SCALE MISSION BROCHURE

Sample Celestial Ampex Lunar Endeavour

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Introduction

The space exploration industry has undoubtedly seen one major trend towards the end of the 2010s: the re-emergence of the space race to the moon. Not only have most of the major space agencies put moon missions back on their agenda, but also a number of commercial lander providers have emerged following the Google Lunar X Prize competition. These lander companies are on the brink of beginning regular operations to the moon, which opens doors for many interested parties, such as universities and other research institutes, which would not have had the opportunity of conducting their research on the moon otherwise. This has inspired countless technologies to be investigated and further developed for our future as humans on the moon.

The SCALE (Sample Celestial Ampex Lunar Endeavour) mission combines three diverse technologies to be demonstrated in a mission to the moon. SAMPLE is a life-sustainment experiment, Celestial is a communication system, and AMPEX will test the manufacturing of fibres made of lunar regolith. These systems started as university student projects in the IGLUNA campaign, an initiative by the Swiss Space Center and supported by the European Space Agency. During IGLUNA, students are guided in the design and development of innovative projects for the future of space exploration. The SCALE mission aims to bring these three products, which had their beginnings as student projects, to their destined spot on the moon.

SAMPLE payload

The SAMPLE (Semi-Autonomous Modular Plant and other Life-sustaining Experiment) aims to enable the storage of biological specimens in extreme conditions outside of a human habitat.

SAMPLE can be used for the cultivation of edible plants during a space exploration mission, for example on the moon. Sustaining non-human life in space raises several issues. Human habitats on a space exploration mission must provide conditions required for survival. Those conditions are very strict, resource consuming and demand careful control. Some biological samples, however, do not pose such strict requirements and so there is no need to store them in the main human habitat. Space in the habitat is also scarce and insufficient for the cultivation many plants. There should be a separate space designated for this purpose, with conditions designed for the specific species. There is also a need for experimentation towards sustaining life directly on the surface. Such early experiments can be conducted on non-human species, with the goal of developing reliable technologies which can later be applied to human bases.

SAMPLE addresses these issues by proposing a modular solution, with each module able to adjust to the very specific conditions required by the life inside. The modules are designed to be as autonomous as possible, by using a closed cycle of matter, which has had promising results in applications on earth. The modules will be appropriately insulated against heat loss and radiation and equipped with remote devices to control the internal conditions and with sensors recording the scientific data of the experiment.

Parameter	Value
Dimensions	[TBD]
Mass	< 55 kg
Expirement duration	7 days at minimum
Power (nominal)	50 W
Power (peak)	100 W
Radiation (plants)	8.3 uGy/h
Working temperature	15 to 25 °C
Heat emission	50-100 W

Celestial payload

Celestial aims to enable cis-lunar communication to support a growing space economy, by providing communication and antenna systems for an earth-moon communication link through a data relay small satellite constellation.

Celestial aims to enable cis-lunar communication to support a growing space economy. In the long-term Celestial will offer a communication link service between earth and moon based on a data relay small satellite constellation, thus aligning with strongly increasing lunar exploration and commercial activities. In the short-term Celestial's products will find applications for satellites in earth orbits as well. This will be in the form of communication and antenna systems. These systems will be deep space-qualified which will make currently unexploited orbits accessible. The products will also find many use cases in non-space industry sectors thus increasing the application potential of Celestial's core technology.

Parameter	Value
Dimensions	350x350x15 mm^3
Mass	< 0.6 kg
Satellite form factor	1U
Antenna	Rx & Tx
Data transfer rate	3 Mbps
Power	< 2.5 W
Temperature	-100 to 150 °C
Frequency	X & S band

Celestial's communication system and patch antenna have already been developed and will soon fly to Low Earth Orbit. The next step is to test its application as a phased array antenna system, which is the aim of Celestial on the SCALE mission. This will allow for an increase in the mission flexibility through its low powered reconfigurable communication system. as well as enhancing communication capabilities of lunar missions by relaying data to multiple satellites using this multi-beam array antenna. Celestial will also serve as the communication system for the SCALE payloads, which can alleviate some responsibilities from the lander regarding the SCALE operations. As mentioned, Celestial will work with relay satellites, and is designed to be adaptable to the satellites that are or will become available in the lunar orbit.

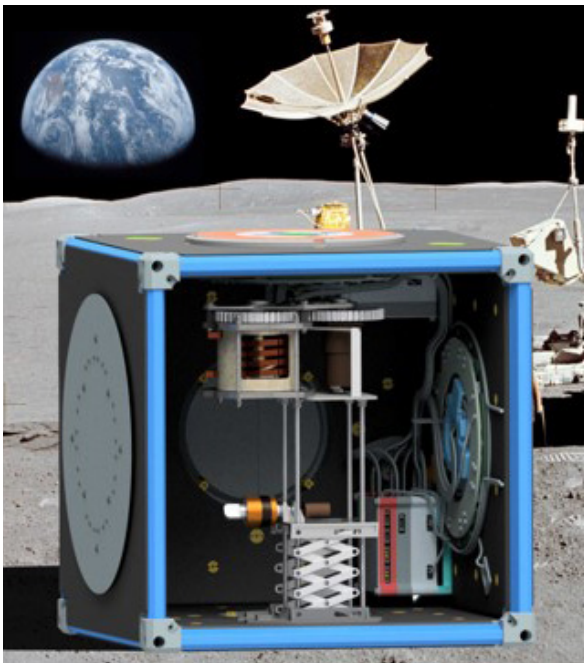
AMPEX payload

AMPEX (Aachen Modular Planetary Exploration) aims to demonstrate the technological capacity for the manufacture of continuous material fibres from lunar regolith, and thus the economic viability of extra-terrestrial infrastructures made of in-situ resources. AMPEX is supported by the MoonFibre project of RWTH Aachen University.

The transport of payloads into space, e.g. for research missions or the construction and supply of manned lunar stations, poses immense economic challenges in addition to technologically complex tasks. With payload costs of 1.1 million €/kg to the lunar surface and space projects requiring large freight volumes, weight reduction is essential. However, raw materials from the moon or Mars in the form of regolith are suitable for producing habitat building materials and thus reducing freight costs for further missions into space. For this purpose, continuous mineral fibres, e.g. basalt fibres, can be utilized in situ to produce fibre composites, thermal insulation, filters and hydroponic mineral wool for plant cultivation, among other things. However, this requires a spinning unit that can be operated under the extreme space conditions.

The goal of AMPEX is to demonstrate a miniaturized spinning unit to produce mineral continuous fibres on the moon. The overall design is realised with an edge length of 30 cm. The system serves as proof of concept of the ISRU spinning technology, that will be demonstrated on SCALE. The result is a functional prototype of a basalt fibre spinning plant, that can be upscaled to larger plants in the future. This first mission of AMPEX will use prepackaged lunar regolith simulant, whereas later versions will use the regolith itself.

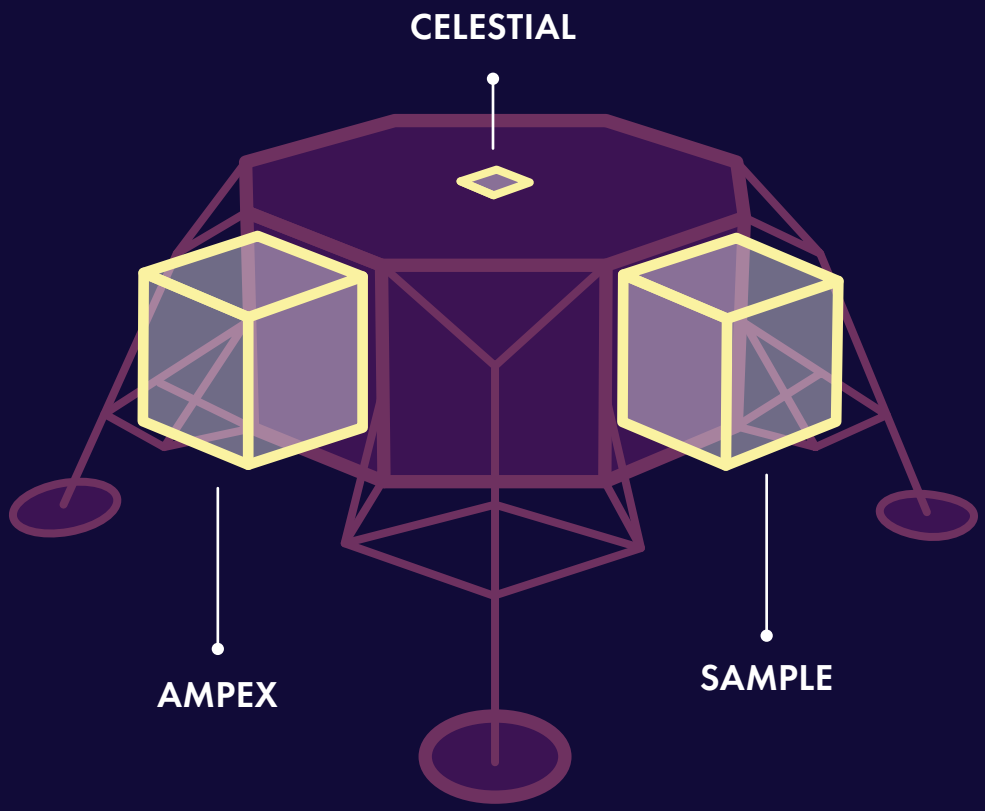
Parameter	Value
Dimensions	500x500x500 mm^3
Mass	< 55 kg
Exp. duration	< 3 hrs
Power	< 600 W
Working material	Moon regolith simulant (prepacked)
Working temperature	1270 ± 20 °C (inside crucible)
Heat emission	[TBD]



Payload integration

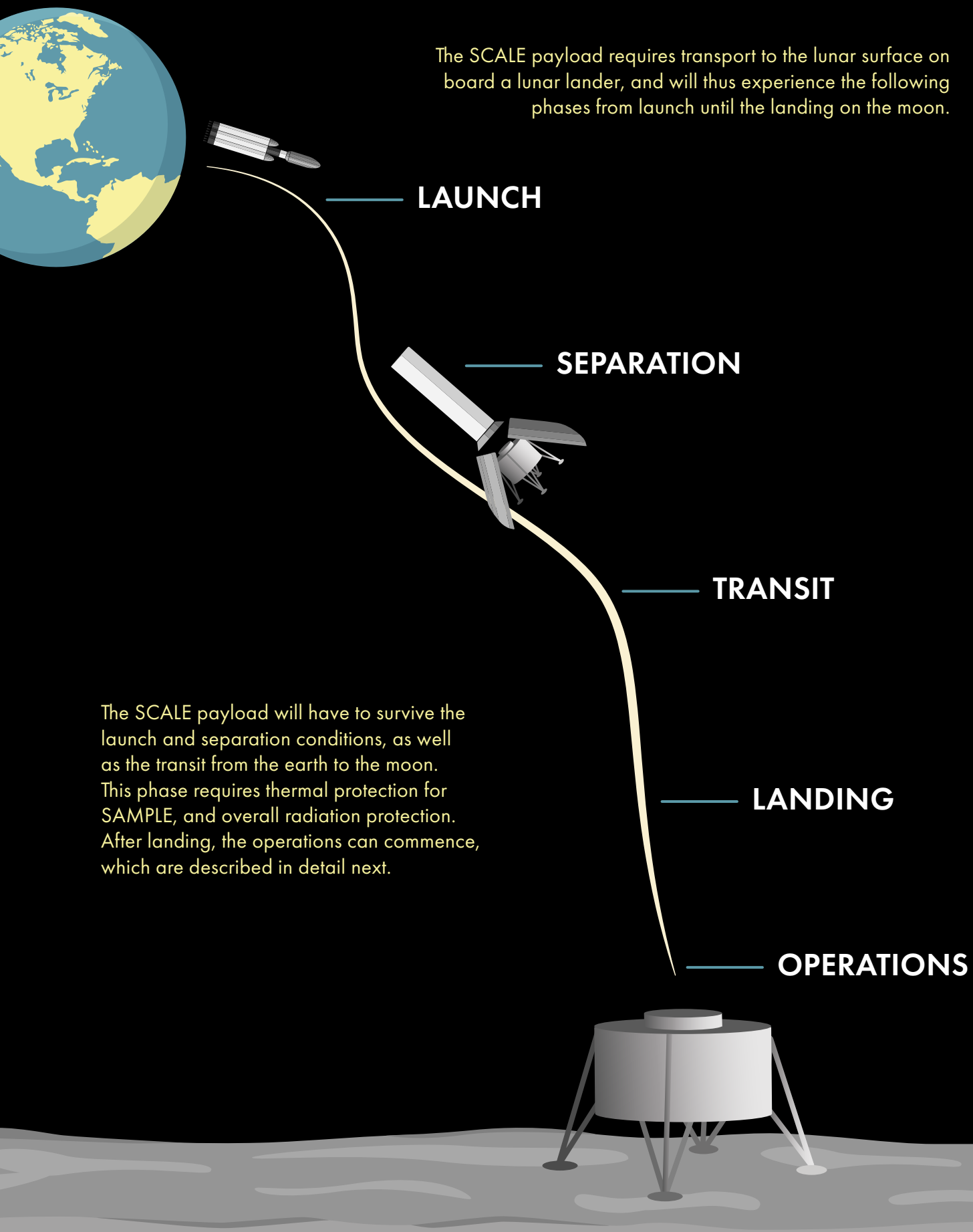
SCALE combines the SAMPLE, Celestial and AMPEX payloads into one payload group that aims to fly on a single mission to the moon. The three individual payloads are integrated into one system that will handle its operations, power distribution, data handling and thermal control. This central system will then interface with the lander to transfer its resources to the payloads as needed. The physical integration of the SCALE system and individual payloads to the lander will depend on the options provided by the lander itself, and is thus open for discussion. Due to the high power demand, in part due to the strict thermal conditions needed by some of the payloads, SCALE may also be equipped with its own batteries to meet the power demands. This will also depend on what the lander is able to provide.

Parameter	Value
Landing site	Shackleton crater rim
Mission duration	1 lunar day (14 earth days) at minimum
Total mass	±125 kg
Total power (maximum)	600 W
Orientation	±5° maximum tilt
Temperature (storage)	[TBD]
Temperature (operations)	[TBD]
Heat emission	[TBD]
Data transfer rate	[TBD]



Mission phases

The SCALE payload requires transport to the lunar surface on board a lunar lander, and will thus experience the following phases from launch until the landing on the moon.



The SCALE payload will have to survive the launch and separation conditions, as well as the transit from the earth to the moon. This phase requires thermal protection for SAMPLE, and overall radiation protection. After landing, the operations can commence, which are described in detail next.

Operations

DAY 0 — Lander lands

DAY 1 - 4 — Lander initial commission & operations, Comission of SCALE payload

DAY 5 — SCALE payload operations start

6 HRS

AMPEX

The AMPEX operations will consist of heating, spinning, cooling, and subsequent transfer of data. After the experiment, AMPEX will not be used for the rest of the mission.

CELESTIAL

Celestial will test its own operations on the moon during the SCALE mission, and will also serve to transfer data for the other payloads. Therefore, Celestial will start its operations together with AMPEX, and will be used for data transfer as needed throughout the mission.

2x12 HRS

SAMPLE

After the AMPEX operations, SAMPLE will commence with its first day cycle, in which lamps are turned on to simulate the earth day time, which will last for 12 hours. After the day, the night cycle will start, also lasting 12 hours. The lamps will be off during the night, and an active heating system will keep the plants at the correct temperature.

DAY 6

DAY 7-13 — SAMPLE will execute its Day-Night cycles 7 times in total

DAY 14 — End of mission: Decommission of SCALE

Roadmap

2021 **Phase A**
Concept & Technology Development

2022 **Phase B**
Preliminary Design

2023 **Phase C**
Final Design & Fabrication

2026 **Phase D**
Assembly, Testing & Launch Preparations

2028 **Phase E**
Launch & Operations

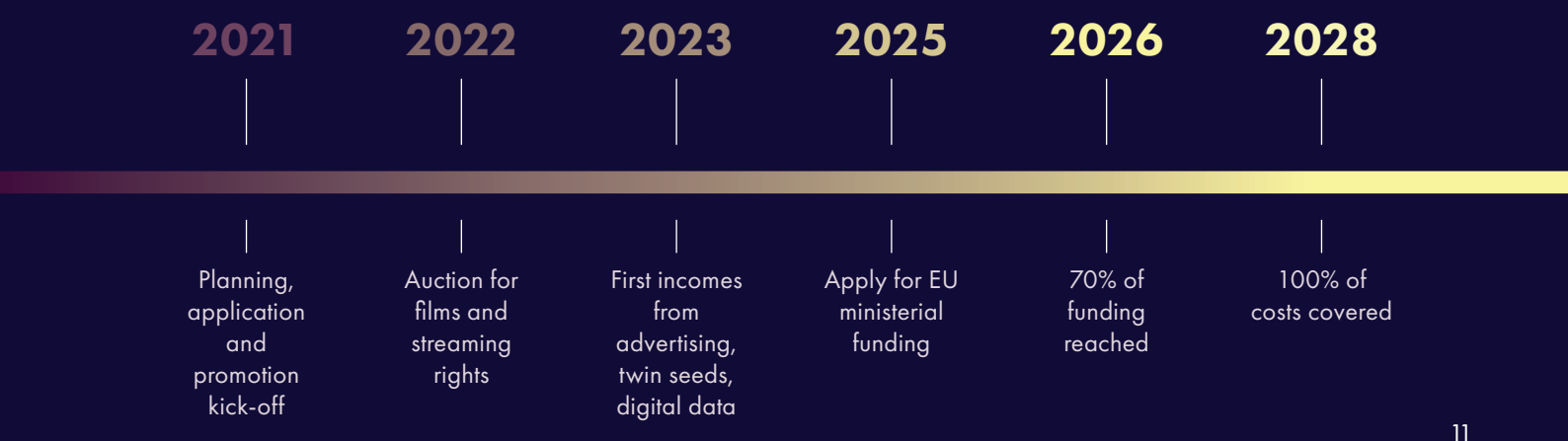
Business plan

SCALE will apply for ministerial and other sources of funding to make this mission possible. To further aid in securing this mission, SCALE will pursue several business opportunities that will provide diverse revenue streams over the course of the years towards the mission.

The SCALE mission combines three payloads that started out as university projects by student teams. Though some teams have branched out to become start-ups already, SCALE will require a long-term business model to secure funds to ensure that the mission can go through its life cycle and successfully arrive on the moon.

Several revenue streams have been identified that can be pursued to achieve this goal. The first is advertising, namely offering commercial companies advertising space on and throughout the mission, which is a popular trend among upcoming space missions, especially to the moon. Next, it is planned to film a documentary regarding the SCALE mission, its development over the upcoming years, and of course highlighting its beginning as a student project. The rights for this documentary would be sold to the highest bidder. Similarly, the launch and the mission can be livestreamed, and the rights for airing this can also be sold to the highest bidder. Having a camera livestreaming the growth of the Sample plants is also being considered.

The next concept in the SCALE business model is to provide a platform to customers to send their encrypted digital data to the moon, which can either be seen as a novelty, or an investment to be retrieved in the future. Lastly, SCALE plans to sell twin seeds of the Sample payload. The seeds growing inside the experiment on the moon will have twins back on earth. Space enthousiasts can buy and grow their own "space" plants, which may be especially exciting and inspiring for children. These multiple revenue streams would be in addition to any ministerial funding and other sources of funding that would be acquired for the SCALE mission.



Contact

SCALE is a part of the IGLUNA campaign organised by the Swiss Space Center.
For more information about the mission, please feel free to reach out.

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SAMPLE

AMPEX 20