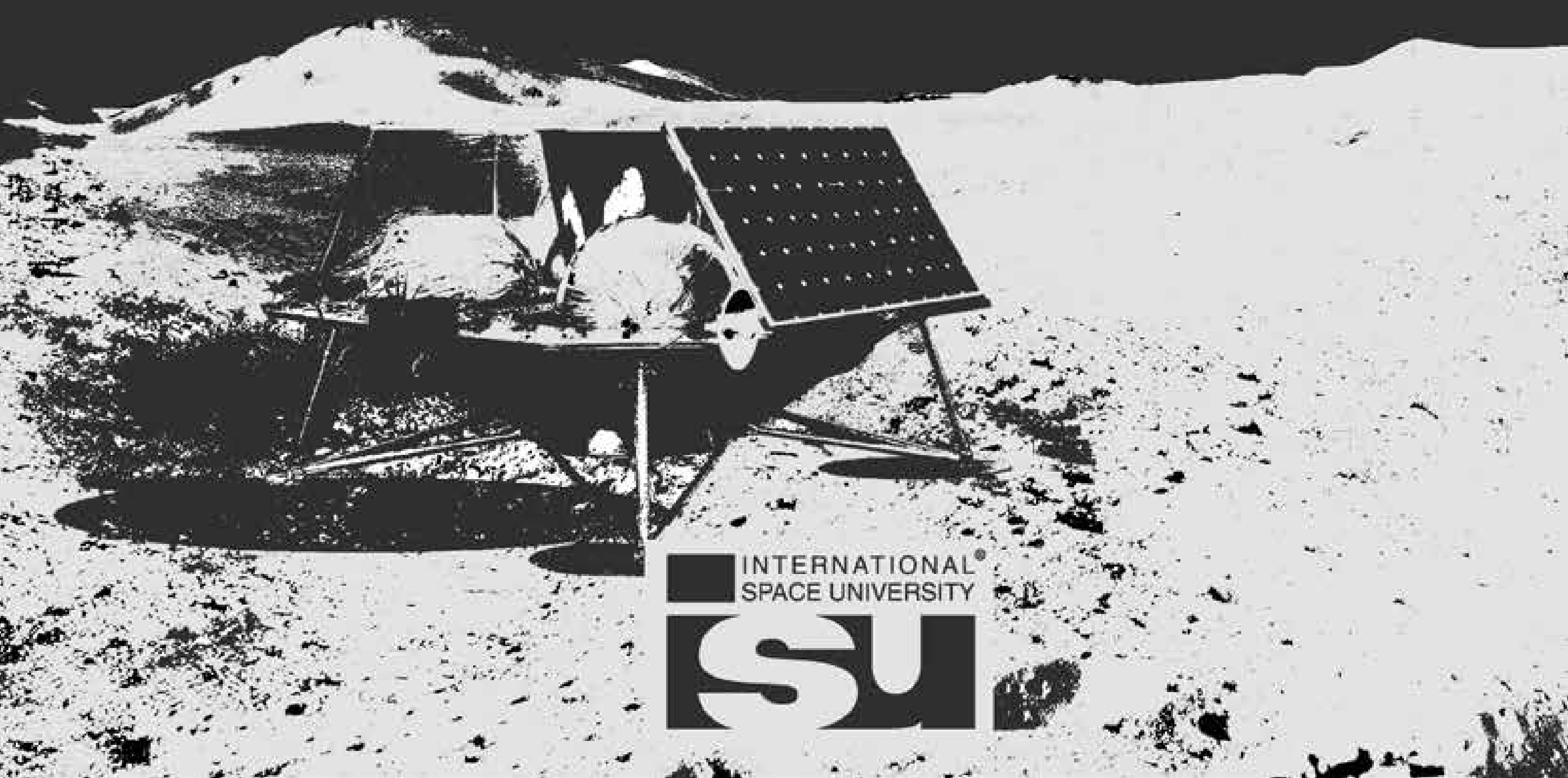
Masters of Space Studies 2016

Executive Summary

Luna Hathor

International Deep Drilling Lunar Mission Study



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Luna Hathor

International Deep Drilling Lunar Mission Study

Mission Statement

Luna Hathor will develop a framework for future international space mission collaborations and assess the scientific and technological aspects of a deep drilling mission to the Moon.

Motivation

The motivation in the project stems from the necessity of promotion of international collaboration between different nations and private entities while obtaining valuable scientific and technical knowledge to further push the future frontiers of humankind.

Luna

Hathor

Luna, the divine embodiment of the Moon from Roman mythology.

Hathor, the Egyptian goddess of foreign lands and mining.

Luna Hathor

Methodology

A new framework for analyzing international collaborations is introduced to assess various space missions in an international environment from the policy, economics and industry perspective. Consequently, it is used to propose new collaboration/ partnership structures. It is then applied to a deep drilling lunar mission. Subsequently legal feasibility, scientifically interesting regions of interest, technology, and outreach strategies are analyzed to complement the core framework.

Rationales

Decision level framework. Entails the drivers and willingness of a stakeholder to pursue a space mission

- Political and Security Rationales
- Economic Rationales
- Science and Technology Rationales
- Public Participation and Outreach

Opportunities

Project implementation level framework. Entails the ability of the private or public stakeholders to pursue a space mission

- Stakeholders, Funding Access, Budget Allocation
- Technology Access and TRL Cost Levels
- Mission Objectives (Science, Technology, Business)
- Risks and Cost of Risk

Collaboration Structures

Collaboration structures for international projects are analyzed for two cost cases with participation of combinations of seven major space faring nations. A mission case study for 'validating drill technology for Moon or asteroid drilling' s then presented with proposed mission scenarios.

Policy and Industry

Defines and implements the core frameworks for seven major space faring nations' interaction with the eight key elements grouped into rationales and opportunities for a deep drilling lunar and proposes recommended collaborations

Legal Feasibility

Identifies relevant legal aspects and assesses feasibility of recommended collaborations

Regions of Interest

Elaborates on scientific rationales and Regions of Interest for deep drilling on the Moon

Technology

Assesses key technology related to potential future deep drilling lunar missions

Outreach Strategies

Explores communication and outreach strategies for a deep drilling lunar mission

Policy and Industry

The Rationales and Opportunities frameworks analysis forms the basis for the report. The frameworks were applied to seven major space faring nations to produce international collaboration structures specific to a deep drilling lunar mission.

Europe

Rationales: Socio-economic benefits and industry creation, scientific research and technology, neutral & central global actor
Moon Interest: High, missions planned, potential Moon base

Canada

Rationales: Key space missions technologies development, participation
Moon Interest: Low, mission participation as a collaborator

Russia

Rationales: Space economy through technology transfer, case for military advantage through space
Moon Interest: Medium, mission concepts, aspirations for a Moon base

USA

Rationales: Private sector expertise, easy access to capital, asteroid mining and extraterrestrial resource legal initiative
Moon Interest: Medium, missions planned, and stimulation of private enterprises

Japan

Rationales: Key space missions technologies development, participation
Moon Interest: Medium, past and potential future robotic missions

China

Rationales: Prestige and foreign policy, uninterrupted funding, key technology redundancy for international collaboration
Moon Interest: High, missions planned, on-going Moon program

India

Rationales: Lost cost, high Technology Readiness Level potential
Moon Interest: Low, past and future mission plans

The Mission Scenarios

The Recommended Collaboration structures resulting from the Policy and Industry analysis were used to generate three high-level mission scenarios

1 Europe and/or Russia and/or China

2 US Space Vision on Public-Private Partnerships

3 China's Probable Vision on Leading the Moon Race

Technology

To achieve the mission, the lander has to perform a soft landing on the Moon. After deployment the surface operations are initiated by driling and extracting samples from at least 20 meters. The in-situ data is then communicated back to the mission control center.

Deorbit

A major deceleration is performed to position the module in a descent trajectory from its parking lunar orbit.

Powered Descent

The velocity is reduced during this phase and pre-scanning of the targeted landing area is carried out to adjust the trajectory.

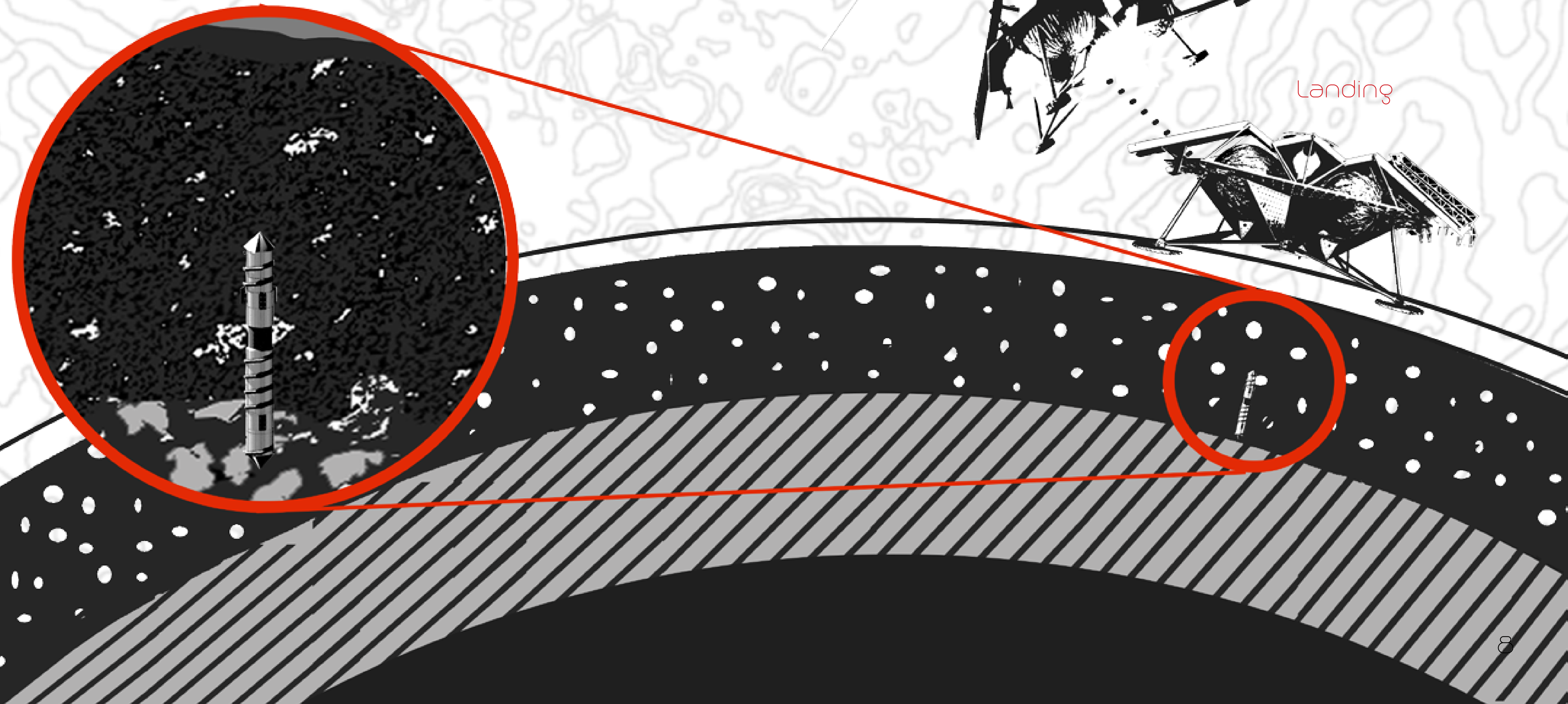
Approach

During the approach phase, vertical and horizontal control is realized to reach the selected lunar area. The vertical speed has to be controlled to perform the soft landing.

Landing

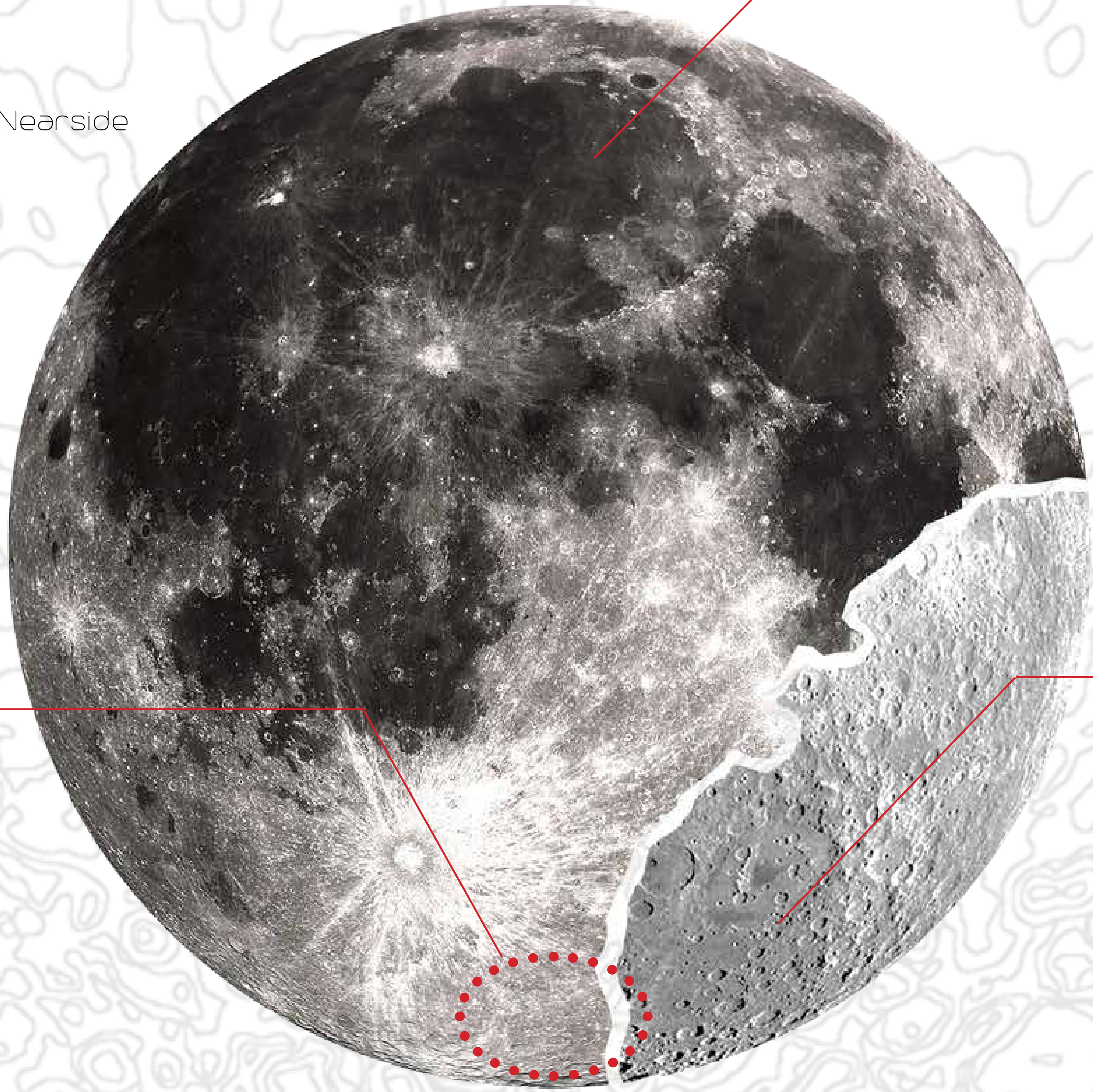
The Drill

The drill has to be designed to bore 20 meters through the regolith layer in extreme space conditions. The main specifications of the selected system, the Inchworm Deep Drilling System, are RTG powered, Tether free, and Rotary mechanism. This system is inspired by the movement of an inchworm and its body is expanded and contracted driven by standard motors.



Regions of Interest

Luna Hathor will contribute to answering the most pressing questions from the Committee on the Scientific Context for Exploration of the Moon, advancing the scientific knowledge of our satellite. Three regions of interest for the mission were identified, and one was selected, along with two general scientific objectives; Study the variety, age, distribution, and origin of lunar rocks and determine the vertical extent and structure of the megaregolith.



Maria Regions

Determine the vertical extent and structure of the megaregolith to characterize ancient regolith. Understand the lunar volcanism, which provides a window into the thermal and compositional evolution of the Moon. Determine the lava flux to interpret evolution of volcanism through space and time. Analyze lunar basalts for their origin, variability, age, composition, and the extent of their deposits. Study impact processes on planetary scales, characterize melt sheet differentiation and determine the structure of multi-ring basins.

South Pole Region

Determine the compositional state and distribution of the volatile component at the lunar South Pole. Determine and analyze the source(s) of lunar polar volatiles. Understand the physical characteristics of the extremely cold polar regolith. Study the atmosphere and dust environment around the poles.

South–Pole Aitken Basin

Infer the precise age of the SPA Basin by gathering and analyzing samples from its initial forming period. Determine the ages of impact-melt rocks from the SPA Basin, and major craters within it, in order to test the cataclysm hypothesis. Study the thermal state of the interior of the Moon by analyzing drilled samples and seismology. Determine the composition of the lower crust and bulk Moon by drilling.

Legal Feasibility

In order to assess the legal feasibility of a deep drilling lunar mission, specific mission scenarios are analyzed, followed by a long term legality of rationales behind them.

The three Mission Scenarios

1 Europe and/or Russia and/or China

2 US Space Vision on Public–Private Partnerships

3 China's Probable Vision on Leading the Moon Race

Mission Scenario Legality

Luna Hathor's three mission scenarios were analyzed for legality, reviewing a range of potential mission elements with legal impact in current space law. The framework used can be applied to other scenarios as well.

Long Term Drivers and Motivators

The mission scenarios' rationales were mapped to a variety of potential long-term drivers and motivators and their feasibility under potential future legal regime frameworks was analyzed. The regimes were grouped in archetypes for cooperation requirements analysis.

Legal Feasibility of Mission Scenarios

All three mission scenarios have variants that are legal within current international law. For all of them, there are several potential future legal regimes that would provide legality of each scenario's underlying long-term drivers and motivators based on its Policy, Economics, and Industry rationales.

Legal Regime Cooperation Requirements

The top three legal regimes prioritized for the stake-holders of each mission scenario were found to be the same – Modified Moon Agreement, US-Luxembourg Mining Laws, and Luna Gaia Settlement. They require high cooperation and long time to establish, therefore work on them should start today.

Legal Domains and Elements

Exploration

e.g. science, sampling prospecting, etc.

Exploitation

e.g. resource and territory appropriation, benefits sharing, etc.

Property Rights

e.g. land, intellectual property, movables or immovable facilities, etc.

Planetary Protection

e.g. drilling, extraction occupancy, nuclear or bio contamination, etc.

Rule of Law

e.g. full sovereignty, self-governance, militarization, etc.

General/Other

e.g. registration, liability, authorization, frequency acquisition, etc.

Outreach Strategy

Luna Hathor is a superb opportunity to advocate for a return to the Moon. Triggering a wide-spread sympathy in favor of lunar exploration will help this mission lift-off.

Space Agencies Communication Departments

Scientific Community

The key scientific channels of communication are: scientific blogs, scientific publications, press releases and free publication on the Luna Hathor website.

Data from the scientific instruments onboard the lander will be published freely. Input from the scientific community will help guide the choice of experiments once the initial objectives are complete. This mission is a great opportunity to increase transparency, connectivity and investment in science.

Political Community

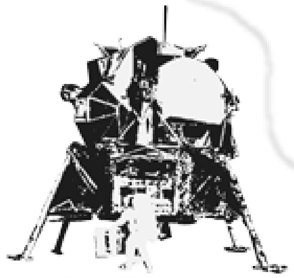
The key political channel of communication is a lobbying campaign.

This project will bring jobs and prestige to the countries involved in it, reinforce the industrial base and will generate a number of spin-offs, with only a slight increase in agency budgets. This project is a natural continuation of the International Space Station and will strengthen commercial ties between the partners involved. This mission will be carried out in cooperation with international partners in a spirit of peace and progress.

General Public

The key channels of communication are divided into: Classic media: TV, Radio, Newspaper. Internet media : Facebook, Twitter, Instagram, YouTube, blogs.

The general public has no unique identity. Their interest in space exploration depends on many factors including culture, nationality, and generation. The influence of the different generations is discussed on the next page.



Apollo generation

1945 to 1960

Born between 1945 and 1960. They remember the lunar landings and are the generation that has the greatest emotional investment in space.

This is the easiest audience to reach out to, but they use the most expensive channels of communication: TV, radio and newspapers. Key messages are: “Together, we can settle the Moon”, “The Moon, our new frontier”, and “The first brick of the Moon village”.

Generation X

1960 to 1980

Born between 1960 and 1980. They lived during the Space Shuttle and Space Stations era, when spaceflight proved less spectacular than during the Space Race.

This audience is challenging, as not particularly interested in space exploration, but could be sensible to spin-off technologies and new applications arguments.

Generation Y

1980 to 2000

Born between 1980 and 2000. Highly connected but not very interested in space exploration.

Impervious to corporate messages, they need direct and instantaneous interaction to be interested. Communication should primarily be through social media.

The MSS 2016 Team Project work was conducted at the ISU Strasbourg Central Campus in Illkirch-Graffenstaden, France.

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