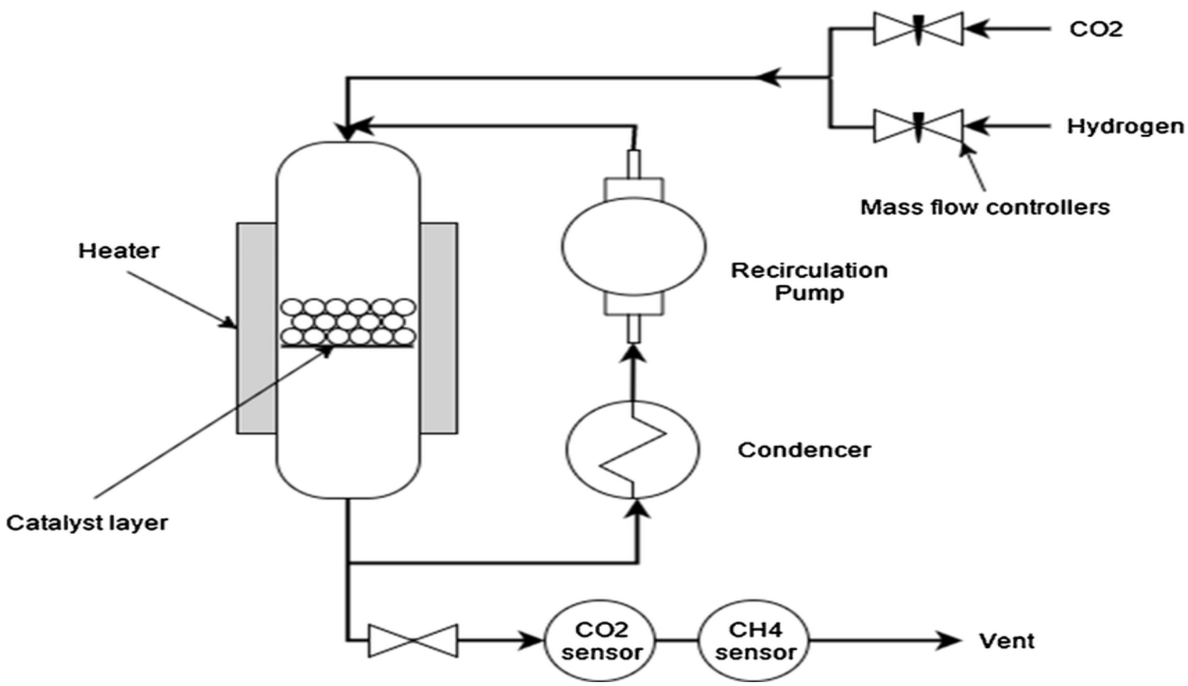

Sabatier Reaction

Eliminating Carbon Dioxide

At high concentrations, Carbon Dioxide (CO_2) presents a threat to our crew members and other settlers of HM_{102}. To eliminate Carbon Dioxide from within our space settlement, we have developed a carbon dioxide removal system that removes CO_2 from cabin air. Carbon dioxide removal, or CO_2 scrubbing, involves the use of heterogeneous granules of synthetic rock called zeolite. When cabin fans blow air through the beds of zeolite, CO_2 and water stick to the zeolite (NASA, 2014). The Zeolite is then regenerated by heating it and exposing it to the vacuum of space. A similar process can be used in our hospitals to provide portable oxygen for any potential patients. Zeolite can also be used to filter nitrogen from the air. Additionally, CO_2 can be collected and fed into the Sabatier Reaction where it will produce CH_4 and H_2O.

Air Filtration System

To ensure clean cabin air and manage the potential 2000 contaminates produced by off-gassing, we will employ a trace contaminate air filtration system that uses membranes and catalysts to purify cabin air to ensure breathability. Once trace contaminants are scrubbed from the cabin, they are stored in a bed until the bed is saturated.

Maintenance of Livable Temperatures

Outlined by Geetika Chitturi

Heat From Solar Radiation

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2011 HM_{102} is around 30 AU from the sun. This makes it difficult for solar radiation to reach the trojan, so not much heat can be obtained from solar irradiance. Taking the distance from 2011 HM_{102} to the sun to be 30 AU, using the inverse square law (Simmons, 2019) it can be determined that the trojan receives around $\frac{1}{900}$ of the solar irradiance Earth receives, around 1360 watts per square meter (*Climate and Earth's Energy Budget*, 2009). This is equal to around 1.511 watts per square meter. The full calculation is shown below.

$$\frac{1}{30^2} \times 1360 = 1.511\, W/m^2$$

It can be assumed that this would not be enough heat to sustain human life.

Heat From Cosmic Rays

It can be assumed that the thermal effect of cosmic rays on 2011 HM_{102} is similar to the effect of cosmic rays on Earth. This indicates that heat from cosmic rays would not be enough to sustain human life, especially in an insulated structure.

Heat From Equipment

A primary source of heat would be the ASRGs. Each ASRG can produce 130 watts (Advanced Stirling Radioisotope Generator (ASRG), 2013) which, after conversion, is around 4.1°C produced per minute. With enough ASRGs situated around the settlement structure, adequate heat could be produced and dissipated throughout the settlement structure to sustain human life, provided that sufficient layers and clothing acting as insulators are worn by settlers.

Heating and Cooling Pipes

To maintain stable temperatures in the settlement, pipes would be integrated into the walls of the settlement structure. The pipes would be connected to an automated system with temperature detection and control capabilities.

Hydrogen gas heavily diluted with nitrogen to prevent combustion would be inside of heating pipes lined with a nickel manganese alloy to act as a catalyst. When temperatures cooler than desired are detected, the system would release oxygen into the pipes, creating an exothermic reaction to release heat and raise temperatures in the settlement.

Cooling pipes would be made of Polyvinyl Chloride (PVC) and contain water. When temperatures warmer than desired are detected, ammonium nitrate would be released into the pipes, creating an endothermic reaction and reducing heat in the settlement until temperatures are back to an appropriate level.

Multi-Layer Insulation

Multi-layer insulation (MLI) can be used to prevent the loss of heat through radiation. MLI is composed of multiple highly reflective layers of thin metal-coated plastic sheets and generally has the appearance of a gold foil. Covering the settlement in MLI would prevent the heat produced inside the settlement structures from being lost.

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SUSTAINABILITY OF SETTLEMENT

Outlined by Briana Chen

Sustainability is best achieved through an effective waste and garbage disposal routine.

In the most consistent venture in space, the International Space Station, approximately 2 metric tons of trash are stored (Gohd, 2018). However, it is ultimately rid of by being sent back to Earth. Clearly, due to the distance from Earth and the resulting length of travel needed, it is difficult for the Trojan Initiative to dispose of all their trash the same way as the ISS does. The option of sending trash out into space poses a hazard to the existing environment, while collecting it for each person’s lifetime will lead to biological issues and uncleanliness. Thus, it is clear that proper disposal of trash for the Trojan Initiative lies in sustainable trash processing.

In one year, four astronauts can create 2,500 kilograms of garbage (Herridge, 2018), which means that each person on the Trojan Initiative will be responsible for around $150 * 2,500 / 4$ kilograms of trash each year. Thus, we will use around 93,750 kilograms of waste per year that we must find a way to convert into supplies.

A heat melt compactor may currently be our best option, as it can easily be powered by the generators. In the images below are examples of tiles produced by a heat melt compactor currently in development. As observed, there are multiple forms of tiles that may work, and it will be up to the members of the Trojan to decide upon the best option. Essentially, the heat melt compact compresses trash into 81 square inches of tiles. These tiles are heated over 300 degrees Fahrenheit, which removes dangerous fumes and boils any water in the compressed tiles (Nasa & Nasa, 2018). Any toxic gases can be released into space, while the resulting water vapor can be used within the settlement’s bounds. These tiles may even be used within the Trojan settlement for radiation shielding due to the large amount of plastic utilized in many forms of trash, which can deflect radiation (see “Shielding and Protection” for further information). Thus, these tiles can even be put to use to further protect the human population.

The compact nature of these tiles illustrates how effective this method is. It both reduces the size of any trash while also removing any biologically active substance, which is extremely beneficial for the well-being of the Trojan members.

(Nasa & Nasa, 2018)

(Gohd, 2018)

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LIFE ON SETTLEMENT

Entertainment

Outlined by Briana Chen

As the location of the Trojan Initiative is so far from Earth, it is necessary to develop our own form of sports to provide more exciting opportunities to exercise and physically interact with others.

With TROJAN ball, we have developed a team sport to ensure collaboration among the people on the Trojan Initiative. Although slightly similar to soccer or basketball, there will be multiple physical goals located around the settlement. The goals may be located wherever seen fit, thus not requiring a specific space to play this game. In addition, the goals will be varied: hoops (similar to a basketball), wide pits, or a square on the wall.

Each team is given a ball and a goal to guard. It is up to each team to determine the number of people they are willing to leave behind to guard the goal. Then, the rest of the team must run and find the other goals. If they score at all of the other goals before the other teams, which will also be protected by other teams' members, then they win the game.

TROJAN ball, consisting of a multitude of sports, will test the players' physics prowess and long-term teamwork abilities. Teams who clearly communicate a cohesive strategy will undoubtedly have an advantage. Modifications can be easily made to accommodate all ages, making this a game for all.

Beyond sports, one of the most crucial ventures we can solve in the entertainment business is finding an accurate representation of space-related scenes. While science-fiction movies such as Star Wars, the Martian, and Interstellar have long imagined life on and travel to different planets, the Trojan Initiative would spark a newfound understanding of human existence in space. We have already seen footage from astronauts on the moon and in the International Space Station, but to observe a new form of human settlement so far from Earth would be immensely helpful in modeling those same, long-distance survival tactics in sci-fi movies. Perhaps Trojan Initiative members will even film a movie of their own on this settlement, to provide the most authentic and accurate portrayal of space-living!

Transportation

Outlined by Briana Chen

Due to the gravitational force still felt by the population, there would be no need for any gravity-providing transportation within the settlement. Walking would undoubtedly remain a feasible method of transportation, and would also help to increase physical activity for the population.

In addition, cycling is another option. Fashioning a public bicycle system, which crosses each sector of the settlement, would effectively provide a faster form of transportation for the population. Bicycles would likely have to be transported from Earth, which also should not be an issue considering the effectiveness of the antimatter engine. They could also be self-made on the settlement using scraps of

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rubber, although importing bicycles seems to be the most efficient option considering the population on the Trojan Initiative will be conducting research.

The most efficient form of transportation would be a motorized track, which would once again go around the entire settlement. They would be powered by the generators, and consist of a track similar to a moving walkway. It would function similar to a rack and pinion, in which carts carrying humans will be rotated around the settlement. This is a way for the settlement population to travel long distances in a short period of time, and as the settlement is only 150 people at any given moment, it will be easy to conduct a schedule of when carts arrive and depart. Each person may fill out a time slot in which they will need to use the carts, and based on the need for carts, time slots can be encoded into the motorized track. A few people can manage this system as well, which allows the track to be efficient and monitored by humans as well.

Tracking Time

Outlined by Briana Chen and Geetika Chitturi

The orbital period of 2011 HM_{102} is estimated at around 167.08 earth years (*Jpl small-body database browser*), which means that 1 year on Trojan Initiative settlement consists of about $167.08 * 365 = 60984.2\ Earth\ days$.

With this in mind, it is necessary to mention that tracking time would pose a challenge on the settlement due to the little sunlight that would reach it. Without an indication of the length of time that has passed, days could blur together, confusing settlers.

The same system used on Earth to track time would be used on the settlement, i.e. 24 hours in a day, 365 days in a year, etc. To help keep track of time, the settlement would have an artificial lighting system synchronized to the daylight hours and trends on Earth. This system would simulate time passage in a way familiar to settlers which would help them adjust to the change in environment.

Communication

Outlined by Geetika Chitturi

Communicating efficiently would be vital to the success of the settlement in that it would be necessary for organizing events on the settlement, maintaining good social health of the settlers, ensuring the logistics of the settlement society are in order, and much more.

Cellular Communication

Cellular devices with lithium-ion batteries would be used for communication between two people with cellular devices given that a cell tower is built near the settlement structure. Cell towers constructed near the settlement structure would provide a way for those with cellular devices to communicate with each other through calls and text messages. Cellular communication would provide a convenient way for people to communicate in a way that they are already very accustomed to. Furthermore, due to their small size, 150 cellular devices would be easy to transport from Earth to the settlement.

Radio

Radios would be used to send messages and share information with the entire settlement community from one location all at once. Two-way radios would also be used for communication between two or more people at different locations. Multiple usable frequencies for radios ensure that channels can be organized in a variety of ways for maximum usefulness such as by living quarter locations, occupation, or sports team to provide an easy and flexible system of communication. Radios would also easily be transported to the settlement from Earth because of their small size.

In-Person

Due to the close distances between people and an efficient transportation system in the settlement structure, in-person, face-to-face communication would be convenient. This proves as a benefit, additionally, because face-to-face communication is often the most advantageous form of communication due to the importance of nonverbal cues and increased clarity in conversation.

Economics

Outlined by Geetika Chitturi

Currency

Currency would be in a digital form and be called TroyCoins. All settlers would have a credit card with a chip able to track transactions. Currency would be managed and monitored by a central bank on the settlement that would accept deposits and withdrawals while also granting loans.

Occupations

During the Trojan Initiative, the population of the settlement would be composed of scientists and researchers. Among this population would be agriculture experts who work at and run the farms, medical professionals able to take care of any sick or injured settlers, mental health professionals to oversee the mental and emotional health of the settlers, civil and industrial engineers who can maintain the structure of the settlement, electrical engineers for monitoring the power on the settlement, researchers to execute planned research projects, and other professionals who would be needed on the settlement.

Salaries would be paid to each settler by the customers of their goods or services. For example, an agricultural expert may be paid in exchange for food to make a living while a medical expert may be paid by the government to care for the sick and injured.

Taxation

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The settlement would have a progressive tax system where those with a greater capability to pay taxes would pay more taxes. All settlers would have to pay an income tax to the government. Taxes would be used to pay settlers employed by the government for services and goods that would benefit the entire settlement. For example, a civil engineer may be paid to check the structural stability of part of the settlement structure and members of the government would be paid with tax money as well.

Universal Healthcare

Taxes would also go towards a universal healthcare system where the government would pay medical experts to take care of and treat the sick, injured, and mentally ill. Those in critical condition would be transported back to Earth.

Government

Outlined by Geetika Chitturi

Governing Body

The settlement would have a leadership council consisting of five people as the governing body. This government would be elected by those on the settlement every two years with a four term term-limit in place. The governing body would write policy, decide what tax money is used for, and decide whether any member of the settlement should be sent back to Earth for being a potential threat to the success of the settlement.

Voting

Every settler would vote for who they think should govern. The settlement would be divided into five voting districts of thirty settlers each with one representative for each district. Voting would also take place on the policy changes presented by the governing body to determine whether the changes would be implemented. The voting system would be a majority system where settlers in each voting district vote for one settler to represent them. Policy changes would need at least two-thirds of the settlement's votes, or at least one hundred votes, to pass.

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