

PROJECT CRESCENT: A PROPOSAL TO BUILD A SUSTAINABLE MOON BASE

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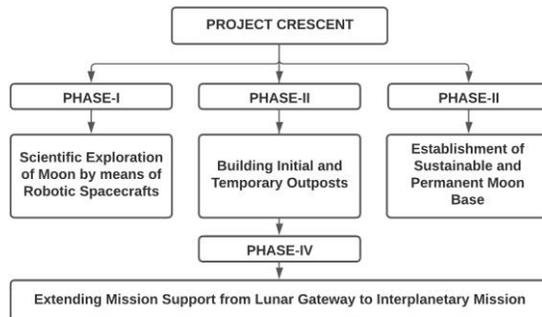
Introduction: Be it harsh snowy mountains or dry hostile deserts, wherever there is space to expand into humans have done so boldly. With Earth mostly discovered and inhabited it is hardly surprising that many countries, organizations and space agencies are already making preparations to build permanent settlements and bases throughout the solar system starting with the Moon and Mars. The Moon our only satellite and the closest celestial body to the Earth is the next logical step in the ladder to becoming an interplanetary civilization. We have the technology to do so and NASA's current estimates say it could be possible with a budget of 20 to 40 billion Dollars spread over the time of a decade. This budget is comparable to that of the International Space Station or a mere 1% of the United States Federal Budget in 2019. A small investment with an immeasurable payoff if done right. This is a step in the right direction towards becoming a type 2 civilization on the Kardashev scale, develop new technologies and discover new sources of energy.

degrees Celsius in temperature (Maximum Temperature = 127 degrees Celsius and Minimum Temperature = -173 degrees Celsius). There is no atmosphere to protect the surface from asteroids and meteors or shield from solar and cosmic radiation. The lunar surface is covered with a jagged dust. The lack of atmosphere or oxygen, radiation shielding and a regular flux of asteroids and meteors can make a Moon base seem like a very unlikely project for mankind but with proper planning and preparation we could overcome these challenges and build the first fully sustainable human settlement outside Earth.

Phase 1 (Scientific Exploration): The scientific exploration of the Moon has already been started and has been continuing since the first Lunar flyby by the Luna 1 in 1959 and the Apollo missions to the Moon half a century ago. Since then satellites like the American Lunar Reconnaissance Orbiter have mapped the Moon while rovers like Yutu have studied the composition of the lunar surface looking for ice, water and metals. This is still being continued by current and future missions to the Moon like the Chandrayaan-3 mission by Indian space agency ISRO and the American government funded international human spaceflight program called "ARTEMIS", carried out predominantly by American space agency NASA along with the help of many international partners and other missions by various countries and space agencies. These missions in the past have gathered a lot of scientific data, like landing sites, terrain data and maps, weather and temperature conditions, radiation maps, lunar samples from various locations on the Moon, asteroid impact data etc. All of this data has been studied and researched on to gain new perspective and knowledge about the Moon. The first phase of our proposal focuses on using this data to plan missions to the Moon for the phase two to set up temporary outposts.

Phase 2 (Building Temporary Outposts): Before we can build a sustainable base for human life on the Moon, we first need to lay the groundwork required for civilization to thrive outside Earth. In the second phase of our study we provide a framework to build the first temporary Moon bases using resources from Earth with crews of a few members to lay the groundwork for future permanent settlements. We can use the data gathered from the first phase to jumpstart the second phase. The habitats will be light and inflatable making it easy to send them in rockets from Earth. The bases will need to be built in places with natural shelters like caves, underground lava tube

Figure 1 Project Crescent Mission Phases



Proposal: This paper proposes a detailed plan for building a sustainable Moon base and subsequently establishing a permanent human settlement on the Moon. In this study we have divided the settlement of Moon into three primary phases namely, "scientific exploration of the Moon", "building initial and temporary outposts", "building permanent bases and a sustainable future for human life on the Moon". Then the final phase is extending mission support from lunar gateway to interplanetary mission. The primary intent of this paper is to answer the question, "If we started today, how we would build a Moon base? We have shown the overall mission phase in Figure 1.

About the Moon: As we are all aware the Moon is not a very hospitable place for humans. A Moon day lasts 29 Earth days with a difference of 300

tunnels or craters near the poles. The bases could be subsurface habitats, capable of stabilizing habitat's internal temperature during night-time. Further, the habitats would be environment tolerant to keep the astronauts secure from every critical condition. Its thermal stability is enhanced by the thickened wall structure sealed with either in-situ thermal insulating material or synthetic insulators. Apart from its wall design, its potentiality to isolate itself from the surface environment at night triggers additional temperature stability. These temporary bases will have small crews which will need to be rotated on a regular basis of a few years for more efficiency of research and reducing risks of various space hazards to the crew (like over exposure to radiation and other health risks caused by low gravity and isolation) and the mission. These habitats will also have to be abandoned or shifted as solar panels will not be able to produce energy during the lunar night. The second phase will primarily focus on studying and experimenting extensively on the available lunar material composition, finding ways to extract and use the lunar resources, finding shelters like caves for building bases, locating and converting frozen water under the lunar surface into water and its components; Hydrogen and Oxygen (which can be used for rocket fuel, storing energy in Hydrogen cells and breathing) and use water for drinking and experimenting with growing plants for food and a natural source of Oxygen.

Phase 3 (Building Permanent Habitats and a sustainable future for human life on the Moon):

As the name suggest the third phase of our proposal will focus on using all the data and groundwork laid by the first two phases to build permanent settlement or habitats for humans. But these settlements will not be permanent if the funding from Earth stops. To become a sustainable base, it needs to become self-sufficient via trade with Earth. The base can be used as a depot of fuel and water (produced in the base) for other scientific missions to space. Due to very low gravity on Moon (1.62m/s^2) compared to Earth (9.8m/s^2) the Crescent Moon base can also be used as a space station and launch pad for all missions to outer space. The abundance of precious metals like titanium, platinum, uranium, gold and many more, left by asteroids in impact craters could be used in repairs and to build rockets. This could also create a supply chain of precious metals to Earth resulting in flow of income to the base. Mining of ${}^2\text{He}^3$ and building nuclear fission and fusion reactors to produce cheap and clean energy for the Crescent Moon base as well as to export to Earth is another promising possibility. Asteroids that flyby the Moon could be pulled into the Moon's orbit and mined for precious metals and minerals. If possible Moon could be used as a controlled tourist vacation spot to create even more flux of cash towards the base building a strong economy.

Phase 4 (Future of the base): The settlement can now grow and expand exponentially (which can be dubbed as the fourth and final phase of the mission) using the income and the lunar material for construction of new bases and massive structures without having to depend on Earth. With this vast array of possibilities of commercialization of the Crescent Moon base the settlement will outgrow its third phase and become independent, self-sufficient and economically productive.

Conclusion: Building a Moon base is an expensive and daunting task that will take a lot of time, effort and patience from those brave enough to undertake it. But once a Moon base is fully operational it will become the hub of scientific and technological advancement like asteroid mining, clean energy, space elevators etc.; unlimited resources in the form of precious metals, minerals, nuclear fuel; space exploration and expansion of mankind into the solar system. It is the logical step to setting foot and settling on Mars and moving towards the outer solar system. A Moon base is our gateway to becoming a type 2 civilization on the Kardashev scale and to ensure the survival of humanity beyond Earth.

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