LINSHIPXD

our sustainable future on the moon and beyond

linShipXD- OUR FUTURE ON THE MOON AND BEYOND

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AN OVERVIEW OF OUR THOUGHT PROCESS

What we wanted to do:

When brainstorming, we wanted to ensure that all success criteria and aspects of the challenge were hit. As such, we have developed key ideas that we believe achieve that.

Therefore, we are focusing on:

-**obtaining resources**
-manufacturing
-reducing costs
-infrastructure and
-**sustainability and the environment**

Locating and mining resources is vital for sustaining human life on the moon. Without oxygen, water, food and, materials, astronauts would not be able to stay in orbit for long periods of time. Successfully gaining these resources is vital for sustaining human presence on the Moon and exploration.

Unless human beings go into space with the ability to independently manufacture infrastructure, robots etc., they won't be self sufficient. They will rely on these items being launched into space from earth which is both expensive and damaging to the environment.

Building safe and fit for purpose infrastructure is paramount for human life on the Moon. Infrastructure must be able to withstand environmental hazards and enable astronauts to undertake everything from daily menial tasks to complex science experiments.

Finally, ensuring that all our proposed solutions are sustainable on both the earth and the moon is important to us. We want future generations to have the same access to resources- or better- than we have now.

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OUR CHOSEN HYPOTHESIS

After discussion and assessment of our brainstorm, we ultimately decided to investigate these hypotheses:

1) Can we use regolith and debris to manufacture the infrastructure and materials required for human habitation on the Moon?

2) How can we use further space exploration to obtain materials to support human life in space and to reduce costs on earth?

To explore these hypothesis, we have created a series of protypes and engaged with mentors in the fields of space an engineering in an aim to create valid solutions to the problem presented to us.

POLICIES FOR EXPLORATION

THE LAWS OF SPACE

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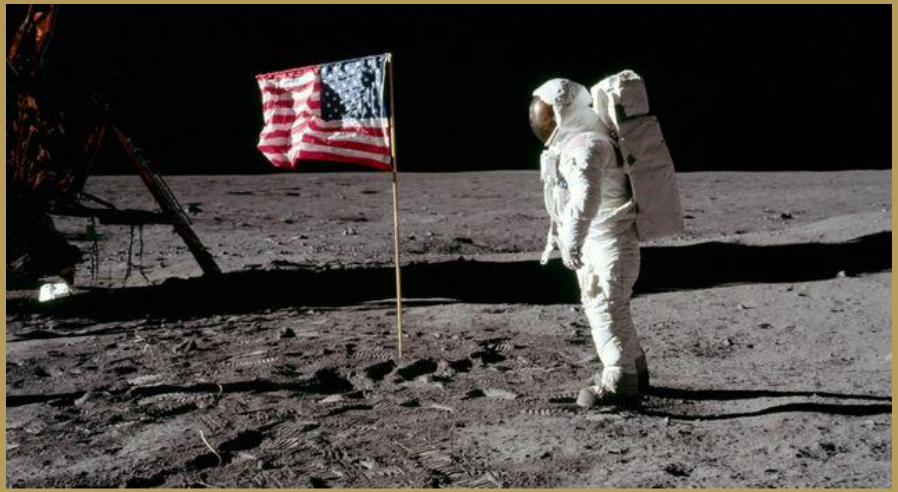
Obeying the law:
Space exploration is complex and has a history of causing conflict. Our ideas and concepts obey the current laws surround space exploration.
Most importantly, we will not refer to these ideas as concepts for ‘colonisation’ as that implies that we are claiming ownership of it (the Moon). This cannot be done; space and the items in it cannot be owned by one person or by a government or by a country. Our ideas aim to simply improve our understanding and further our exploration of the universe.

(Image courtesy of nasa.gov)



MINING

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Mining to reduce costs on earth:

To reduce the costs on earth, we aim to mine from near-Earth asteroids and the Asteroid Belt. There are a wide variety of asteroid types with each asteroid containing a different composition of metals and minerals. These include:

-The **C-type** (chondrite) **asteroids** are most common, these are dark in appearance

-The **S-types** ("stony") are made up of silicate materials and nickel-iron.

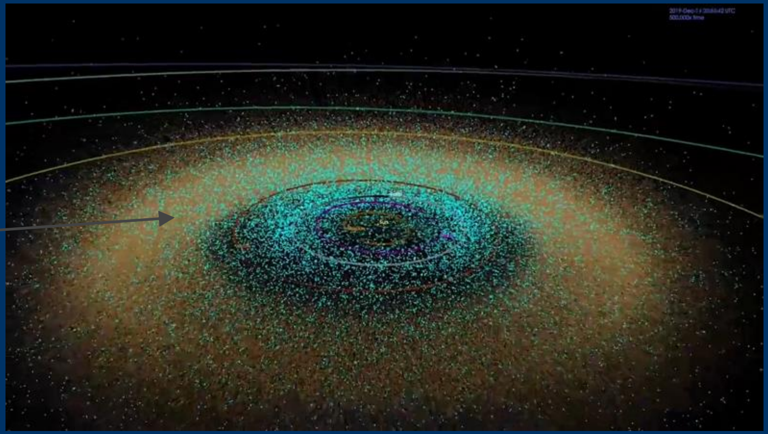
-The **M-types** are metallic (nickel-iron).

Using developing technologies like CubeSat spacecraft, we aim to scout near-Earth asteroids and identify their composition. Then, collect these materials using developing DragonFly or Harvester Tug spacecraft. Once the minerals or even whole asteroids are collected, these can be bought on Earth. This will reduce the cost of buying these minerals as although they are in short supply on our planet, they are plentiful in space. Metals like gold and platinum are rare on Earth but in space they are common-place. On the asteroid belt alone, it is estimated that there is an estimated worth of $700 quintillion in these minerals! This means the demand for such materials will be met, hence, lowering their cost considerably,

(Images courtesy of nasa.gov)

CubeSat technology

Observation of near-Earth asteroids



FURTHER EXPLORATION

OBTAINING WATER

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Mining for water:

Many near-Earth asteroids are rich in H_2O and this is invaluable for a few reasons.

First, once extracted, this compound can be used to create rocket fuel. Using electrolysis, pure Hydrogen and pure Oxygen can be obtained from the molecule. Essentially, this is rocket fuel. This is vital for life to be sustained in space without having to frequently return to Earth.

Moreover, refuelling spacecraft in space will require the use of less water as less energy will be required. This is because the payload does not have to break through the Earth's atmosphere and overcome gravity. As such, water will be conserved.

Additionally, this will enable astronauts to launch rockets etc from the moon itself or other near-Earth asteroids. This will make the exploration of planets like Mars and areas like the asteroid belt far easier to explore as the mathematics and engineering required to launch something from the Moon to Mars is far simpler than that of the Earth to Mars. As stated, this is because the force of gravity on the Moon is 17% of that on Earth making it far easier to project from.

Furthermore, water is required for human and plant life to be sustained. Any obtained from neighbouring asteroid can be used as drinking water. Moreover (via electrolysis again) be broken down into Hydrogen and Oxygen. The former of which can be removed to minimise the risk of explosion. The latter can be used to fill the spaces for human habitation with the oxygen concentration that is required for human beings to breathe and respire (around 21%).

Near-earth asteroid rich in water

A small rocket launching from the asteroid

FUEL CELLS AND RECYLING SYSTEM

OXYGEN AND WATER

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Using fuel cells to obtain water and oxygen:

Fuel cells, like asteroids rich in water, can be used to obtain water and oxygen due to the reaction within them:

$2H_2 + O_2 \rightarrow 2H_2O$ + electricity

These elements can then be recycled for various purposes.

$2H_2 + O_2 \rightarrow 2H_2O$ + electricity

Oxygen generator system

Cabin air

Moisture removal

Carbon dioxide removal

Sabatier reaction (4H2 + CO2 → 2H2O + CH4)

$2H_2O$ + electricity $\rightarrow 2H_2 + O_2$

Water recovery system

Methane removal

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Recycling:

This method of recycling is important for sustaining life on the moon. This is because it ensures that the waste is produced is minimal which is important for not polluting the Moon's environment. Furthermore, it makes certain that items like Oxygen and Water will not have to be launched from Earth. This will protect the environment on our planet too.

(Image courtesy of nasa.gov)

Oxygen recovery system on-board the International Space Station.

INFRASTRUCTURE

Design:

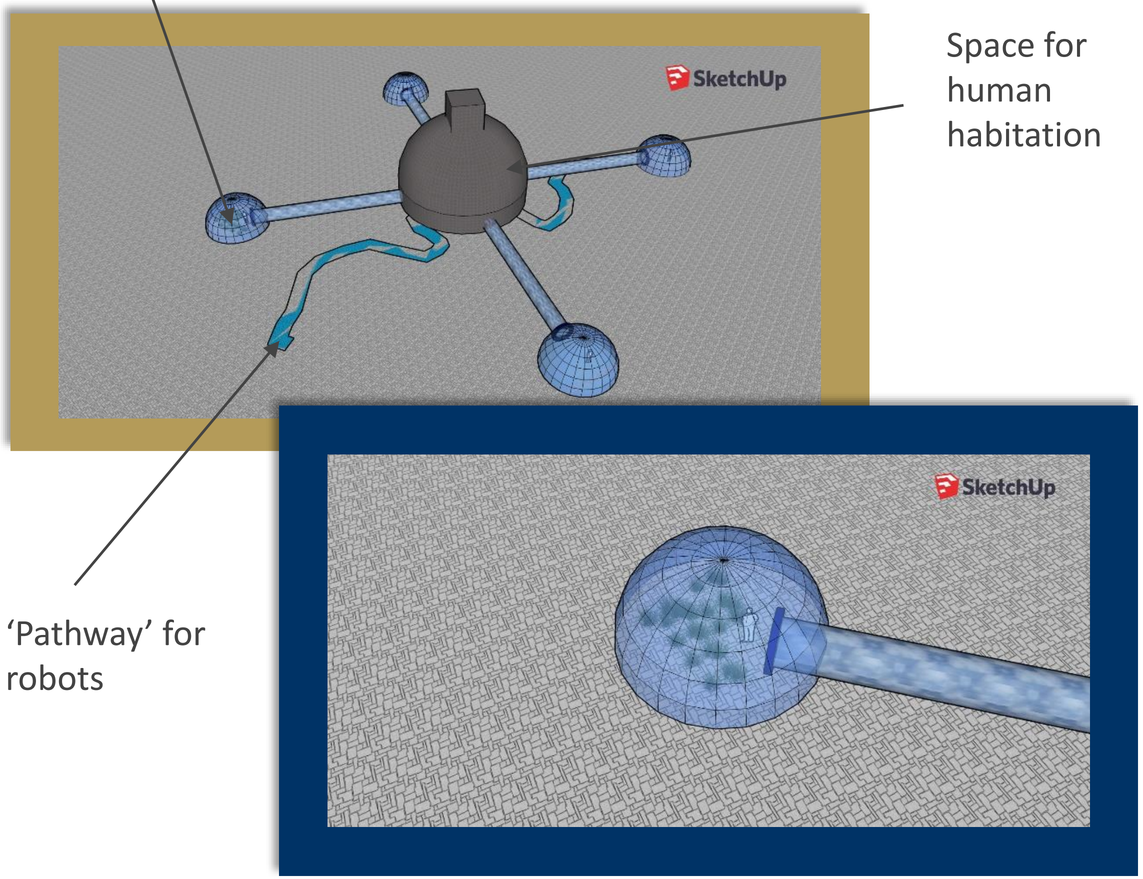
The infrastructure we have designed has been done in a way to ensure that humans are protected from the environmental challenges of being in space.

All structures for habitation and growth will be cylindrical or sphered shape to ensure that an air pressure of 100kPa is maintained. It is easier to do so with this shape than with cube or cuboid shapes as the geometry is far more stable.

In terms of the air in these cabins, O_2 will make up 21% of the molecules while N_2 will compile the rest- similarly to how it is on our planet. This is because this gas is very stable and easy to transport in carriers from Earth to low-Earth orbit or to the Moon.

Each area designed for human habitation will be connected to greenhouses. These greenhouses will be formed using aerogel and melted regolith (anhydrous glass), enabling light from the sun to reach the seedlings. Thus, enabling them to photosynthesise and grow. This is vital for sustaining astronauts on the moon as they will have to cultivate their own produce. Moreover, the plants will provide a valuable source of excess oxygen.

Lastly, we aim transport items from each human habitation space using robots. This will limit the time astronauts are exposed to cosmic radiation. Therefore, we aim to build 'roads' between each individual pod- interconnecting them all, making it easier for the robots to travel. These pathways will be constructed from regolith.



INFRASTRUCTURE

MATERIALS

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Aerogel:

Aerogel will be used to create our greenhouses. This synthetic material is considered to be one of the most insulating in the world making it highly suited to plant growth, Moreover, it is translucent, enabling natural sunlight to provide the energy required for photosynthesis (artificial lights will be used too). Aerogel can also be reinforced with polymers whilst maintaining the above properties. This is vital for use on the moon to withstand things like lunar quakes.

Recycled low-Earth orbit debris:

There are an estimated 500,000 pieces of debris in low-Earth orbit. To recycle this material, we would launch a crucible into low earth orbit. This crucible would use robotic arms to capture debris. Melted using a large solar concentrator, the junk could be heated according to the melting points of the different materials in it. The raw materials obtained could then be reused for infrastructure, utensils, robotics etc.

Regolith:

Regolith will be used to create infrastructure like roads and some buildings. Anhydrous glass made from lunar dust is stronger than alloy steel and has a fraction of the mass. This means that it is both easier to transport and, can resist lunar hazards.

Kevlar and Ceramics:

Spaces suited for human habitation will be coated in Kevlar and ceramics. These materials are both extremely hard- often used in bullet-proof vests. These are also relatively lightweight. Most importantly, they will protect these spaces from solar radiation that could increase an astronauts risk of sickness and even long-term illnesses like cancer.

Non-Newtonian Fluids:

Non-Newtonian fluids would be used for asteroid protection. These fluids behave like solids when pressure is applied. If the areas for human habitation were coated in it, the asteroids would not penetrate the capsules.

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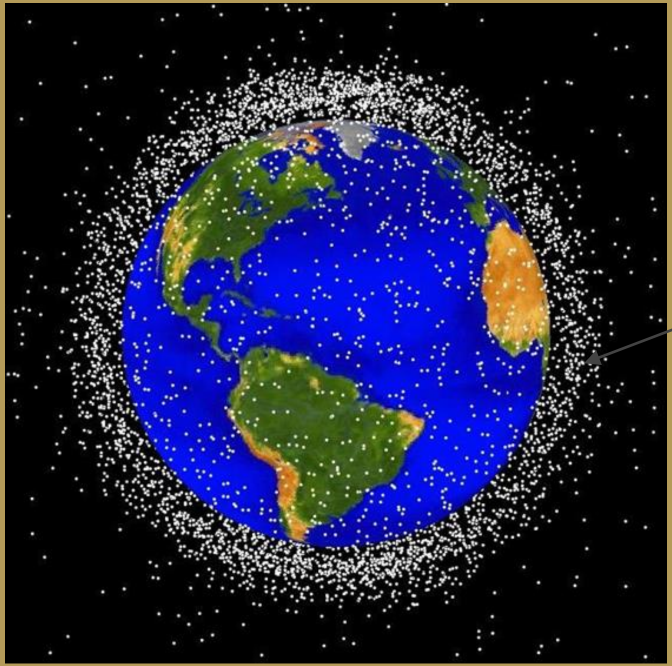
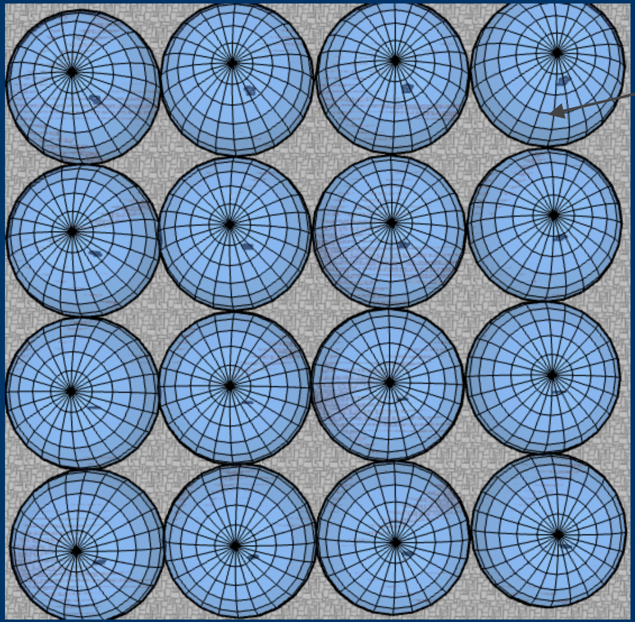


(Image courtesy of nasa.gov)

'Space debris'



Small 'bubbles' ($0.25cm^3$) filled with a non-Newtonian substance. This material can then be wrapped around spaces for human habitation.

MANUFACTURING

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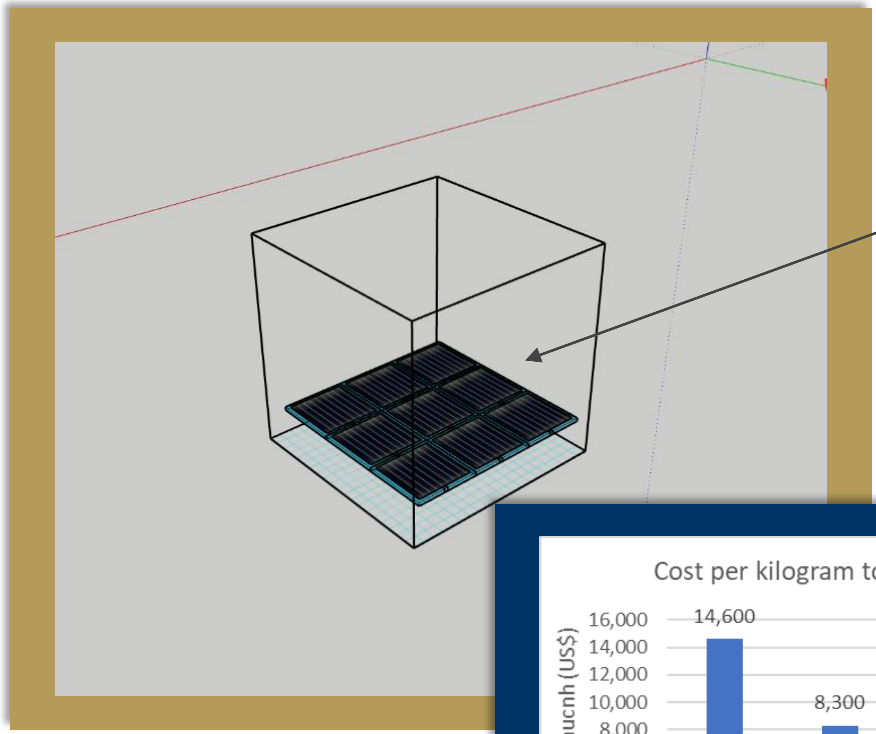
3D printing in space:

The cost of launching payload into space is massive. Both in terms of money and the environment. The energy required to overcome the force of gravity is massive and this, if done regularly to sustain life on the Moon, would have a detrimental effect on our planet.

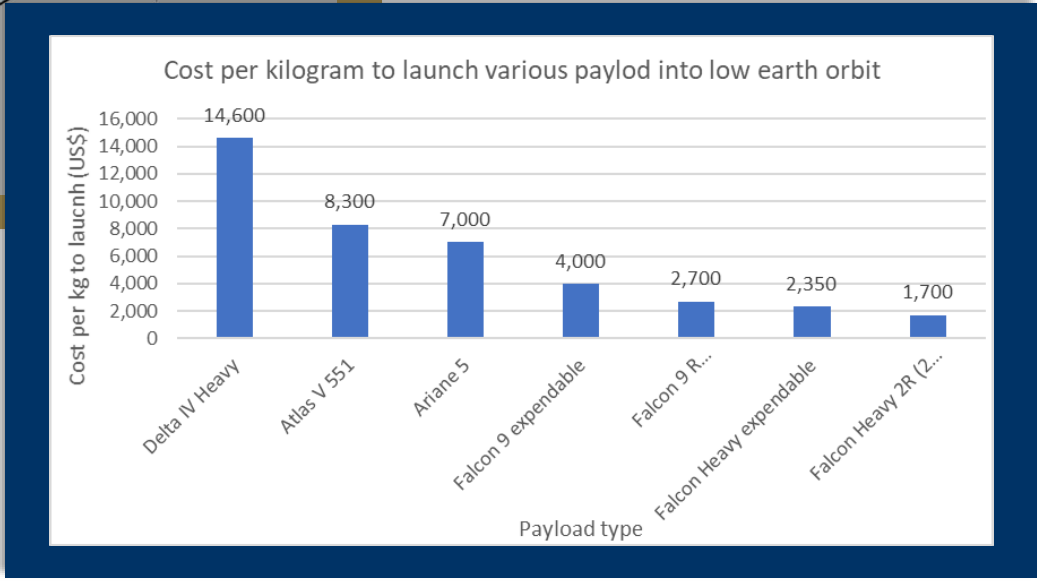
As such, we aim to manufacture large objects in space itself. This is viable due to developing technologies with 3D printing and automated assembly.

We will create printing feedstock using 70% regolith and 30% polymer. These can be heated for use for 1/30th of the energy of sintering.

This could be used to create things like large solar panels as an energy source and any other large infrastructure.



Solar arrays being manufactured in space



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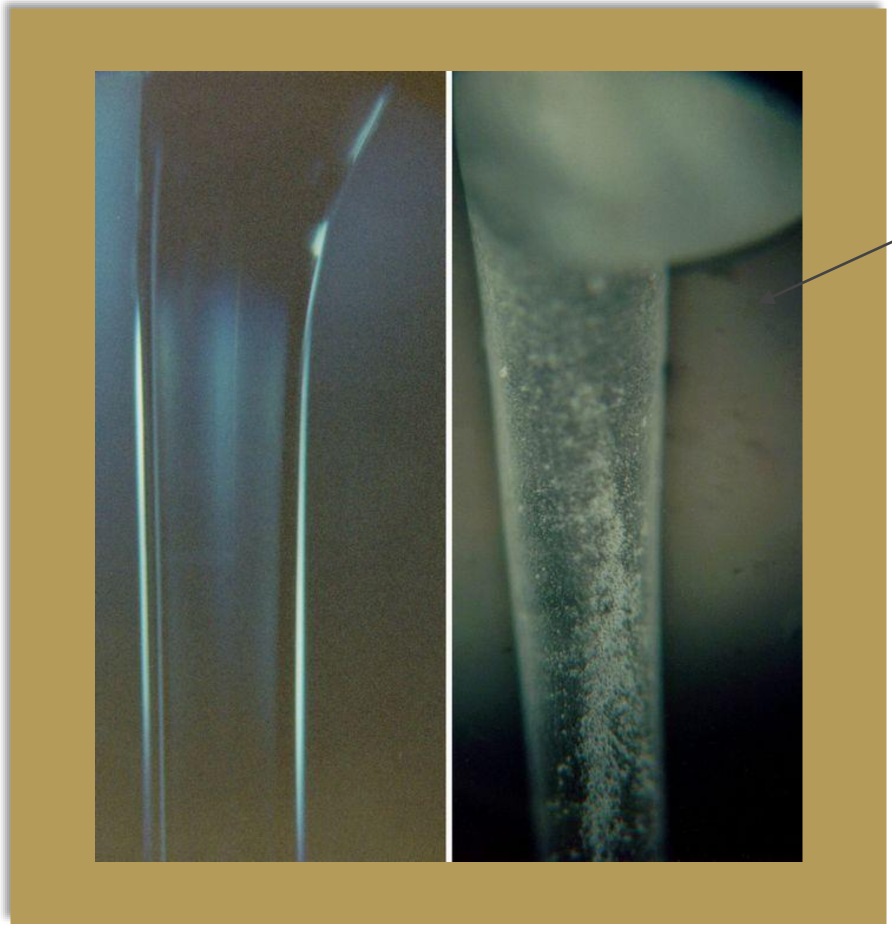
Commercial manufacturing:

Manufacturing in microgravity has endless opportunities. Creating items like 'tough' materials in space would have a far better outcome than producing them on Earth. This is because the elements involved could mix evenly together without the effect of gravity. Moreover, being manufactured in a vacuum ensures that the product can be made without impurities.

For example, materials like optic fibre (ZBLAN) could be made without any imperfection. The reason for that being the mitigated effect of convection which ensures that the crystal flaws that occur naturally on Earth are minimal in space.

These materials could then be traded back on our planet for profit. This profit could be used to reduce the costs of manufacturing in space even further.



Right: ZBLAN (optical fibre) made on Earth (has impurities)
Left: ZBLAN made in microgravity using a KC-135 plane (few impurities)

(Image courtesy of nasa.gov)

ENERGY

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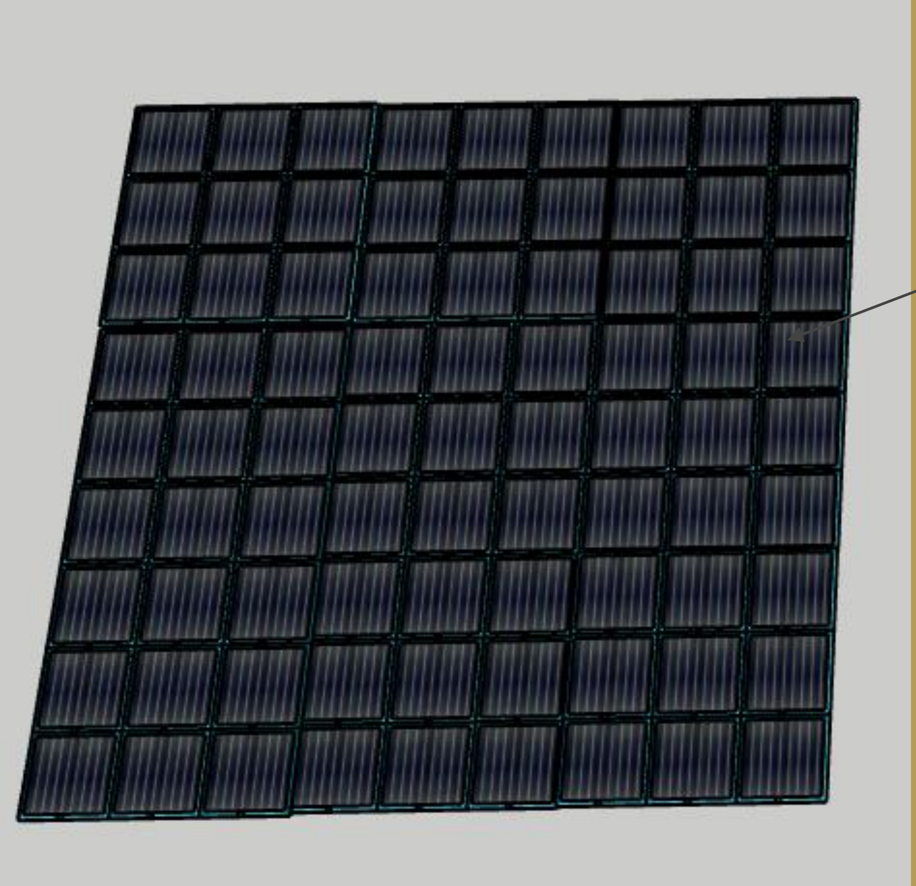
Main energy source:

Our main source of energy whilst in space is the energy from the sun. We plan on harvesting this power using large solar arrays in both low-Earth orbit and, on the moon itself.

The solar arrays would be made from silicon and will directly convert the energy from the sun into electricity through a process called photovoltaics.

If only 20% efficient, these solar arrays could produce approximately 20kW of energy for every $1000m^2$ of them.



Large solar array ($1000m^2$) used to generate electricity)

ACKNOWLEDGEMENT AND THANKS

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Thank you from us:

We would like to take a moment to thank the Junior Academy for running this challenge. It has given us the opportunity to develop knowledge and skills in areas that we are passionate about and, apply these in ways that we had not previously experienced. To engage with like-minded students across the glob and make life-long friends.

Moreover, we would like to thank our mentor, Saurov Shyam for providing support and guidance. To Kathy Korsen and Megan O’Shea for giving us feedback and encouragement when we were struggling to find feedback from others.

This has been an invaluable experience, thank you all very much.

-linShipXD