Lunar Ice Operations Architecture
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A- Business Objectives

A1- Context

The main components of water, hydrogen, and oxygen are two of the biggest materials that are used to power rockets right now. And making rocket propellant out of the water on the Moon could drastically cut down on the cost of doing ambitious missions in space. In one study, researchers detected water directly on the lunar surface, finding the molecule on areas of the Moon lit by the Sun. A second study speculates that water ice might be trapped in tiny pockets or small craters littered all over the Moon's surface, making water potentially more abundant and more accessible than we could have imagined. The two studies were published today in the journal Nature. But the only water we've been able to find and verify up until now is really difficult to reach. It seems to be primarily located in large craters at the lunar south pole that are in perpetual shadow. The frigid craters are dangerously cold, possibly reaching -400 degrees Fahrenheit making them practically impossible to access with modern technology. The craters in the poles are thought to be potentially rich in ice 100 million to 1 billion metric tons, according to some estimates because they are permanently in shadow. But scientists still don't know much about the ice that might be there.

Using images taken by NASA's Lunar Reconnaissance Orbiter, the researchers believe these small regions are cold enough to store frozen ice. Unlike the giant craters at the south pole, these ones are small and easy for, say, an astronaut to reach. "There are billions and billions of them, which means that you could land in an area that is lit by the Sun, and then bend over or get down on your hands and knees and extract samples from these micro-cold traps," says Hayne. He and his colleagues estimate that 40,000 square kilometers (around 15,400 square miles) of the Moon are capable of trapping water this way.

In a tweet, NASA Administrator Jim Bridenstine announced that NASA was looking for companies to help mine the moon.

NASA anticipates paying roughly between $15,000 to $25,000 for between 50 to 500 grams (1.7 ounces to about 17 ounces) of material, and companies would also be able to set prices in their bids.

United Launch Alliance is maintaining its $3,000-per-kilogram ($1,360 per lb.) offer, first made in 2016, for moon-derived propellant delivered to low Earth orbit.

A recent report has identified a near-term annual demand of 500 tons (450 metric tons) of lunar-derived propellant, equating to 2,700 tons (2,450 metric tons) of processed lunar water, generating $2.4 billion of revenue annually.

At the core of NASA's future in space exploration is a return to the moon, where we will build a sustainable long-term human presence with new spacecraft, robotics, and life-sustaining technologies. Living and working on the moon will provide opportunities for research and technology development that will prepare humans for further exploration to Mars and beyond.

A2- Lunar Ice Strategy

We are a French mining oil and gas corporate expanding its activity to the moon. The new branch, LUNAR ICE, is specialized in ice extraction and transformation on the moon. The extractions will be transformed into rocket propellant and drinking water.

Robotic systems will do all the work. No human presence is required on the moon.
How do we design a device that can do all that work? How can we create an automation that is a rover and water filtration center and power plant all rolled in one rolling vehicle? On the one hand, the robot in question has to be light enough to feasibly fly on a rocket. On the other hand, though, the machine has to be heavy enough to operate in less gravity than that offered by Earth. (In the moon's case: less than 20 percent of that gravity). It also has to be generally substantial enough to dig into soil without tipping over, and to operate as a kind of multi-purpose machine. We are partnering with SpaceX, the American heavy launch vehicle manufacturer, to land the Ice extractor system, the processing plant, and the storage system.

Why having a partnership with SpaceX ? Since its inception in 2002, SpaceX has played a key role in the conquest of space. After a successful launch and return from space, it was the first commercial company to successfully send an unmanned spacecraft into orbit and dock it to the International Space Station. Elon Musk founded SpaceX with the goal of changing the aerospace industry and making spaceflight accessible. SpaceX has sent 48 satellites and 22,700 pounds of supplies to the International Space Station, earning more than 60 percent of the world's commercial launch contracts.

Among SpaceX's many strengths, we note the following that justify partnering with the company to develop a robot extractor.

- Partnerships: SpaceX would not exist without the help of industry leaders. These relationships have helped the company break into the industry. The company's early collaboration with NASA's Kennedy Space Center illustrates the power of partnerships. SpaceX has used NASA's launch facilities, landing sites and oversight to complete some of its missions. For LUNAR ICE, this partnership will address barriers such as lack of capital, facilities and lunar missions.

- Intellectual Property and Innovation: SpaceX places a high value on advanced technologies and intellectual property. It must constantly explore new avenues to develop high-tech products in competition with NASA, China and Russia. SpaceX has built a reputation for mission success by manufacturing its equipment and training its workforce. Because of intellectual property protection, competitors must now design better spacecraft or produce at SpaceX's technology level. Through a partnership with the company, lunar water will benefit from the latest technologies to best design the robot that requires a particular combination of technologies.

- Reusable system: SpaceX has a reusable rocket technology, which allows it to save money on rocket fuel costs. In addition, it does all of its development, testing and manufacturing in-house. This can be a great opportunity for LUNAR ICE to sensibly reduce the cost of this diversification.

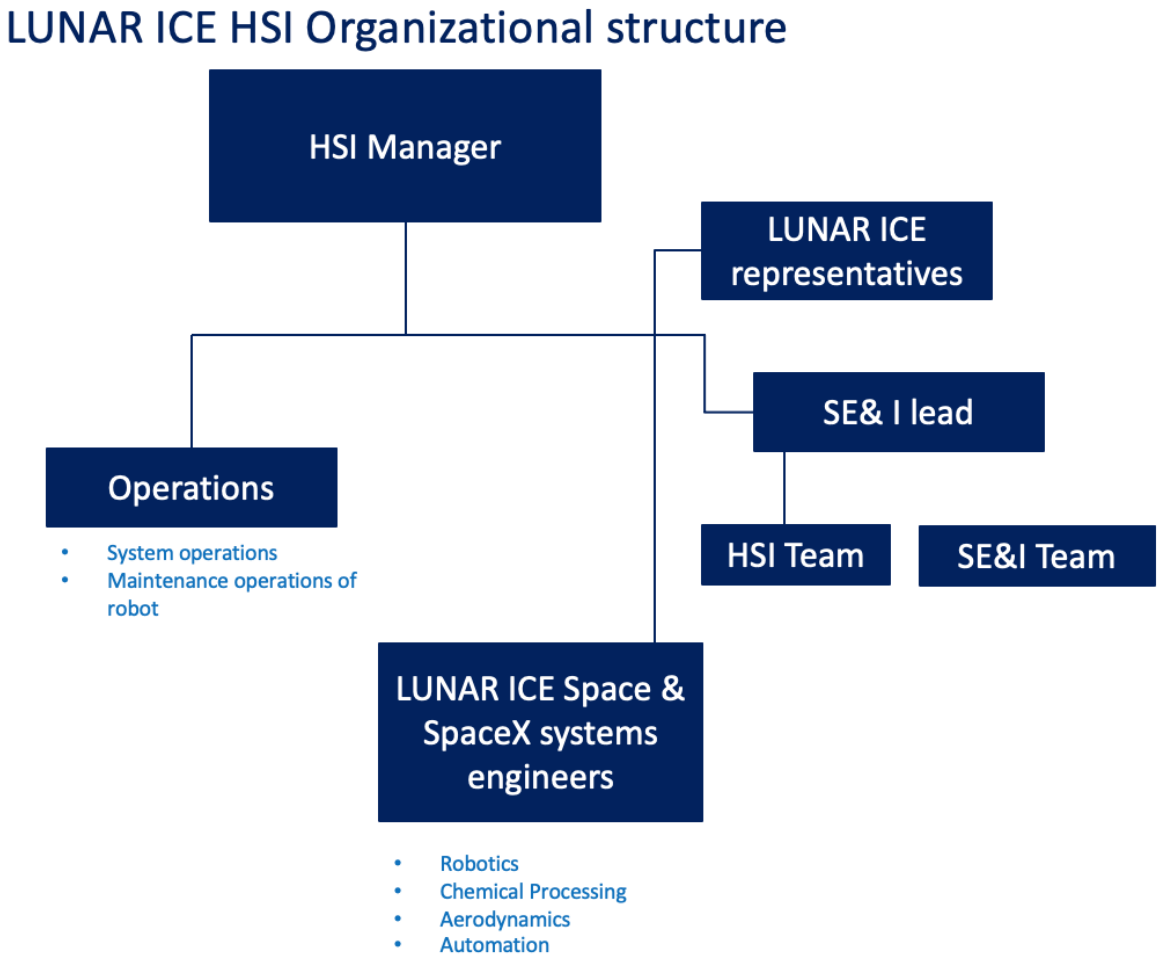
- SpaceX’s Super Heavy rocket, the most powerful rocket ever built, has recently completed a successful ground test of its engines.

- Employee bonding: The company's open atmosphere allows employees to come up with creative solutions to problems, which helps them achieve their goals. Everyone is treated fairly and always tolerates their teammates' mistakes. Hard work is the order of the day. It is in this state of mind that LUNAR ICE and SpaceX engineers can work hard on robot design.This engineering collaboration is highly important since Human Systems Integration (HSI) means not only making certain that the systems we design are friendly to the end user, safe, and resilient, but also ensuring that all phases of life-cycle development that involve humans are integrated in a cohesive manner that results in the highest probability for mission success (*cf course ppt NASA Handbook, NASA HSI Fundamentals*).

Our vision is to become the main propellant and water supplier on the Moon : LUNAR ICE is created to share SpaceX's journey in the space conquest of humanity.

A-3 HSI Organizational structure and Stakeholders Analysis

The organizational structure of LUNAR ICE follows a typical single project program structure.



The stakeholders analysis of LUNAR ICE is as follows. Investors, SpaceX partners and engineers are the key resources contributing to either the effort and the decision making process of LUNAR ICE.

Stakeholders	*Expectations / Needs*	*Effectiveness Metrics*
Investors	Profitability	ROI
Space Agencies	Refuel the rocket on the moon; Water for human consumption and Radiation Shielding.	Demand fulfillment & Sales
Partners (SpaceX …….)	Profitability	ROI
Engineers	Resources for effective technologies design	Technologies that meet the requirements
Scientists & Academics Experts	Resources for Innovative solutions	Variety of technologies and Improvement Rate
Government	Sustainable Exploration & Production	Environmental Impact
Space Lawyers	Operations with respect to the space regulations	Violation Rate

B- Concept of Operations

Before the start of the operations, Obtaining more data on conditions within the shadowed regions is vital to the design of a lunar ice processing plant.
How much water is actually present, and at what percentage in the lunar regolith? How deep is the ice resource, and in what state is it deposited amongst the regolith? These and other questions must be answered by precursor prospecting and science missions.

Unlike terrestrial mining operations that utilize heavy machinery to move resources, the mass constraints of a lunar polar water mine are highly restrictive because of delivery costs.
NASA has introduced a revolutionary concept that will solve this issue.

Water will be extracted from the regolith by sublimation—heating ice to convert it into water vapor without going through the liquid phase. This water vapor can then be collected on a cold surface for transport to the processing plant .

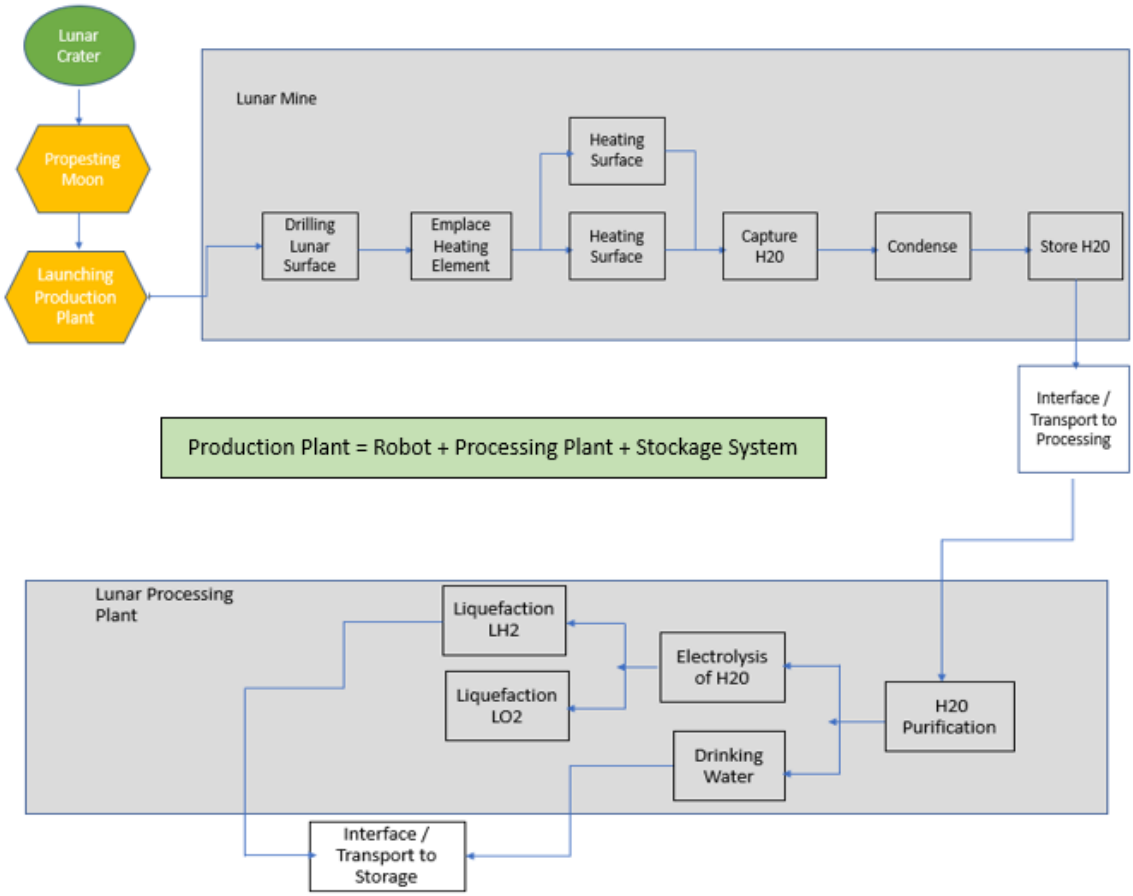
The equipment needed for this lunar propellant operation will be built from existing technologies that will be modified for the specific needs on the Moon. Extensive testing on Earth will precede the deployment to the Moon to ensure that the robotics, extraction, chemical processing, and storage all work together efficiently.

The majority of the electrical power will be needed in the processing plant. We will use solar panels, and the captured solar energy must be transported via power beaming or power cables.

B-1 Functional Flow Diagram of Lunar Surface Operations

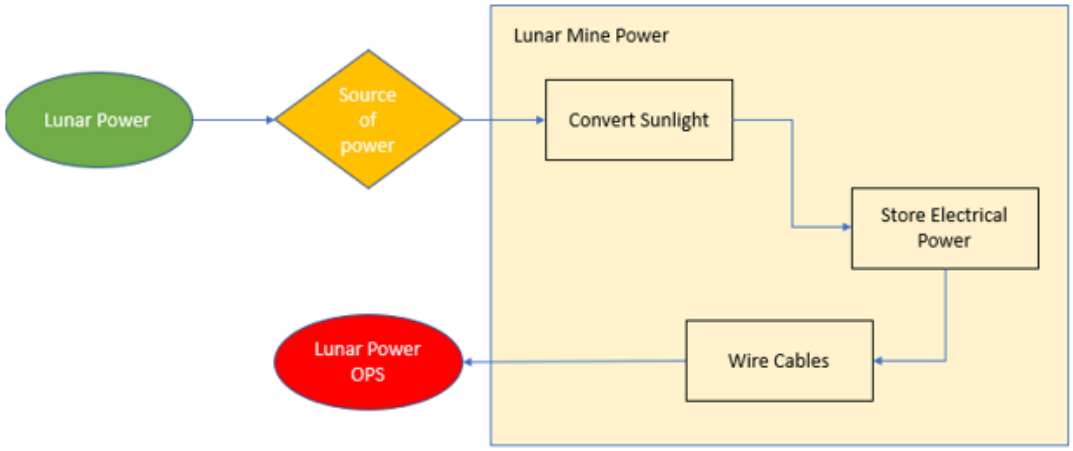
- Lunar Ice Mining & Processing

Lunar Ice extraction is done by sublimation. Drilling and heating the regolith to transform the trapped ice into water vapor. The captured vapor is condensed and transported to the processing plant.
In the processing plant, after the purification, the vapor is either transformed into rocket fuel or drinking water.
To get the rocket fuel, the water vapor is split into hydrogen and oxygen; then, each molecule is liquefied and stored in the stockage.



- Lunar Mine Power

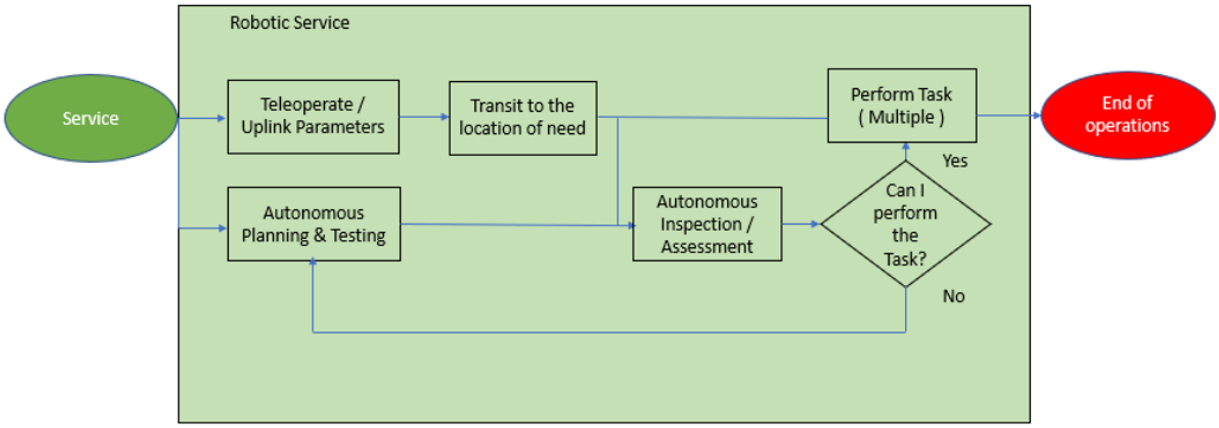
The Lunar Power System will convert the sunlight to electrical power, then supply the processing plant and the stockage system. It will also recharge the robotic system.
The electrical power will be supplied through power beaming or power cables.



- Robotic Service

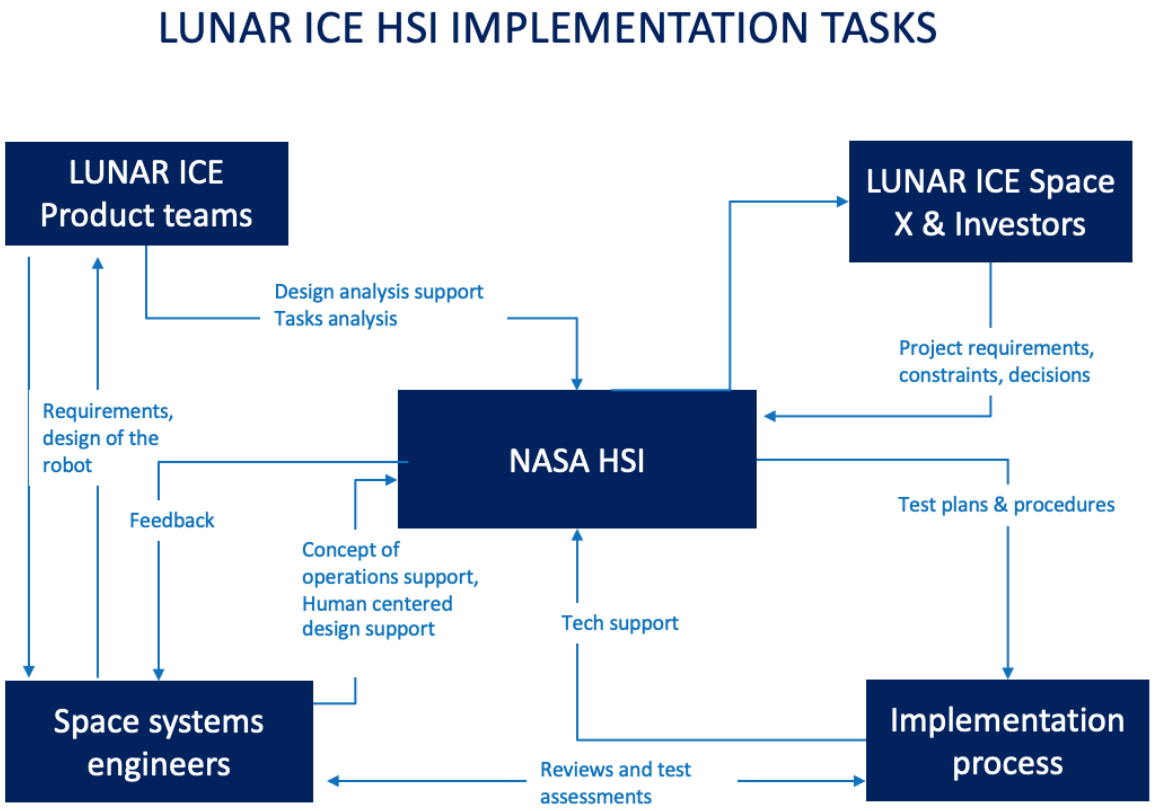
The Robot will be operated from the earth via telemetry or can be completely autonomous. The main activity of the robot is to transit to the location of need and perform the task.

Tasks performed: Drilling and heating the regolith; Capturing water vapor and transport in the Processing Plant; Power recharge from the Lunar Power System.



B-2 HSI Implementation tasks

Here's an overview of the concept architecture of the LUNAR ICE robot extractor solution with System Engineering Integration including HSI.



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