Asclepios I

Mission Report

- Public Version -

August 2019 – March 2020

Asclepios.ch

Abbreviations:

AIFAA: Artificial Intelligence for Analogue Astronauts

BME: Biomedical Engineer

CAPCOM: Earth Communicator

DVA: Detection Victim Avalanche

EPFL: École Polytechnique Fédérale de Lausanne

ESA: European Space Agency

ESTEE: Earth Space Technical Ecosystem Enterprises

EVA: Extra-Vehicular Activity

FDM: Fused Deposition Modelling

FLIGHT: Flight Director

FP: Flight Planning

HI-SEAS: Hawai'i Space Exploration Analog and Simulation

ILEWG: International Lunar Exploration Working Group

LNA: Low Noise Amplifiers

MCC: Mission Control Center

MEDOPS: Medical Officer

NASA: National Aeronautics and Space Administration

NSF: National Science Foundation, The Public Health and Safety Organization

PI: Principal Investigator

PLA: Polylactic Acid

PROCEDURES: Procedures Monitoring

RECORDS: Records Manager

RF: Radio Frequencies

SAS: Special Airlock System

SCS: Science Specialist

SKIL: Student Kreativity and Innovation Laboratory

SOP: Standard Operating Procedure

SSC: Swiss Space Center

UKAM: United Kingdom Analog Mission

VPE: Vice-Presidency for Education

POI: Point of Interest

VP: Viewpoint

1 At a Glance

Due to the Covid-19 Pandemic, Asclepios I was postponed to the year 2021. This report is a summary of the work completed until early March 2020.

In April 2020, the first analogue mission of the Asclepios project will be conducted in Switzerland. The mission aims to simulate a 7-day long mission on the Moon for 6 analogue astronauts, supported by a small ground team in direct communication with the crew.

The mission is mainly directed by students from the École Polytechnique Fédérale de Lausanne (EPFL), but also integrates students from other Swiss universities and from other countries. It is an interdisciplinary project, as students from many different scientific fields and design are taking part in it. Laboratories and start-ups are also involved, allowing technical expertise, financial support and counselling for the project.

The project's objectives are the following:

I. **Promote space exploration using immersive projects for young generations.**

II. **Design and build a platform to test experiments lent by laboratories.**

III. **Organize a yearly analogue mission to build upon previous missions.**

The project also aims at teaching skills differing from the ones learned in class to the students taking part in it. These skills include project management, communication and research techniques but also more technical skills, that can be learned through the conducting of various experiments.

Figure 1.1: *Photo of the Moon Base, La Dôle*

Furthermore, the project has a focus on sustainability. Indeed, it is a central question that needs to be considered, as sustainability becomes a raising concern on Earth and crewed space exploration may be an opportunity to test and develop new technologies related to this burning issue. The mission will take place in La Dôle, in the Canton de Vaud in Switzerland. The habitat (Fig. 1) that will be used is lent by skyguide from the 6th of April 2020 to the 19th of April 2020. Being secluded from civilisation, it allows the analogue astronauts to be placed in isolated conditions.

2 Management

2.1 Mentors

Dr. Angelo Vermeulen is a mentor for Asclepios. He is a space systems researcher, a biologist and an artist. Dr. Vermeulen was also the analogue astronaut commander for NASA HI - SEAS I.

Figure 2.1.1: *Photo of Dr. Angelo Vermeulen*

Prof. Claude Nicollier is a former ESA Astronaut and currently a professor at EPFL. He is a member of the Swiss Space Center in Lausanne and has participated in the astronaut selection process at ESA. Claude is a mentor for the astronaut crew of the Asclepios mission.

Figure 2.1.2: *Photo of Prof. Claude Nicollier*

Prof. Bernard Foing is a scientist at the European Space Agency (ESA) and the executive director of the International Lunar Exploration Working Group (ILEWG). Through ESA, he will provide supervision and equipment to the Asclepios mission, as well as mentorship and advice to the team.

Figure 2.1.3: *Photo of Prof. Bernard Foing*

Théodore Besson is the managing director of ESTEE SA, as well as a researcher at UNIL and lecturer at EPFL. He has been working on a ground simulator preparing a crewed exploration mission for 10 years. He is a mentor for the entire team.

Figure 2.1.4: *Photo of Théodore Besson*

2.2 Partners

Several laboratories, companies and institutions are supporting Asclepios either financially or in the form of in-kind sponsorship.

2.2.1 Main Partners

eSpace EPFL Space Center	eSpace is responsible for the research component of Asclepios. They provide financial support and supervise the logistics of the mission. One eSpace employee is working at 30% on Asclepios.
swiss space center	The Swiss Space Center brings financial support and supervision for the mission's logistics. ESA astronaut Claude Nicollier is participating in the recruitment process of the astronauts.
skyguide	skyguide owns the habitat that will be used for the simulation in la Dôle (Switzerland). The company is providing access to their base during 11 days to the Asclepios team. At least two skyguide employees will permanently be on call, ready to come to the base, to ensure the crew's safety in case of an emergency.
ASSOCIATION DES COMMUNES CRANS MONTANA Absolutely Start-up Friendly Service de la promotion économique	The association of the towns of Crans-Montana (ACCM) is a group of towns comprised of Crans-Montana, Icogne and Lens. The service for the economical promotion has helped organize a workshop in extreme environment lead by French polar explorer Alban Michon for the formation of the astronauts. They also offered us a financial support.
EPFL	The College of Humanities at EPFL is providing us financial support.

2.2.2 Support Partners

esa European Space Agency	Several employees from the European Space Agency are helping with the logistics of the mission. Asclepios was also present during a workshop at ESA ESTEC.
ÖWF	The Austrian Space Forum is advising Asclepios based on their own analogue missions. The project leaders of Asclepios also attended their Analog Mission Basic Training workshop.
ESTEE	ESTEE is helping the Asclepios team on the technical aspects of the mission and is supporting the conception of the habitat.
planted.	planted. is a start-up from ETH Zürich, which produces plant-based food. They agreed to provide the astronauts with “vegan chicken” to nourish them during the mission and the month before (this will be detailed in the experiments part of this document).
	Saint-Sulpice municipality agreed to lend a shed to store equipment.
naanu	Naanu is a start-up, which produces plant-based cookies. They agreed to provide the mission with vegan cookies to nourish the astronauts during the 7 days and the month before.
SWISS POLAR INSTITUTE	The Swiss Polar Institute offered us a financial support and two seats for their *Health and Safety Training* workshop for the analogue astronauts.
MARS SOCIETY SWITZERLAND	The Mars Society Switzerland, a Swiss member of the Mars Society family, is dedicated to the promotion of crewed missions to Mars and the accession of man to this world. It is interested in everything that is necessary to achieve this goal and fully supports the Asclepios project, which it sees as an intelligent and effective contribution to faster progress.

FROGGIE PRODUCTION	Froggie Production is an executive production company. They agreed to lend us a camera and to make our final project movie.
	Chéserex will host the Mission Control Center (MCC) during the mission. They agreed to lend us a room to install our MCC team and also a shelter for them to sleep during the simulation.
logitech	Logitech offered us some technological devices for the crew of analogue astronauts, the Mission Control Center, and the communication between them.
EPFL	The School of Computer and Communication Sciences at EPFL is providing us financial support.
EPFL	The School of Architecture, Civil and Environmental Engineering at EPFL is providing us financial support.
EPFL	The School of Basic Sciences at EPFL is providing us financial support.
SPORTS UNIVERSITAIRES LAUSANNE	The Unil-EPFL sports center agreed to lend us some sport equipment for the Dress Rehearsal and the Mission, so that the analog astronauts can train accordingly to their fitness program.
Stadler Form SWISS DESIGN SINCE 1998	The company aims at enhancing the world air treatment. They will be providing us with an air purifier Roger for the base.

2.3 Educational Institutions

The Asclepios team is composed of students and laboratories from different universities. Although this is an **EPFL** project, the universities concerned are the **Eidgenössische Technische Hochschule Zürich, Université de Lausanne, Massachusetts Institute of Technology** and the **Royal Academy of Art -The Hague.**

EPFL	**École Polytechnique Fédérale de Lausanne** Most students and experiments are from EPFL, most of the work is also done at EPFL and several EPFL entities supported financially the mission.
ETH	**Eidgenössische Technische Hochschule Zürich** EPFL's Sister school is strongly involved in the project.
Unil UNIL | Université de Lausanne	**Université de Lausanne** The UNIL campus is located on the same premises as EPFL and provides resources and knowledge, which is not covered by EPFL's scope, such as psychology.
	Massachusetts Institute of Technology The institute is working on experiments, which will be performed during the Asclepios mission (Hydration).
Royal Academy of Art The Hague	**Royal Academy of Art - The Hague.** The academy collaborates on the space suits.

3 Finance

The statement of accounts can be visualized on the following graphs:

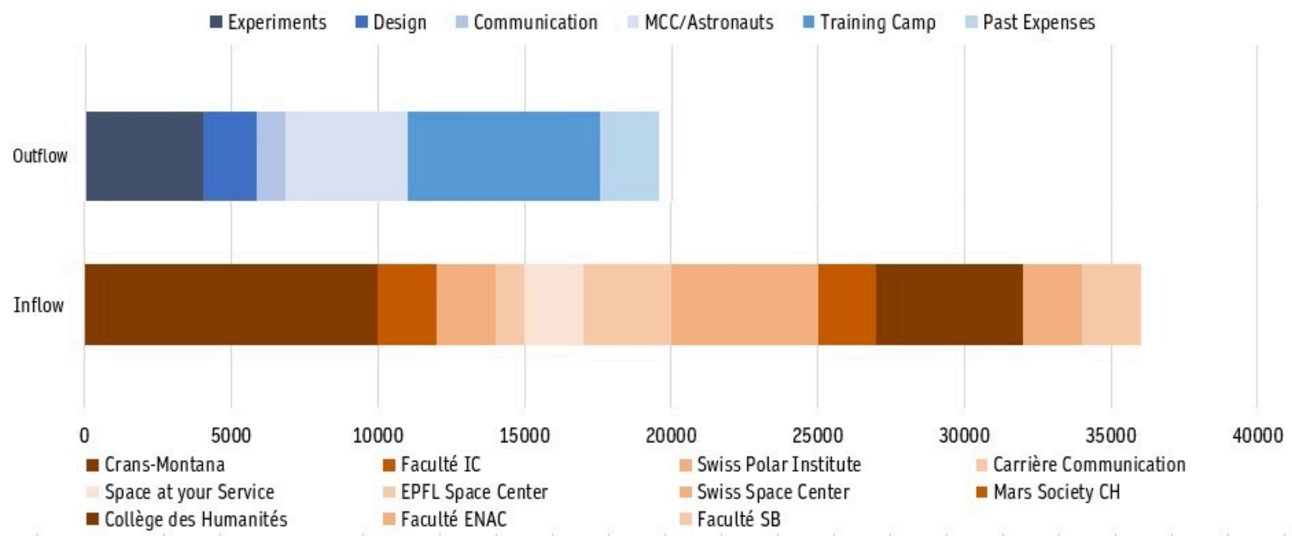


Figure 3.1: *Cash inflows and outflows until the end of April 2020*

The expected cost of the mission until the end of April is of 19'585 CHF. The confirmed sponsorship in cash is of 36'000 CHF to this day. Additional requests for sponsorship are being made to pay for the Asclepios 1 logistics after the April mission and for next years' missions. This means there is a margin of error of more than 16'000 CHF.

When taking into consideration the in-kind sponsorship, the estimated value of the mission increases significantly, reaching a value of 159'455 CHF.

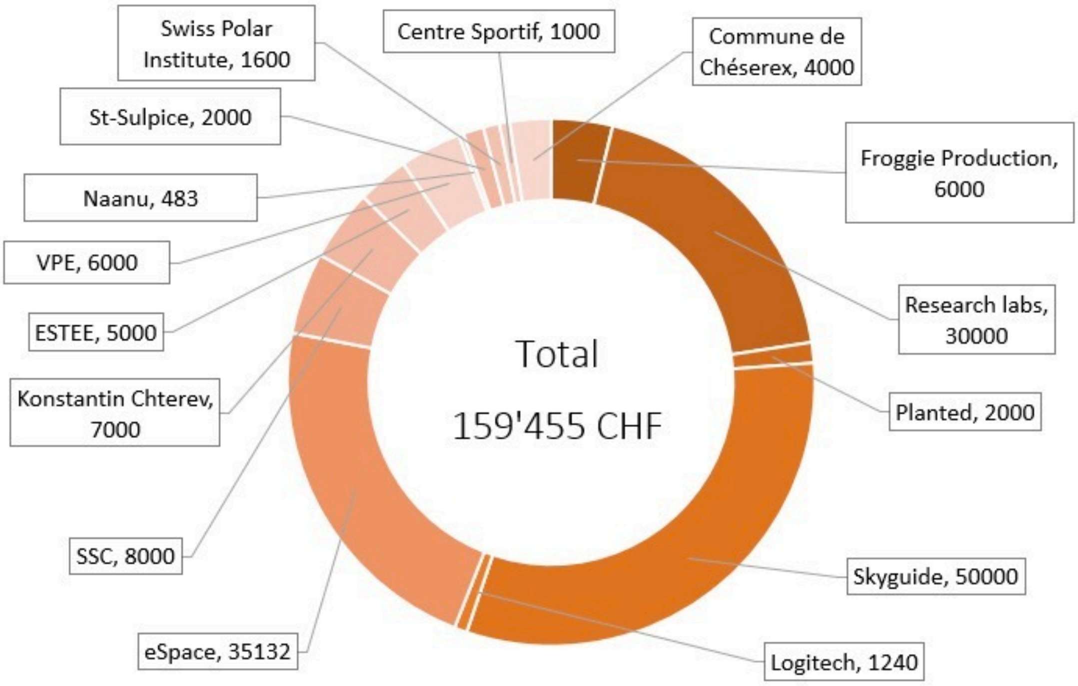


Figure 3.2: *In-kind value*

Most of the entities appearing on this diagram and their roles in the mission are described above (sections Main and Support Partners). The research labs will be working on the mission's experiments to ensure they are implemented rigorously. The VPE (Vice-Presidence for Education at EPFL) is helping us with advices on interdisciplinary projects and different logistic issues. The SKIL is an initiative based at EPFL which enables students to have access to equipment (for example 3D printers) for their projects. The Centre Sportif Unil-EPFL is lending us fitness equipment for the astronauts during the simulation. Konstantin Chterev is a psychologist who agreed to help us select the final crew of analogue astronauts by meeting each one of them separately.

Insurances:

In case of any damage (material and/or physical), the astronauts' personal insurances (that all are valid in Switzerland) combined with the EPFL "La Mobilière" insurance and the different signed contracts will cover the costs generated. Indeed, as an EPFL project, Asclepios can be covered by the insurance company "La Mobilière". The insurance certificate can be found in the appendix.

4 Coordination

4.1 Space@yourService

Figure 4.1.1: *Photo of Space@yourService committee*

Space@yourService is a non-profit organization recognized by EPFL. It aims to promote space sciences to students and the general public, with a focus on astrophysics, space technologies and astronautics. The organization is collaborating with the Swiss Space Center, the EPFL Space Center and the EPFL Laboratory of Astrophysics (LASTRO).

Space@yourService also organizes various conferences revolving around space and the different fields touching upon space, on EPFL's campus or in the French-speaking region of Switzerland. These events are an opportunity for space entities to share their research and discoveries with EPFL students.

4.2 Risk Analysis

RISK	PROBABILITY (1-5)	CONSEQUENCES (1-5)	PROB×CONS (1-25)	MITIGATION
Budget underestimation	4	5	20	Establish a margin and adaptation of design and experiments for the budget obtained
School work conflict	4	5	20	Communication with every member and adaptation of workload
Members showing less involvement	4	4	16	Team building, gratification of members work
Coordination errors	4	3	12	Double check of important informations through coordinator and other leaders
Lack of communication	4	3	12	Clearly definite communication flows (up and down)
Sponsor stopping funding	3	4	12	Different sources of incomes and different sponsors
Members abandonning project	3	4	12	Large number of members and continuous recruitement
Laboratory or Professor withdraw	3	3	9	Large choice of unrelated experiments and backup experiments

Table 4.2.1: *Global Risk Analysis*

4.3 Teams

4.3.1 Head team[1]

Heads of work packages are responsible for overall strategy, decisions-making and coordination within the team. They are affiliated according to organigram in figure 4.3.1.

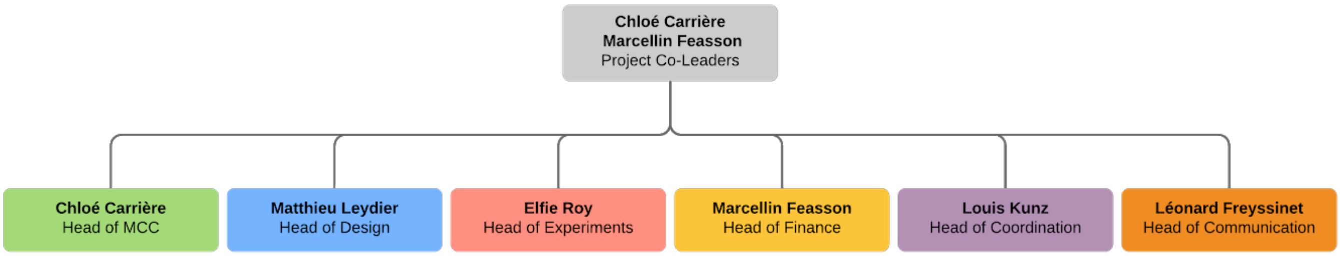


Figure 4.3.1: *Head team organigram*

Figure 4.3.2: *Picture of the Head team before the workshop in Crans-Montana.*

[1] *Full organigram can be found in Appendix.*

4.3.2 Design

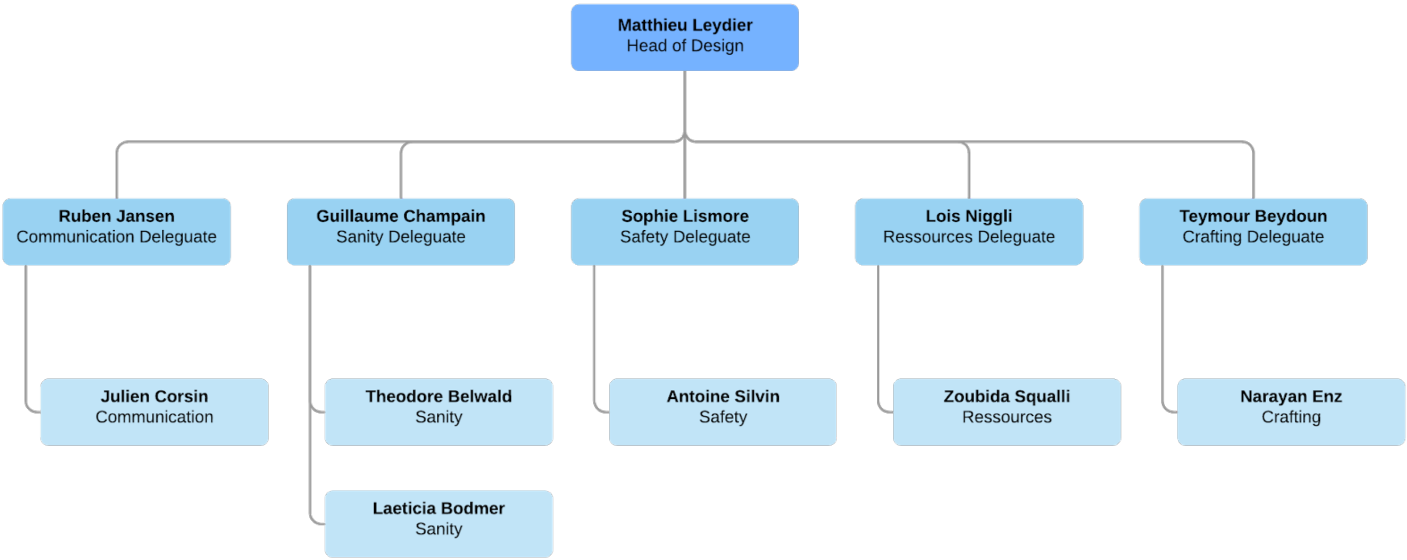


Figure 4.3.3: *Design organigram*

The design team's objectives are to find a location for the mission, prepare the habitat for the analogue astronauts and plan for the needs of the analogue astronauts for a 7-day mission. Different aspects of the design are delegated to smaller teams:

- *Communication:* Responsible for the communication between the astronauts and mission control.
- *Sanity*: Responsible for the astronauts' hygiene, nutrition and sport.
- *Safety:* Responsible for collecting safety procedures from partners (Laboratories, skyguide) and write complementary safety procedures.
- *Resources:* Responsible for providing necessary resources such as water and electricity, and to measure their use.
- *Crafting:* Responsible for crafting and building the necessary equipment for the habitat arrangement.

Figure 4.3.4: *Picture of the Design team at EPFL*

4.3.3 Experiments

Elfie Roy
Head of Science

Orane Valette Psychology	**Christopher O'Hara** Chatbot	**Milad Dulloo** Physiology	**Matthieu Meilhac** RadioAstro
Flore Barde InSight probe	**Dora Babocs** Sport and Nutrition	**Gustavo Jamanca Lino** Perchlorate	**Anne-Marlène Ruëde** Bioplastic
Camille Aussems GrowBot	**Lukas Powollik** GeoReMap	**Chloé, Marcellin, Louis-Amine, Youssef** Hydration	**Fabio Albertani** Chatbot
Grégoire Biot Solar Refinery	**Karl Khalil** Air quality	**Sisinio D'argent de Vicente** Lyf Drones	

Figure 4.3.5: *Experiments organigram*

The experiments team contacts laboratories and start-ups to set up new experiments, write protocols for each experiment and analyse the data collected after the mission.

Organisation: Each experiment that will be conducted during the mission is assigned to one member. This member is responsible for his/her experiment and reports to the head of experiments. Some Members of the experiments team are working remotely like the Hydration experiment, which is conducted as a laboratory project for physics students in third year of Bachelor at EPFL.

Figure 4.3.6: *Picture of the Experiment team*

4.3.4 Communication

The communication team is the public face of Asclepios. Social Media, public events and press coordination are managed by its members. The project website is also updated by the team.

Figure 4.3.7: *Communication organigram*

4.3.5 Mission Control

The mission control team is writing the procedures and flight planning for the mission. The team is monitoring and managing the dress rehearsal. Its members are also in charge of the astronauts' recruitment and training.

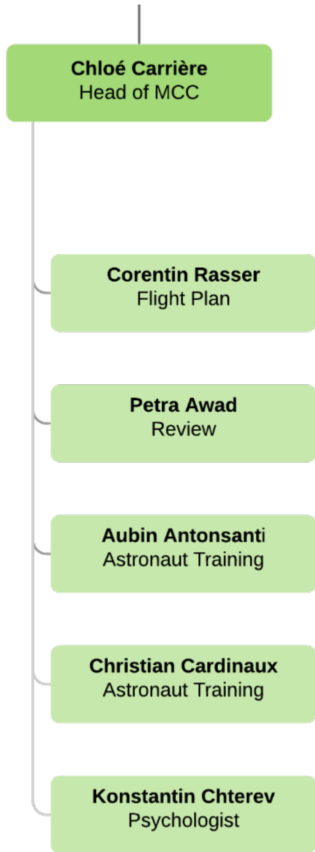


Figure 4.3.8: *Mission Control organigram*

4.3.6 Finance and Coordination

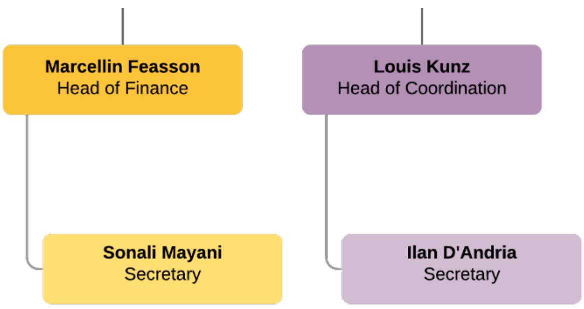


Figure 4.3.9: *Finance and Coordination organigrams*

Finance: The team is looking for sponsors, partners and in-kind support. Members also serve as treasurer of the project.

Coordination: The team is ensuring coherence in the project. Timeline and project organisation are also part of the team's work package.

5 Timeline and Milestones

Before 20 Dec. 2019:	Setup of Asclepios, Experiments Research & Protocols writing
05 Dec. 2019:	Preliminary Design Review at EPFL
20 Feb. 2020:	Critical Design Review at EPFL
28 Feb. – 01 Mar. 2020:	Dress Rehearsal
06 – 08 Apr. 2020:	Setup in La Dôle
09 Apr. 2020:	Outreach Day
18h – 09 Apr. 2020:	Mission Launch
18h – 16 Apr. 2020:	Mission Landing
17 – 19 Apr. 2020:	Clean-up and Outreach
After 19 Apr. 2020:	Data Analysis, After Movie editing & Documentation

Figure 5.1: *Preliminary Design Review*

6 Mission Overview

6.1 Scenario

6.1.1 Future of space exploration

Human's return to the Moon is planned for 2024 according to Artemis mission's agenda [1]. Even if there is a delay, it is likely that crewed Moon missions will be a reality in the early 2030's. Furthermore, in addition to NASA, ESA, other national space agencies (ROSCOMOS, CNSA, LISRO, JAXA, etc.) are working on Moon missions. Private companies also are working on Moon exploration, either crewed or not. ESA is highly interested in a Moon Village concept [2]. It is possible that in the near future, Moon exploration will be comparable to polar habitats such as Concordia [3], allowing to operate long (longer than 3 months) and short (1 to 3 weeks) term crewed missions. Moon exploration will be useful for testing technologies and procedures in order to go to locations further in the Solar System, such as Mars or asteroids.

6.1.2 Assumed Moon mission

6.1.2.1 Mission typology

In this project, we consider a short-term mission, when a lunar base is well installed, and the main focus is to prepare for Mars exploration. In preparation to go to Mars, long term missions on the surface of the Moon will be essential. But if the access to the Moon is less expensive and a base is developed, it is possible that scientists/astronauts could live in those habitats during short-term missions. They could use those already installed infrastructures to focus on technologies and science they want to test on the Moon.

Figure 6.1.1: *Moon base concept [5]*

6.1.2.2 Landing and installation site

NASA plans to land humans on the South Pole of the Moon [4]. The Chinese space agency (CNSA) also showed great interest in this part of the Moon. There is a reason why this is the case: lunar Poles contain water ice [6]. Water is a precious resource, as it is essential for humans to live, and can be decomposed into rocket fuel or for other applications. Water ice only remains on the darkest and coldest regions of the Moon, and near the Poles exist points, which are never exposed to sunlight. Those regions are shown in Fig. 6.1.2 and are potential landing sites. Furthermore, polar regions are filled with large craters and there also exist regions, which are nearly always exposed to sunlight. This could be useful for producing solar energy in-situ. A Moon base may likely be built in this type of region, which is "rocky" and can be compared to mountainous regions on Earth. A day on the Moon lasts 28 days on Earth. At the South Pole, some regions are exposed to permanent darkness or sunlight and this could potentially have a negative influence on the astronauts' mental health.

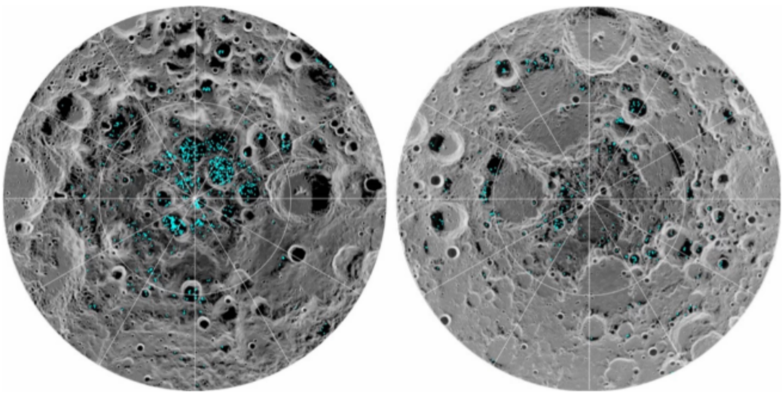


Figure 6.1.2: *Distribution of water ice (blue coloured) in the south pole (left) and the north pole (right) [6]*

6.2 Localisation

The mission will be located at the La Dôle summit, in the Jura mountains. The habitat belongs to Skyguide, a Swiss air guidance company. Skyguide provides us with in-kind sponsorship through the loan of a part of their habitat.

6.2.1 Outdoor

The habitat is located on the summit of La Dôle, a region where extreme meteorological conditions could appear. This is a summary of the average weather in April, month during which the mission will occur:

Mean Temperatures [°C]	1.5 °C
Freezing days	18.3 days
Precipitations [mm]	128 mm
Including snow [cm]	60.8 cm
Snowy days	8 days

The North face of the mountain could serve as an area for Extra Vehicular Activities (EVA), whereas the South face is too steep and therefore not adapted. There is a ski station on the North face where astronauts may encounter hikers or skiers (depending on the quality of the snow) but their timetable will take into consideration those events, in order to preserve the crew's isolation.

Figure 6.2.1: *Picture of the Habitat in early November*

6.2.2 Indoor

The station will be split into two parts, one for the crew and the other for the company: employees must have access to the base in case of an emergency or an important task to complete. The employees will try not to come into the base during the mission, but if they do have to, they will not penetrate into the astronaut's habitat. It shall not have an impact on the confinement situation.

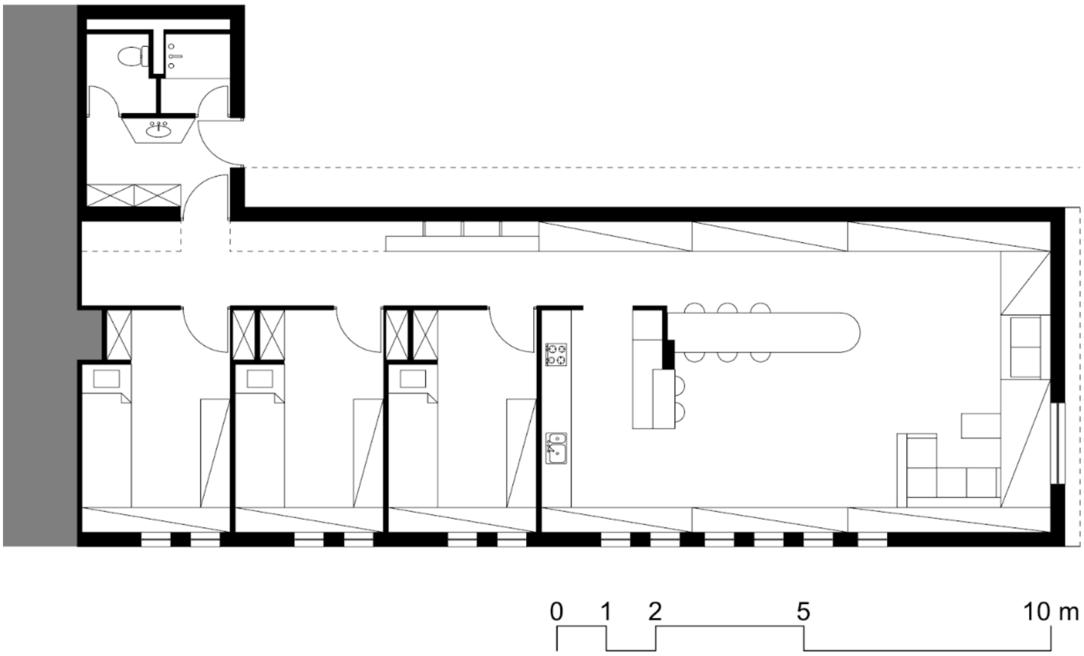


Figure 6.2.2: *Plan of the area that the crew will have access to*

This part of the station is about 120 m² and contains three rooms, one open kitchen, a living room and a bathroom (which will also serve as a SAS due to the exit door). At the left, a wall made of expanded polyester will be built and serve as the habitat's separation and secondary exit door.

Figure 6.2.3: *Indoor view*

The 6 members of the crew will sleep in two bedrooms of 11 m² each, containing three beds. If the space allowed turns out to be too small, they may sleep two per room. Figure 6.2.3 shows the living room (45 m² of surface) with chairs and a sofa. Radiators can be found at the base of all surrounding walls, in order to keep the room temperature at 19°C. This temperature can be adapted.

6.3 Design

6.3.1 Light

The Asclepios Mission will take place in an enclosed space at La Dôle in Skyguide's facility. As the mission is meant to simulate a stay in a lunar habitat, light exposure will be different from the one on Earth. For this reason, we have decided to simply cover all windows with blackout shades made out of carpet and use artificial light provided inside the facility (expecting between 10 000 to 30 000 lm depending on the time of day). As the mission will take 7 days, most of the crew won't be exposed to natural sunlight for a week, except those that will go out on an Extra-Vehicular Activity (EVA) for experiments. As it is the case in space, particularly on the International Space Station, NASA has found that irregular exposure to sunlight disturbs the circadian rhythm [7]. Even the habit of looking out at the window before sleep can send the wrong messages to the brain, resulting in poor sleep patterns. Therefore, it is necessary to simulate a mission in which the lunar habitat's windows would be covered and artificial light would guide the body's sleep pattern. The artificial light would mimic a 24 hours light cycle. Exact light/dark times and intensities are to be determined later.

Absence of sunlight can cause serotonin levels to dip and lead to depression (in an extreme case, major depression with seasonal patterns [8]). However, the mission is too short for such effects to cause depression.
The blue spectrum of light triggers a drop in melatonin levels. In absence of this "blue light" at night, melatonin levels increase and facilitate the transition from the first to the second sleep cycle and increase sleep stability. We may therefore have an adjustable light source similar in periodicity and intensity to that of sunlight on Earth, as that is what the astronaut's bodies are used to. Astronauts will be informed of the effects of reduced exposure to sunlight and we will work with them carefully to ensure their mental health is preserved throughout the mission, through daily psychological interviews or questionnaires.

We therefore believe this aspect of the Asclepios Mission is in accordance with the three basic ethical principles, namely respect for persons, beneficence and justice.

In case the light provided inside the facility would be inadequate, we are planning to use HappyLight Compact Energy lamps from Verilux [9] that are up to 2500 lux of natural spectrum daylight (depending on the chosen model, we can vary the number of lamps and/or the intensity of the lamp to get the desired luminosity at a given time). The Verilux light mimics daylight by providing full spectrum light without the harmful UV rays. As we have explained before, bright light exposure early in the day stimulates our body's production of serotonin (which improves mood and happiness) and regulates melatonin in the evening (which promotes sleep). The use of that kind of light will stimulate the production of these hormones naturally.

6.3.2 Hygiene

The Astronauts will have a hygiene routine designed to minimise water loss and waste. This means that all body hygiene will be maintained using dry soaps and shampoos. The toilet will remain standard, as installing a zero-waste system was impossible for the current iteration of the mission. Menstrual cups are planned for female astronauts.

Figure 6.3.1: *Roger air purifier unit [10]*

In the event where the dry washing products are insufficient to properly clean or are perceived as such to a detrimental degree, the Moon base is equipped with standard showers allowing a more usual practice of hygiene. If a female astronaut is strongly uncomfortable with using menstrual cups, it will be considered, and an alternative solution agreed upon.

Due to the size of the habitat and all the activities that the astronauts will perform in the base without opening the windows, an air purifier will be installed in order to deal with the smells, and air particles that can impact astronauts' welfare. In collaboration with StalderForm, a Roger unit will be placed in the main room [10].

6.3.3 Clothes

Astronauts will bring their own clothes, including their Asclepios polo and their sponsored t-shirt; it is a t-shirt where all the sponsors' logos are displayed. In order to limit the quantities of clothes each astronaut may bring, a specific amount will be determined.

6.3.4 Waste

There will be different bins for waste (food, fabric and hygiene wipes, plastic, paper, metal cans), all taken out at the end of the mission (1 week). If it is too long, an EVA could be organised to put the wastes in other recipients out of the base.

6.3.5 Resources

<u>Water</u>

Based on the daily consumption of the Crew 137 of the Mars Desert Research Station (MDRS) mission [11], 6 litres of water per day and per crew member will be available to support their needs in drinking water, cooking and other activities requiring water. The toilet flush consumption is counted separately. The quantities will be tested during the small simulation to verify that 6 litres of water are enough for each member of the crew. In addition, there will be water extracted during EVA from snow/rain and filtered with a reverse osmosis water extractor. The use of the Osmosis water extractor will be done in the SAS to avoid any contamination inside the base. Note that the reverse osmosis systems are one of the most popular and best water filtration methods available. It removes pollutants from water including nitrates, pesticides, sulphates, fluoride, bacteria, pharmaceuticals and arsenic, among others. The reverse osmosis system is certified by the American National Standards institute (ANSI), so it falls within the scope of NSF/ANSI 58 [12]. If the water treatment process made by the reverse osmosis is not accepted, analogue astronauts will simply use tap water if 6 L/day per astronaut is not enough.

Food: a vegan diet

Nowadays there is widespread agreement that inappropriate food intake and lack of sport lead into decrease of skeletal muscle and increased amount body fat. For this reason, our goal is to maintain the essential amount of nutritional needs, to prevent muscle loss and avoid gaining body fat. Nutrition has a great influence on these points. We need to provide enough amount of protein, fat and carbohydrates for our analog astronauts. On the other hand, the nutrition plan should consist of healthy and diverse ingredients. The human body needs protein, carbohydrates, fat, as well macro and micronutrients.

Furthermore, growing food in space is a challenge and it’s more than probable that the first source of food grown on a lunar base will be vegetal. Thus, studying the impact of a well-balanced vegan diet on the body is also interesting. In addition, it also permits to plan more sustainable space missions.

Two of our partners are going to help our astronauts in their daily nutrition. The Planted. company will provide vegetal chicken made from pea protein. Another Swiss company, Naanu, will provide vegan cookies for our astronauts’ snacks. The crew will follow the diet described below for at least one month before the mission and during the mission. They willgive us qualitative feedbacks on how they feel:

- 8am: Breakfast
    - 50g (80g for men) of oatmeal, buckwheat flakes, millet flakes, or quinoa flakes. Serve with any vegetal milk/yoghurt, fruits, or vegan dressing you like.
    - Supplements
    - 20g of nuts
- 12am: Lunch
    - 70g of Planted chicken or alternative (tofu, tempeh, seitan, any “false meat”, quinoa, vegan steaks, vegan sausages)
    - 50g of basmati rice, semolina, wholegrain pasta, pasta, sweet potato, potatoes, b, noodles.
    - 100g of lentils, chickpeas, kidney beans, green peas, split peas.
    - Vegetables (as much as desired)
- 4pm: Snack
    - 50g (80g for men) oatmeal
    - 10g raisin
    - Fruits
    - 20g of nuts
- 6pm: Workout then post-workout snack
    - 2 or 3 rice cakes or a vegan cookie
- 9pm: Diner

- 70g Planted chicken or alternative (same rule than for lunch)
- Vegetables (as much as desired

6.3.6 Communications - IT design

Data connection

A data connection between the base and MCC will be provided in order to transmit voice, text, video and experiment data.

To simulate realistic conditions, the bandwidth, delay, and time during which internet access is available as well as the websites the astronauts can access will be restricted. If the communications between MCC and the base are too complicated with the delay implemented, it'll be possible to delete the delay. The uplink and downlink of data may be separated as well.

From an ethical point of view, it is important not to push these restrictions too much, to still provide the astronauts some link to the outside world. The exact limits will still be determined and may vary as part of an experiment during the simulation, but we guarantee at least a daily meeting with MCC, and they will also have the opportunity to communicate with friends or family via voice chat, or at least via text. The frequency of this is still to be determined. Interviews by medias may be carried out as well, with prior agreement of the astronauts.

With regards to monitoring the data consumption, privacy concerns of the astronauts of course must be respected. We can aggregate all **personal** internet use in categories like "communication" and "non-communication personal internet use". Apart from the abovementioned website restrictions, we shall not monitor this personal traffic for the sake of privacy. The data consumption will be measured and can be anonymised if the astronauts wish so (the data consumption is just the number of bytes used).

Emergency line

To make sure the astronauts are never endangered (physically as well as mentally) because of a lack of communication, a fixed telephone line is accessible to the astronauts. It shall be made available at all times and will not be artificially restricted as the main data connection will be.

Communication with MCC

At least one computer and one webcam will be provided to enable voice conferences with MCC for briefing and to record and transmit videos for eventual interviews.

The whole communication system between MCC and the base will use a TeamSpeak server, built by one member of the Asclepios design team. TeamSpeak is a very adapted communication tool because it allows to create some "whispering lists". It means that it's relatively easy to implement authorisations of communications such as "only CAPCOM is able to speak with the astronauts", etc.

These videos can be used for press and media. Astronauts have been asked for prior consent for these videos and voice communications to be saved and possibly publicly disseminated.

Personal communications are not covered by this part and will be guaranteed private (see "Data Connection" paragraph above). Since the communication equipment is mobile (laptop, webcam, Wi-Fi), astronauts will be able to isolate themselves for private communications.

Data processing

All data from experiments and reports will be saved on a computer. Astronauts should give approval for this data being saved for future analysis.

Base monitoring / Experiments recording

Cameras and storage infrastructures will be available to record video of the base and of the experiments. For recording experiments, astronauts will use a Logitech C920 webcam, plugged directly in their laptop.
To respect the privacy of the astronauts, the cameras will not record the base 24/7. Cameras will not be installed in the bedrooms, nor in the bathrooms. The cameras do not have the capability to record video in the dark. The astronauts will be notified when the cameras are recording and should give their approval for the video to be saved for future analysis.

Wake-up message

Astronauts will be woken up through music or a message every morning. These messages are predefined. Astronauts could be asked for their approval in advance for these specific music or messages if deemed necessary.

EVA Communication & video

Equipment (walkie-talkies) will be provided so that the astronauts can communicate with each other, the base and MCC during an EVA. Video will also be recorded and possibly streamed by a camera on the spacesuits.

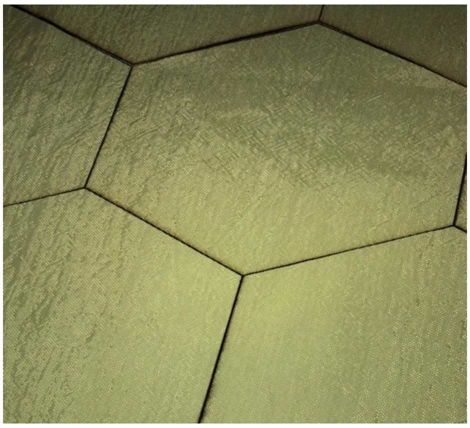
These communications can be recorded, and astronauts should give their approval for this. These communication tools are provided to allow for extra safety mechanisms during the EVAs.

6.3.7 Space Suits

As a contribution to the Asclepios mission, two types of Space Suits will be provided: one experimental suit and two functional suits.

The project was inducted (phase 1) by Anna Sitnikova and Elisaveta Glukhova. Phase 2 is now led by Jamal Ageli, in collaboration with other students.

The Royal Academy of Art, The Hague (KABK) will provide one experimental space suit. The experimental space suit contains sensors that are designed to detect micro meteorites impacts. It should include a WIFI communication system in order to transfer the data to the remote support. The experimental suit is made by a several number of Kevlar tiles (approximately 80). Each tiles has an electric circuit integrated and interconnected such that if a perturbation (for instance: micro meteorite impact) is detected, the information goes directly to the central mini-computer (a Raspberry Py). The electromagnetic interferences between the tiles can be interpreted and decomposed as the Astronaut movements.



ILWEG & VU Amsterdam will provide two functional space suits. They are designed to include embedded systems such as sensors, communication or cameras. The other aspect of these space suits is to have the opportunity to remove and replace tools, according to the needs of the mission. The arrangement of the functional space suits is being led by Geoffrey de Abreu Azevedo, in collaboration with Eibhlin Downes, two interns working at ESTEC/ILEWG&VU Amsterdam.

In addition to the space suits, a helmet is being developed by Carl Conquilla. The 3D-printing technology will make it lighter. It should include space for embedded systems such as an integrated communication system, cameras and lights.

6.3.8 Overall Security at the Base

The habitat belongs to a private company (Skyguide) so it has all the habitable norms and security procedures already in place. The access to the station is possible by private cable car. Skyguide's employees will be able to reach the habitat anytime. The interior is equipped with fire extinguishers, fire covers, first aid kits and a defibrillator.

Contact has been made with Skyguide, in order the have access to their security norms and procedures. However, they are not available yet.

Figure 6.3.3: *Fire prevention in La Dôle*

6.3.9 Workout

Beside the inadequate calorie intake, the lack of activity can lead to muscle atrophy. Our purpose is the prevention of skeletal muscle loss. However, in space, the weightlessness effects more those muscles which helps us to walk straight and maintain posture and stability, during our mission we won't simulate microgravity. For this reason, we focus on the analog astronauts' well-being and muscle maintaining.

The crew will follow a strength training and a cardio training. Strength is very important to increase protein synthesis and fiber hypertrophy. This can be helpful to maintain or increase muscle mass and decrease body fat. The resistance exercises are all easy to perform and don't required so many equipment. It takes approximately 40 minutes. The cardio training has positive impact on the cardiovascular system, and it helps burn body fat as well. The cardio training should be performed as an interval cardio exercise. The whole time will be 20 minutes.

Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
Upper body	Lower body	Upper body	Rest	Lower body	Upper body	Rest
Shoulders/ chest	Legs	Back		Legs	Arms	
- Lateral raises - Front raises - Rear raises - Shoulder press - Single arm pecfly - Chest press BB (hands up to the ceiling)	- Squat BB - Sumo squat BB - Deadlift BB - Walking lunges - Straight leg deadlift BB	-Bent over rows wide grip BB - Bent over rows narrow grip BB - Superman - Lumbar extension		- Hip extension - Step ups - Single leg squats - Standing lateral leg raises (bot sides)	- Bicep curl - Hammer bicep curl - Triceps dips - O/H triceps extension	
	- Plank (you can put a weight on your back) - Hollow			- Sit-ups - Russian twists - Abs extension		
- 20min interval cardio training	- 20min interval cardio training	- 20min interval cardio training		- 20min interval cardio training	- 20min interval cardio training	

Table 6.3.1: *One-month workout to prepare our astronauts*

6.4 MCC location

The location for MCC will be in the Chéserex town. An "abri PC" or bunker will be available for the team to sleep in for about 30 people (three shifts for MCC and Ground Support). A room for MCC is located right above the bunker at about three kilometres away from La Dole.

Figure 6.4.1: *Photo from Chéserex*

Figure 6.4.2: *Photo of the MCC in Chéserex*

7 Experiments Overview

Asclepios is a platform, where scientists and students can run their experiments in an analogue mission. The different experiments were selected either because they fit well with the "sustainability" focus, they illustrate the daily tasks that an astronaut must do in relation to ongoing experiments on or off the base, or because they could benefit space exploration in one way or another.

Before going to space, every aspect of the mission and every instrument or machine must be tested. In the Asclepios analogue mission, our experiments deal with psychology, physiology, data analysis, geology, astronomy, 3D printing and EVAs, among others. In this international team, each student is in charge of one or two experiments, depending on their involvement and time. We must stay in contact with the professor or researcher (Principal Investigator) to develop the experiment, adapt it to the mission if necessary, write protocols, train astronauts to perform it, and then interpret the data collected.

7.1 Data Analysis

7.1.1 Insight

PI - Principal Investigator: Professor Domenico Giardini (ETH Zurich)

Student in charge: Flore Barde (flore.barde@epfl.ch)

Description: Analysis of the data recorded on the NASA’ s uncrewed InSight mission: geophysical data collected by the seismometer SEIS, the heat probe HP3 and the rotation measurer RISE. This data will be analysed by two astronauts during the mission.

Expected results: Information about Mars geology, insight into the processes that created and shaped the Earth-like planets of the inner Solar System and determine the extent to which Mars is seismically active and affected by meteorite impacts today. This experiment brings a realistic filter to the mission and allows the astronauts to learn how to analyse and interpret data from another planet.

Methodology: One or two astronauts responsible for the experiment will have to be trained during the training period in order to be able to correctly analyse the data. The data will be sent during the simulation week and analysed by maximum two astronauts (preferably students in physics or astrophysics related fields).

Requirements: 1 or 2 astronauts will receive and analyse the data on two laptops. It will take approximately 4 hours.

Protocol: Receiving the data during the week of the mission as if it was sent by a rover. Have to analyse it for 4 hours, according to what they have learnt during the training.

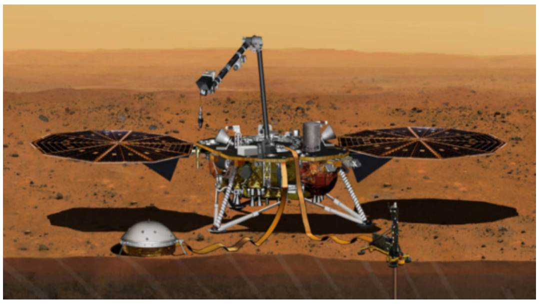


Figure 7.1.1: *InSight Rover, NASA*

Risks and mitigations:

The network could stop working, and the astronauts wouldn't receive the data. All the connections will be verified and tested before the simulation, but if it doesn't work at the moment of the experiment, Insight's data analysis will be reported.

7.1.2 Air quality and thermal comfort

PI - Principal Investigator: Dusan Licina, Human-Oriented Built Environment Lab (HOBEL)

Student in charge: Karl Khalil (karl.khalil@epfl.ch)

Description: Air quality and thermal comfort is an important consideration not only for external environments, but also for indoor spaces, where people spend the majority of their time. The indoor air quality and thermal comfort in enclosed spaces have been linked to human physical and emotional well-being. Because the majority of modern buildings have prioritized energy efficiency over the quality of indoor environment, less fresh air is supplied from the outside. Consequently, pollutants emitted from building materials, furniture, people, appliances and food are not being properly ventilated, which has led to frequent reporting of lung/throat/eye irritation, chronic headaches, fatigue and nausea. Spacecraft, which are closed habitats, require special attention in terms of air quality and thermal comfort, because of their potentially adverse effects on crewmembers and on the entire mission. In the past, the National Aeronautics and Space Administration (NASA) has invested substantial effort in minimizing cabin air pollution and providing the crew with comfortable environment. These approaches involve a combination of specific material selection and active control onboard the spacecraft. However, our knowledge remains limited in terms of what air pollutants the crew is typically exposed to. Without knowing the type and concentration of particle and gaseous pollutants that crews is typically exposed to, it is difficult to design adequate control actions that can prevent harmful health effects and ensure safe and comfortable spacecraft. The specific project objective is to understand the level of indoor air quality and thermal comfort in a simulated spacecraft, which is occupied with human subjects. We will then use the results to propose an optimal ventilation strategy with regard to well-being and safety of crew members.

Expected results: Integrated samples of individual volatile organic compounds (VOCs) and total VOCs, formaldehyde, NO_2, SO_2, O_3 and longitudinal records of CO_2 and size-resolved particles in the diameter range 0.3-10 μm. Measurements of air temperature, relative humidity and surface temperatures.
This project will provide important preliminary insights into indoor air quality and thermal comfort of crew members in a simulated spacecraft. Such knowledge will be valuable for future air quality and comfort studies and can lead to improved ventilation system design and operation – all which can ultimately lead to improved health outcomes of crew members. The results of this project will be disseminated through an open access publication in a highly acclaimed peer-reviewed journal in the field. We also plan to present our work at both national and international conferences and workshops. During and after the study, the team members will actively disseminate their findings to the scientific community, but also to the public via EPFL press release, social media and education/teaching.

Methodology: The different sensors will all be set up and ready before the astronauts' arrival and doesn't require any attention or special treatment during the simulation. An EPFL student will do his bachelor project on this experiment. He will have to analyse the results after the simulation and write a paper.

Requirements: Several small sensors or one measuring instrument will have to be bought.

Protocol: Taken care by the laboratory itself.

7.1.3 Solar-driven refinery for producing fuel and oxygen from CO_2

PI - Principal Investigator: Prof. Aldo Steinfeld (ETH Zurich), Prof. Sophia Haussener (EPFL)

Student in charge: Grégoire Biot (gregoire.biot@epfl.ch)

Description: The atmosphere of Mars is primarily composed of carbon dioxide (> 95%). Solar-driven technologies can convert CO_2 into fuel (CO) and oxygen. Thermochemical approaches for splitting CO_2 using concentrated solar radiation inherently operate at high temperatures and utilize the entire solar spectrum, and as such provide a favorable thermodynamic path to solar fuel oxygen production with potentially high efficiency.
We propose to perform the experimental demonstration of the solar-driven thermochemical splitting of CO_2 into separate streams of CO and O_2 using a reduction–oxidation (redox) cyclic process. The solar experiment should run with high

degree of automation and remote control.

This experimental demonstration will be performed using a solar reactor mounted on a sun-tracking solar concentrator and containing a ceria structure that absorbs high-flux radiation volumetrically and exhibits rapid reaction kinetics. The experimental results obtained under realistic solar operational conditions will provide evidence of the technical viability of the solar thermochemical redox technology for converting CO_2 into fuels and oxygen. We will elucidate the efforts required for the implementation of this solar technology in Mars.

Expected results: This experiment will bring a realistic filter to the mission and allows astronauts to learn how to analyze and interpret data from an experiment running outside of the base. It will also advance the solar technology for producing fuel and oxygen from Mars atmosphere.

Methodology: The antenna will stay at ETH Zürich. The astronauts will receive the data on a laptop and will be able to observe the experiment running. One or two astronauts responsible for the experiment will have to be formed during the training period in order to be able to correctly analyse the data.

Requirements: Cameras will have to be installed in the lab at ETH Zurich, connection with the communication system of Asclepios will have to be set up.

Protocol: 1 astronaut will watch the experiment live running at ETH, will receive the data and analyse how much fuel and oxygen is produced and if everything is going as planned.

Risks and mitigations: The network could stop working, and the astronauts wouldn't receive the data. All the connections will be verified and tested before the simulation, but if it doesn't work at the moment of the experiment, observation of the experiment and analysis of the data will be reported.

Figure 7.1.2: *Solar refinery for converting CO_2 into fuel and oxygen, ETHZ*

7.1.4 Hydration

PI - Principal Investigator: George Lordos, MIT

Student in charge: Sisinio Vicente (sisinio.dargentdevicente@epfl.ch)

Description: HYDRATION is an upgraded version of HYDRA, which was a system designed to melt ice into water and then extract and store it for further use. HYDRATION provides an additional terrain identification sub-system, allowing to analyse and identifying different types of terrain layers. Altogether, this experiment's objective is to allow future space exploration missions and Martian habitats to be able to collect their own water supplies and study the geological characteristics of the Martian soil in the process. The system first drills a hole through the soil while collecting the related data. Once the drill encounters ice, a heater is descended into the hole, melting it into water and it is then pumped into a reservoir.

Expected results:

- Layer identification algorithm testing and analysis
- Water melting and extraction system testing and analysis
- NASA's Moon to Mars Ice and Prospecting Challenge
- Physics' semester project

Methodology: The hardware part of the experiment is located at MIT. Using a specific software, astronauts will be able to remotely actuate the system and watch the date feed while the experiment takes place.

After the data is collected, it is analysed in its entirety and compared to the nominal values. Lastly, confirmation is done by comparing astronauts' conclusions on the layers' identification and the water quantity melted, with the actual results from the experiment at MIT.

Requirements: This experiment will take approximately 4h10: 30 min for drilling, 10 min for aligning, 30 min to melt the water, 180 min to analysing data and experiment. The equipment needed is only 2 laptops.

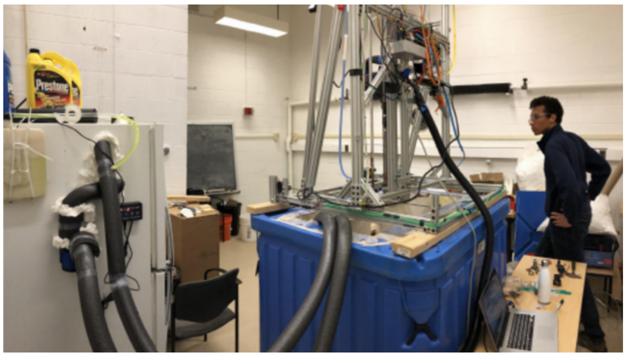


Figure 7.1.3: *Hydration System, MIT*

Protocol: Astronauts' training will consist of familiarization with the experiment. It includes training with the MIT team on the software to be used and discussing with the MIT team to understand what and how to analyse the data collected, and finally, tests runs.

The experiment itself will be conducted this way:

The hardware at MIT will be triggered by the astronauts from the base. The drill will dig a hole into the ground. The revolutions per minute (RPM) and weight on the drill's bit (WOB) are then recorded through the soil drilling, as well as the drawn current. At the same time, a camera on the drill films the advancement and a microphone records the sounds made by the drill through the different soil layers. The data is then sent to the astronauts, where one astronaut looks at the live data feed, while another astronaut will be looking at the live camera and microphone feed.

Once the drill finds its way into ice, it retracts from the hole and the heater and pump system is lowered into the hole. The heater is then activated and starts melting ice into water that is extracted by a peristaltic pump. Water goes through a reversible filter to be cleaned before it is stored in a tank.

If needed, the filter can be cleaned by reversing the process and expelling water from the tank.

The amount of water collected is sent to the astronauts while on astronaut checks the live data feed and a software still to be determined is used to collect and receive the data from the MIT team to the astronauts' base.

Post-experiment examination: After the end of the experiment, the data is collected and summarized, and a team of astronauts examines the data. The astronauts will try to determine which types of layers the drill went through by comparing the data to the normal values given beforehand by the MIT team. The astronauts will also estimate the total amount of water collected. Both the layers identified, and water amount will be checked with the MIT team, in possession of the actual values. This experiment will be done throughout the week and will help determine the accuracy and water-extraction capabilities of the HYDRATION system.

Educational addition: Some students from EPFL, Physics BA6 will participate in HYDRATION development as part of their laboratory project, these developments include the following tasks:

- Analysis of the data from full-scale tests in order to attempt to label where the transitions between different overburden layers occur.
- Remotely participate with the MIT team in the design and coding of the drill user interface used in to operate the drill and monitor telemetry.
- Remotely participate with the MIT team in practice sessions and subsystems tests both as data observers and remote operators.
- Remotely participate with the MIT team in the design of various data collection sensors during drilling (power, RPM, vertical displacement, accelerometer) and in the coding of the software that translates sensors' inputs into data.

Risks and mitigations: The sensor built by the Asclepios team may not be working properly when included into the whole Hydration device. Some problems could also appear on the gear of the MIT team. To avoid this, a test of the integrated system will be done before the Asclepios mission. Since the experiment testing during the 7-day simulation will be run remotely, some communication systems issues may appear during the mission (network). However, the device is thought to be controlled distantly on the Moon and Mars, so once again this will be tested prior to the mission. All the connections will be verified and tested before the simulation, but if it doesn't work at the moment of the experiment, Hydration's experiment will be reported. The astronauts could do a mistake when remotely running the experiment. They will be well trained, so this situation doesn't happen.

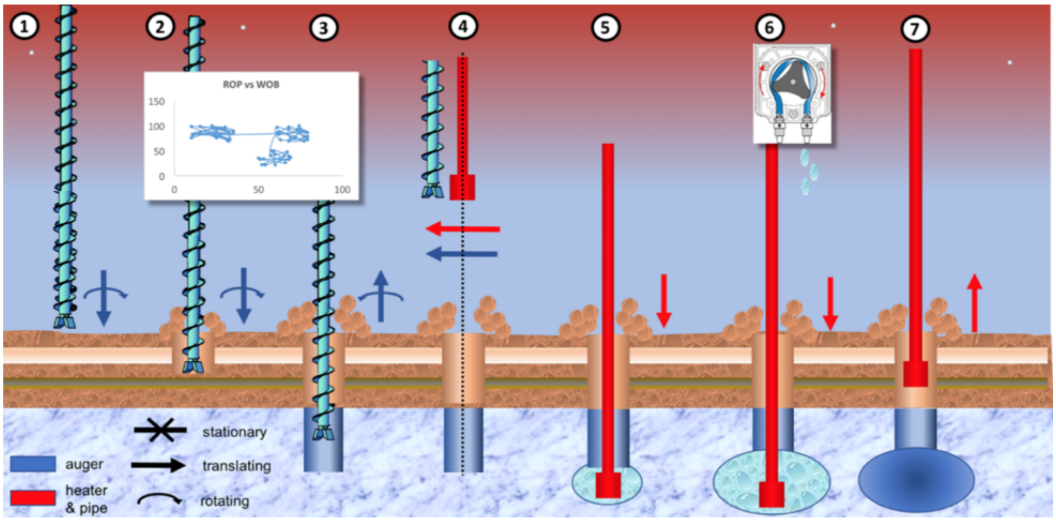


Figure 7.1.4: *Hydration functioning, MIT*

7.2 Life Inside the base

7.2.1 GrowBotHub

PI - Principal Investigator: Jean-Paul Kneib (Head of EPFL Space Center), Auke Ljspeert (Head of Biorobotics laboratory)

Student in charge: Camille Aussems, GrowBotHub (camille.aussems@epfl.ch)

Description: The objective of the project is to develop a structure able to fully autonomously grow vegetables by using fogponic systems. The vegetables will be grown using fertilizer produced from human waste (Aurin from the Swiss Startup Vuna [14]). This project is of interest for such applications because of two reasons. First, it allows the astronauts to have access to fresh vegetables, which has been observed to help with mental health [15a]. Then, as we might be using recycled human waste, we are reducing waste production and we need to bring less supplies to space. To grow vegetables, we use aeroponics, which is an out-of-soil type of culture that uses extremely low amounts of water. In aeroponics, small droplets of water are pulverized directly on the roots of the vegetables through a distribution system [15b]. With fogponics, a fogged produces a fog that will fill the system and water all the plants in that system. That makes this culture extremely adapted for space and extreme environments, where resources are scarce.

For Asclepios, the GrowBotHub system will grow lettuce, peas, cherry tomatoes and pepper to allow some diversity in the diet of the astronauts while focusing on highly nutritional vegetables.

This project has already been tested in June 2019 during the IGLUNA field campaign. Some videos and information about the system can be found on the website [16].

Figure 7.2.1: *GrowBot in lunar base*

Expected results: To validate the developed structure and to observe the efficiency of the system and to be able to fulfil 30% of the astronauts daily nutritional needs.

Methodology: The user interface that can be accessed remotely from Mission Control and a computer/tablet located in the habitat. The user interface will present all the sensor's inputs and pictures of the vegetables, allowing to verify the state of the system. It will also tell the astronauts which task to perform. The astronaut will need to collect the vegetables, move the pots when asked to, and add pots in the space freed by the harvested vegetables. The astronauts will also need to measure the pH of the primary tank with pH papers and add fertilizer if the value is below a defined amount.

Requirements: This experiment will take 15 minutes twice a day (morning and evening), and 30 minutes in case a repair is needed. GrowBotHub's mass is 80 kg if dry and 160 kg if wet, so we will have to be careful when bringing it to the base by cable car. The user's interface will be accessible on a laptop via internet.

Protocol: Twice a day, in the morning and in the evening. The astronauts verify the GrowBotHub user interface in order to get information on the tasks to be performed (harvest a vegetable, move a pot, measure the pH level of the primary tank, add fertilizer in the primary tank). The system will come filled with vegetables at different stage of growth. The first vegetables should be ready by the first day and then at regular interval during the mission. The different kinds of vegetables (lettuces, peas, peppers and cherry tomatoes) will be ready at the same times to be able to make diversified meals.

Risks and mitigations: The fertilizer comes from a recognized start-up and they have been tested at multiple time so there is no risk by eating the vegetables. A risk is that one of the pumps clogs or stops working. Thanks to the sensors, we know instantly that the pump is no longer working, and spare parts are provided to fix this.

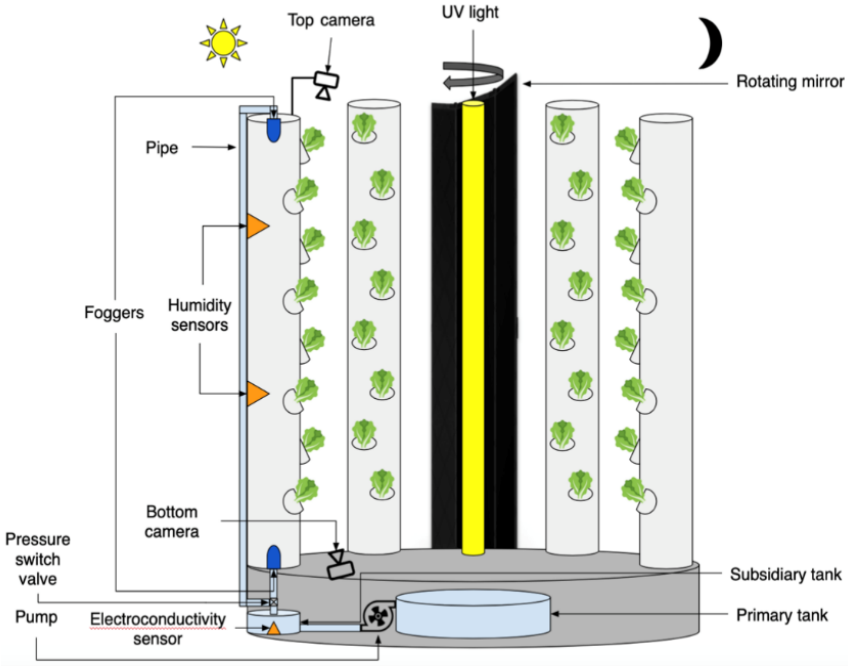


Figure 7.2.2: *GrowBot functioning*

7.2.2 Chatbot

PI - Principal Investigator: Christopher O'Hara

Student in charge: Christopher O'Hara (TU/e) (c.a.ohara@tue.nl), Fabio Albertani (Cambridge) (fa381@cam.ac.uk)

Description: The field of study for this investigation combines human factors and human-robot interaction. The purpose is to save the astronauts precious time, cognitive resources, and to mitigate detrimental interpersonal communications caused by additional stressors that result in a lack of resources. The goal is to create a mixed human-robot team in which a chatbot is responsible for its own tasks allowing astronauts to focus on more important mission events.

Astronauts are continuously bombarded with many tasks and extended working hours, resulting in a high utilization of their cognitive resources. Studies have shown that regular environmental stress leads to decreases in mood, working memory, situation awareness, and performance. Split-attention is a result of "multitasking" which directly impacts a person's communication with other people (imagine looking for a key item during an experiment while being asked a question from a colleague). Decreases in mood impact human factors more drastically in isolation, causing astronauts to become irritable more frequently and more easily in events that would not usually irritate them.

The concept is to create a chatbot, called AIFAA (sounds like German « eifer », meaning « zeal » or « enthusiasm ») that can reduce the working memory and cognitive load of the astronauts. AIFAA is the acronym for « Artificial Intelligence for Analogue Astronauts ». AIFAA would be able to aid by providing locations to useful items, reminding astronauts regarding steps in a protocol (for example, another mission protocol will have a specific sequence and AIFAA could remind the astronaut of certain steps). Furthermore, AIFAA could provide reminders regarding workflows and time (analogue astronauts might need to be reminded to take a break, conduct debriefing, or other daily tasks). AIFAA should be able to project information to the entire crew to prevent an astronaut repeating themselves (i.e. if wearing a headset). However, a headset should also be available (if possible), as some of the astronauts might dislike AIFAA and do not wish to hear it.

The primary task of AIFAA is to provide objective assistance to the astronauts. Effectively, AIFAA will be designed to provide fact-based information related to mission criteria and status. If technologically feasible, a secondary task of AIFAA will be to provide conversational content. Conversational content will be subjective and might include the astronaut talking with AIFAA simply for entertainment or stress-relief content and/or media.

Expected results:

- Frequency of Interaction
- Changes in Astronaut Performance
- Changes in Astronaut Temperament

Conference Paper, Article (depending on privacy, data, and non-disclosure agreements).

Methodology:

Quantitative: AIFAA will be monitored whenever astronauts interact with it. The frequency and content type will be documented. Content that is regularly accessed will be the focus of future improvements.

Qualitative: Astronauts will complete a simple cognitive test (like the NASA-TXL or NASA-PVT) to evaluate their subjective, self-reflected evaluations based on interacting with AIFAA. Additionally, astronauts will be asked to provide information regarding their mood and general opinion on the AIFAA system.

Astronauts will need to consent to allow their usage type and frequency to be documented (conversation content will not be stored). Only interactions with the chatbot will be documented.

The chatbot will be activated using an "activation command" to minimize unintended usage. The activation command will be used when requesting real-time assistance from the chatbot. Reminders can be set to be activated at set times. The chatbot will also provide a list of its commands by activating the "help" command.

Data storage: Astronaut will be held with the same strictness as GDPR requirements but with more transparency. All collected astronaut data will be anonymized, and no metadata will be attached to the astronaut. Assistance requests to the chatbot (type, frequency) will be saved but additional details will not. Only content that occurs after a single activation phrase will be stored and analysed. After each response from the chatbot, it will be deactivated until an activation phrase occurs again. Astronauts will be given strict confidentiality with their personal comments, routine, and feedback. Astronauts will be manually assigned a random ID number for entry into data processing software (i.e., Excel). Astronauts will be able to request their personal data be deleted based on the Asclepios privacy and data policy. Data will be stored only offline in protected memory devices. Any request for data from Asclepios will result in a physical delivery of the data (no internet-based data usage). Data will only ever be made available depending on the data and privacy policy and internal repository from Asclepios (similar to ESA or NASA open access). However, these repositories will be manned by Asclepios.

Ethics Related to Software Development: All software used in the project will precisely follow the requirements based on the software licenses. No software or programs will be used that do not allow for private usage. No software will be used that automatically uploads data to the Cloud or other internet-based storage systems.

Ethical Considerations Related to Other Experiments: Ideally, the chatbot will be useful for the other experiments within the mission, providing information regarding the workflow/requirements of other experiments. Any information providing from additional research teams will be strictly confidential and never shared outside the immediate persons of responsibility or authority. No information will ever be stored online for the tasks, goals, approach, or results from other teams with respect to the chatbot research team.

In general, all ethics requirements for the GDPR, the country of the Netherlands (base research location), the country of Switzerland, and the ethics policy of Asclepios will be upheld at all times. Any issues or areas of vagueness will be reported immediately.

Requirements: The astronauts will be able to access the chatbot whenever they want so it could take each astronaut between 5 and 60 minutes. More interaction is better for the results, but it will depend on the astronauts' interest. The equipment needed will be: host computer, WIFI, Speakers, Headset, Microphone. If these last items are not already available, they can be provided by the researchers.

Protocol:

Pre-mission: Astronauts will be instructed on how to interact with the system as well as useful commands (~15min). Astronauts will also be informed of how their personal information will be protected and their consent will be requested. If any astronaut does not consent, then the chatbot system will not be used in their presence.

Set-up: One astronaut will be responsible for installing the speakers (if not already installed) and testing the interface (~15min).

During Active Hours: During the normal active hours, astronauts will use the chatbot as per their need or desire. The chatbot will assist in daily events and tasks. Ideally, the chatbot can be broadcast throughout the facility. For astronauts on EVAs, they will be able to access the chatbot through their headset. In this manner, astronauts can request the time remaining for other tasks to be completed or remaining mission time. In realistic scenarios, the astronaut could also ask about changes in the weather or environmental conditions (e.g. wind or snow) that would impact the success of other experiments (e.g. a drone can only operate within certain weather and wind conditions).

During Free Hours: During free hours (within the personal rooms), astronauts can agree to sharing a colocation with the chatbot. The chatbot will continue to provide assistance (i.e., notify the astronauts regarding upcoming tasks or performance metrics). If technologically feasible, the astronauts will be able to interact with the chatbot during free time as a social member of the team throughout the facility. However, it is not currently known how sophisticated this chatbot can be (to be empirically derived prior to the mission). Astronauts will also be able to go to the unoccupied private room to have private discussions with the chatbot at any time. The MEDOPS can also request that an astronaut "takes a break" and communicates with the chatbot to reduce individual stress if necessary.

Pre-Bed Time: A personal survey will be conducted when the astronauts are about to have "bed-time" regarding their subjective feelings regarding the chatbot (~5min). It is currently presumed that the NASA-Task Load Index (NASA-TLX) test will be used to evaluate the chatbot. Astronauts are permitted to complete the survey in their private quarters or within the additional room (unoccupied) if they desire to complete the survey in private.

Post-Mission: A single astronaut may be required to take down the speakers (if not it is not a task of the Support Team or researchers). Astronauts will be asked to complete a brief survey regarding their experiences and feedback (~15min).

Contingency Plans:

1. *Astronaut Requests to not Participate with the Chatbot.* In the event an astronaut is uncomfortable with the chatbot broadcast system, it can be deactivated when they are present (i.e., not on an EVA). Furthermore, other astronauts might be able to individually communicate with the system and receive responses only to their headset (this may not be technologically feasible at this time and will be developed prior to the mission). Otherwise, astronauts can access the chatbot freely in the private room.

2. *Minimum Functionality Requirements.* It will be guaranteed that the chatbot can provide objective assistance for the astronauts related to inventory locations, time-based inquiries, and criteria/requirements for other experiments (provided this information is provided to the chatbot research team in advance). Optimistically, the chatbot will be able to respond to subjective or personal inquiries and comments.

Data Analysis: The first approach is always to all for the system to be running. The focus of this approach is to determine how often astronauts accessed the system. Astronauts will be able to access the chatbot anytime they need. The total number of activations will be counted to find how often the system was utilized. The type of inquiry will be documented (item location, reminder, etc.). For personal conversations with the chatbot, the type of communication will be documented (i.e. "venting", requests for advice, etc.). After each day and after the mission has completed, astronauts will be asked qualitative questions regarding the usefulness of the chatbot and any perceived differences in mood. Feedback will also be requested from the astronauts on how to improve the chatbot for future usage.

Risks and mitigations: The risk is that they don't access the chatbot because they are not used to this practice. Astronauts will have a briefing about the chatbot and they will train so it becomes more natural. The goal is that they don't hesitate to access the chatbot.

7.3 Operations

7.3.1 GeoReMap

PI - Principal Investigator: Prof. Nikolaus Kuhn, Physical Geography & Environmental Change, University of Basel (mentor)

Student in charge: Lukas Powollik, MSc Geosciences, Physical Geography & Environmental Change, University of Basel (lukas.powollik@stud.unibas.ch)

Description: In order to be able to plan an EVA, small-scale maps in which areas of potential danger are recognizable will be necessarily. However, the possibilities of creating such maps with remote sensing techniques are limited and make in situ examinations indispensable. The main goal of GeoReMap (Geomorphological Remote Mapping) is to simulate a new procedure for how astronauts could generate the required information a geographer would need to create a small-scale map of landforms, surface properties and topography.

Expected results:

- Geoinformation (coordinates / height) for 25 points
- Surface images for 20 points
- Landscape images for 5 points
- Assessment of the combined remote / in-situ method
- Identification of the implications of wearing a space suit and the remote character of the mission on the procedure

Methodology: GeoReMap consists of three phases. First, the astronauts will be taught the basics of alpine geomorphology and the principles of mapping methods, they will receive a practical training as well. Before the mission starts, the PI will examine the investigation area and identify landform types by using satellite images. Then, he will determine locations where the astronauts have to collect the required information.

During the mission, two astronauts have to collect the information at the specified points in the landscape during an EVA. The information includes geographical data (coordinates and height information), surface images with a scale bar and landscape images in specific directions. After returning from the EVA, the astronauts have to prepare the data for further processing and send them to the PI.

Based on the surface images, the PI defines more precise landform classes and creates a new geomorphological map, including a DEM (Digital Elevation Model).

To assess each step of the experiment and to identify the implications of the space suit on the procedure, the PI and the astronauts have to fill out several evaluation sheets.

Requirements: This experiment will take 3 hours approximately during an EVA, with 2 astronauts working on the mapping. The equipment needed is: Garmin eTrex 30, a laptop, and a camera (Sony Alpha 7 II).

Protocol: As this experiment protocol is quite long and detailed, it has been added as an appendix to the document.

Risks and mitigations: As this experiment is an outside activity, if the weather is bad, the EVA will be cancelled. The astronauts' schedule will be flexible to adapt to the weather. Also, the astronauts will be trained so they will be able to perform the experiment. They will be careful so there is no reason that they fall or hurt themselves. If it happens, they won't be alone so the other astronaut(s) can help go back to the base.

7.3.2 Drones

LYF Rescue Drone

PI - Principal Investigator: Octanis laboratory at EPFL, Valentin Ibars

Student in charge: Sisinio D'argent de Vicente (sisinio.dargentdevicente@epfl.ch)

Description: Lyf is a start-up company that aims at designing and producing rescue drones to be used in cases of avalanches. When a victim is buried under the snow, an activated beacon will send a signal to the drone, which will receive it and follow the signal up to the victim's position. Once the drone has gotten a fix on the position, the victim will be able to be taken out of the snow by rescuers. The drone will be able to be used by rescue operators and individuals in the future. The drone will be tested during Mission Asclepios.

Figure 7.3.1: *Lyf Drones functioning*

Expected results: Assessment of the drone's beacon search capabilities, assessment of the drone's use and rapidity to find beacon.

Methodology: The experiment will take place during an EVA, an astronaut will go and simulate an emergency, acting as he cannot return to base. He will activate his beacon. The drone will be launched from base and search for this astronaut. Once found, the drone will transmit its location to the astronauts at the base. Another astronaut will then follow the drone's guidance and search for the first astronaut and return while following the drone back to the base.

FP1	Detect autonomously the buried victim and transmit the localization to the rescuer
FC1	Safe the rescuer by keeping an emitting beacon without interfering the search
FC2	Be adapted to mountains weather conditions
FC3	Be energetically able to hold 30 minutes in action
FC4	Move autonomously in a uneven environment
FC5	Respect security norms and universal frequency of DVA

Table 7.3.1: *Table detailing the requirements of the method*

Requirements: The test will take approximately 20 minutes: 5 minutes for the first astronaut to position himself, 5 minutes for the drone to execute the search, and 10 minutes for the second astronaut to rescue the first one (ideally there could be 3 astronauts in the EVA doing the test). The equipment needed is: a Laptop, Beacon, Drone, and eventually Remote Control. The mass of the equipment will be of maximum 4 kg.

Protocol: The experiment firstly consists of an astronaut (astronaut 1) who leaves the base with either a beacon, which is either a DVA device (which uses the induction from magnetic waves) or a remote control of the drone. This is since the part defining the magnetic wave search with the DVA is not yet operational on the drone.

However, even if the DVA part of the drone is not finished during the simulation, it is now possible to make a command on the drone, the so-called "go home" command, which simply allows the drone to go to the place where the beacon is located. This is done using the telemetry antenna located on the drone and the remote control (RF waves).

We must therefore insert four GPS coordinates from the computer at the base, delimiting a boundary perimeter for the search for the drone. Once astronaut 1 is in position, he will have to activate the "go home" command, once it is activated, the drone will start and search until it finds astronaut 1's position.

Once the position is found and blocked, again by telemetry, the drone will remain in hover above astronaut 1 and send its position data to the computer at the base. The other two astronauts (astronauts 2 and 3), having remained inside the base, will then have to follow the direction transmitted by the drone until they reach the position of astronaut 1.

The last step is for astronauts 2 and 3 to bring astronaut 1 back to the base, we can imagine that astronauts 2 and 3 must use a stretcher to be able to transport astronaut 1 if we simulate an injury from the latter, thus preventing him from returning to the base by himself.

As for the return of the drone to base, two options exist. First option is when astronauts 2 and 3 find astronaut 1, command the drone to land at the same place and carry it to base manually. Second option is on the way back to the base, leave the drone there and once the three astronauts arrive at the base, command "go home" again, so the drone will come to the position of the beacon, which is at that moment the base.

We must consider that the time required to carry out the experiment depends greatly on the free area available around the base, since the drone requires about 5 minutes to carry out a search on an area of 5000 m². In addition, it will also depend on the astronauts' travel speed during an EVA, as it is necessary to count 3 trips for the entire experiment.

The data received by the computer from the drone will be transferred either via a coded interface directly to Python or via a mission planning program for drones such as Mission Planner or Ground Control.

Risks and mitigations: As this experiment is an outside activity, if the weather is bad, the EVA will be cancelled. The astronauts' schedule will be flexible to adapt to the weather. This experiment is a test of the drone's system so it could not work. The test would be run again in the newt days of the simulation. If the drone works, it is automatic so there is no risk of collision whatsoever. Astronauts will have to be careful when walking outside the base.

7.3.3 Radio Astro

PI - Principal Investigator: Aurélien Verdier (President of Callista - Student association at EPFL)

Student in charge: Matthieu Meilhac (matthieu.meilhac@epfl.ch)

Description: The goal is to build an antenna able to perform radio astronomy. Weight and space being two major issues for a space mission, this antenna must be lightweight and built by the astronauts. This second requirement would allow to see if a classic antenna can be replaced by a disassembled one, which would allow to leave more room for other experiments. Antenna-0 (see the picture), which will be built by the astronauts, is a prototype, needed to build a more complex antenna in the months to come. Its components are already functional, but the antenna still needs to be upgraded. If possible, this antenna should be able to get some data from a satellite. The data from the antenna will then be studied by the astronauts. The experiment will try to answer questions about abilities to build and use an antenna during a space mission. The impact of wearing a weighty space suit will also be considered.

Figure 7.3.2: *RadioAstro Prototype*

Expected results:

1. Try the different cans.
2. Detect hydrogen sources 21 cm.
3. Observe the Sun.
4. Observe the galaxy and detect its rotation using Doppler effect.

Methodology:

- Cut the carton and assemble the “horn” using the scotch tape.
- Cover the “Horn” using the aluminium leaves and the aluminium scotch.
- Assemble the can with the “horn” to guide the waves, using the aluminium scotch.
- Put the receiver in the can, and stabilize it using the aluminium scotch.
- Connect the LNAs, the filter, and the USB key with the coaxial wires.
- Connect the USB key to a laptop. A program to read the data will be given.

Requirements: This experiment will take approximately 2 hours during an EVA. 2 astronauts will build the antenna with some carton boxes, aluminium leaves, scotch tape, aluminium scotch, copper wire, 2 Low Noise Amplifiers (LNAs), bandwidth filter, coaxial wires, USB key SDR. The equipment's mass is 2 kg. The antenna will be connected to a laptop inside the base by a coaxial wire.

Risks and mitigations: As this experiment is an outside activity, if the weather is bad, the EVA will be cancelled. The astronauts' schedule will be flexible to adapt to the weather. Also, the astronauts will have to be trained in the construction of the antenna to make the experiment run smoothly.

7.3.4 Perchlorate

PI - Principal Investigator: Gustavo Jamanca Lino (gustavo.jamanca@community.isunet.edu)

Student in charge: Gustavo Jamanca Lino (gustavo.jamanca@community.isunet.edu), Elfie Roy (elfie.roy@epfl.ch)

Description: A future settlement on Mars will need to develop agriculture, however the perchlorate content in the Martian soil is so high that it would impede the development of agriculture, as well as potentially contaminate extracted food. The average content of perchlorate in soil ranges from 0.5% to 1%. [17]

The experiment aims to develop a method that reduces the perchlorate content of the soil by 90% percent. The test also aims for a minimal use of water, according to the sustainability goal of the mission. An analogue soil will be testes. The method is based on environmental and hydrometallurgical techniques [18] like dissolution (or leaching) and ion exchange. [19]

The process will allow an effective technique to eliminate perchlorate and contribute to the future development of agriculture on Martian soil. The success of this type of technology would have an impact on the remediation of analogue soils on Earth. In addition to its agricultural implications, perchlorates are also of considerable interest in the exploration of Mars, because by its chemical composition, as it could be an important source of oxygen.

Expected results: Total perchlorate removal = 90%

Example: For a sample of 0.3 % perchlorate in a sample of soil entering the process, the perchlorate content in the soil after the process should be of maximum 0.03%.

Methodology: We hope to achieve these results using a system designed to apply 3 environmental and hydrometallurgical technologies: Dissolution, Filtration and Ion Exchange, in order to eliminate perchlorate salts from the soil of Mars.

Dissolution of perchlorate

Solubility is the quality of a certain substance to dissolve in another. Soluble substances are those that when they encounter another liquid, dissolve and form a solution. The substance that dissolves is the solute and the medium is the solvent. A clear example of this is the dissolution of sugar in water. A summary of the solubility of perchlorate salts is presented:

	g/100 g H20
	Temperature
Magnesio	49.6
Potassium	2.56
Sodium	222
Lithium	63.6
Ammonium	20.85

Table 7.3.2: *Solubility handbook By Khaled Gharib*

Given the high solubility of perchlorate in these liquids, it is expected to allow the removal of perchlorate from the analogue soil.

Filtration

The solid liquid separation is necessary both for the purification of water, and the separation of perchlorate from the analogous soil. For small quantities of sample, filtration is a quick (a matter of minutes) and easy method. The pulp (solid + water mixture) is placed on a membrane and air is introduced into the equipment to increase the pressure and separate the pulp from water.

Ion Exchange

Ionic exchange using exchange resins is an effective technology, in which an electrolyte solution and a complex exchange anions or cations, separates the electrolytes from the solution, therefore purifying it. A solution of water with perchlorate and dissolved low solids, passes through a column with a resin, and exchange an ion therefore trapping the perchlorate.

Process

The first stage is to obtain a sample of Martian analogue soil, in perchlorate content: it can be taken from two sources:

1. Ground of a desert, in conditions of very low humidity.

(Example: Atacama – Chile [20])

2. Ground of a rocket launch zone that uses ammonium perchlorate as fuel.[21]

In any case, the samples must have a content greater than 0.3% perchlorate, which is a good start for the test. According to the mapping of perchlorate content on Mars, shown in the publication [22].

Reviewing the map, we can see that the average content of perchlorate is around 0.4% - 0.5%. The sample should be stored in the driest conditions possible in the analogue base before starting the experiment.

The equipment for the soil treatment system with the capacity of 1 kg per batch will be needed, designed and built. The system will be discontinuous (1 kg at a time).

The proposed system is an idea mixing hydrometallurgical techniques applied in the treatment of analogue soil. It is similar to an experiment presented for iGEM in Boston.[23]

The general system has the following stages:

Perchlorate Dissolution: Mixing and washing the Martian soil sample with water. Perchlorates are soluble in water and this washing step is a way of removing them from the soil. The pulp is moved to the next machine trough a connected pipe.

Separation solid-liquid: By filtration (soil residues). With the equipment tightly closed, air is added at a pressure of approximately 5.0 bar (72 psi). Air is added only until such pressure is reached (approximately 1 minute). Water is received by a pipe. For 1kg samples, the filtration lasts less than 10 minutes. After removing the air in the equipment. The filter opens to manually remove the solid, which must be low moisture content (less than 10%).

Perchlorate Recovery: The water used for washing and removed in the Sludge filtration stage has a high perchlorate content. So that water is not wasted ion exchange technology will be used, to remove the perchlorate from the water, this would be done with a SBA Resin (Strongly basic). The flow of water collected from the previous step is slowly added to an ion exchange column. The treated water, with minimal perchlorate content is stored to repeat the process until perchlorate content is satisfying.

The experiment is exploratory, in which it seeks to test different process conditions to obtain the highest possible extraction of perchlorate in the shortest time.

Depending on the amount of sample, these variables can be modified:

Stirring time: 30, 45 and 60 minutes

Dilution: 2, 3, 4

pH: 5 and 8 upH

11 experiments are estimated, using the methodology of experimental design in the protocol. It is expected to find the best condition and response surface in these variables. The protocol review is also a potential result.

Requirements: One test will take 1.25 hours for one astronaut, so 5 hours in total. Astronauts will do 4-5 tests. The equipment needed is detailed in Annex

- Jones Sample Divider
- Mechanical stirrer - 5 lt. capacity
- Filter press - 5 lt. capacity
- Glass Tank - 10 lt. capacity
- Ion exchange column 5 lt. capacity
- Glass Tank 10 lt. capacity
- Drying Oven. 10 lt. capacity
- Chemical system analysis for perchlorate. (Only if it's decided to analyse the samples in situ. The best option is to bring them at the end of the mission to an external laboratory.)
- Air compressor - 100 ps

In addition to the technical equipment:

- 8 kg of analogue soil with more than 0.3% perchlorate content
- 20 litres of distilled water

This therefore comes to a mass budget of 80 kg for the system and 28 Kg for soil and water.

Protocol

Sampling the soil to be treated

1. Basic information and preliminary chemical characteristics of the soil are required. The sample must be obtained from a soil with characteristics of Mars, very low humidity and perchlorate content greater than 0.3%, these types of samples exist mainly in deserts or rocket test soils.
2. The sampling team must go to the selected area, and must record the location (GPS System), date and team members. The simple random sampling technique will be applied to surface samples, taking samples within a random area. Using a displacer (scoop) to excavate at a depth of 20 cm.
3. All subsamples are placed together on top of a blanket. The quantity of total sample needed is 32 kg. If the sample has rocks larger than ¼ inch, it is necessary to pass it through a manual sieve of 1/4", so that everything has a uniform size.
4. For sample reduction, the technique of homogenization and cracking will be used. Place the samples on the blanket and mix by hand or with a shovel for 15 minutes. Perform quartet with Jones Sample Divider.

5. Sampling and storage are performed according to this diagram.

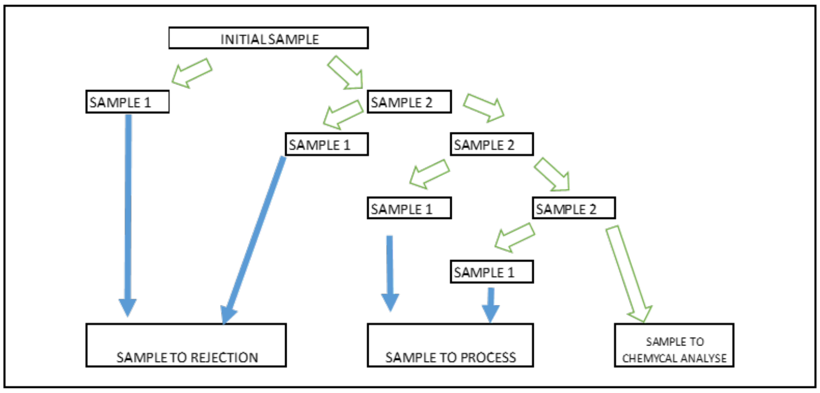


Figure 7.3.3: *Sample Management*

6. Finally, we will have 3 types of subsamples: Rejection samples, which are left in situ; Samples to the process that is stored for the experiments and Sample for chemical analysis. Chemical analysis will be conducted to obtain the chemical composition of the sample to quantify the exact content of perchlorate. Samples 2 and 3 are stored in dense polyethylene bags, properly sealed, for transport and storage. The bags should be placed inside sealed plastic buckets to facilitate transport and storage.

Process

1. The sample must be taken from the bags and carefully weighed (1kg). From this sample a small random amount of 50 g will be taken for chemical analysis. (SAMPLING POINT 1).
2. Turn on the stirrer (MIXING TANK) and add the water required for the process. The amount of water depends on the required dilution. Conditions are given according to the table of experimental design (Table 7.3.2).
3. Extract 10 ml of water for chemical analysis (SAMPLE POINT 2). The turning speed must be above 1200 rpm to avoid sedimentation of the soil sample. After that add the required soil sample.
4. Once the mixture of water and soil sample has begun, extract samples from the pulp (SAMPLING POINT 3) from the tank at time given in Table 7.3.3. , 25 ml of pulp are extracted for each sample.
5. The sample is extracted with micropipettes, and must be filtered using: funnel, flask and filter paper. To the filtered solution, 10 ml are extracted which must be stored in test tubes to determine the concentration of Perchlorate in the solution.
6. The filtered solids and the surplus water from the previous sampling (of the 25 ml), are returned to the tank with the addition of 10 ml of fresh water, to replenish the initial mass to the system.
7. The presence of perchlorate in the extracted samples can be analysed indirectly by volumetric chemical analysis with the Mohr Method or directly with liquid Chromatography

in an external laboratory at the end of the mission or implement a chemical analytical system during the mission.

8. With the concentration information, the kinetics of the process are determined, this should be gradually increasing until the asymptotic curve is returned. It is possible to calculate from this data, the percentage of perchlorate extraction and the residual in the soil sample.
9. The soil sample, after the treatment is sent from the tank to the filtration stage. The transfer is done through a pipe located at the bottom of the tank that feeds the filter.
10. The filter is closed, and air is added for approximately 1 minute at a pressure of 5.0 bar (72 psi). The air valve is closed, and the water is expected to be separated from the pulp by pressure, this process takes 5 minutes. When the presence of water leaving the filter is no longer observed, the exhaust valve is opened to remove the air and return to the initial pressure conditions.
11. Finally, the filter is discharged manually by removing the solid sample, from which a sample is taken to calculate the moisture content. The moisture content can be calculated using a small drying oven, which must be at 80 ° C temperature, for 60 minutes.
12. The dried sample should be labelled and stored to analyse the residual perchlorate content (SAMPLE POINT 4). This analysis is to confirm the results of the process and can be done in an external laboratory at the end of the mission.
13. The solution recovered from the filtering stage is passed through a column of SBA resin, at a constant percolation rate. The addition is carried out, transporting the water from the filter to a small storage tank (TK 1) and from this tank the ion exchange column is fed. Water must be sampled before entering the ion exchange stage and at the exit, to confirm the efficiency of the ion exchange process. 25 ml of sample should be taken per batch of water. (SAMPLE POINT 5 and 6).
14. Be sure to perform all chemical tests in triplicate.
15. After each experiment the equipment must be washed and dried before the next.

Risks and mitigations: A lot of steps could not work during this experiment. Astronauts will perform the whole process several times before the missions and they will learn to use every instrument. They will be protected by their suit so there won't be any risk of touching dangerous products. If we only have one space suit, the other(s) will wear protections.

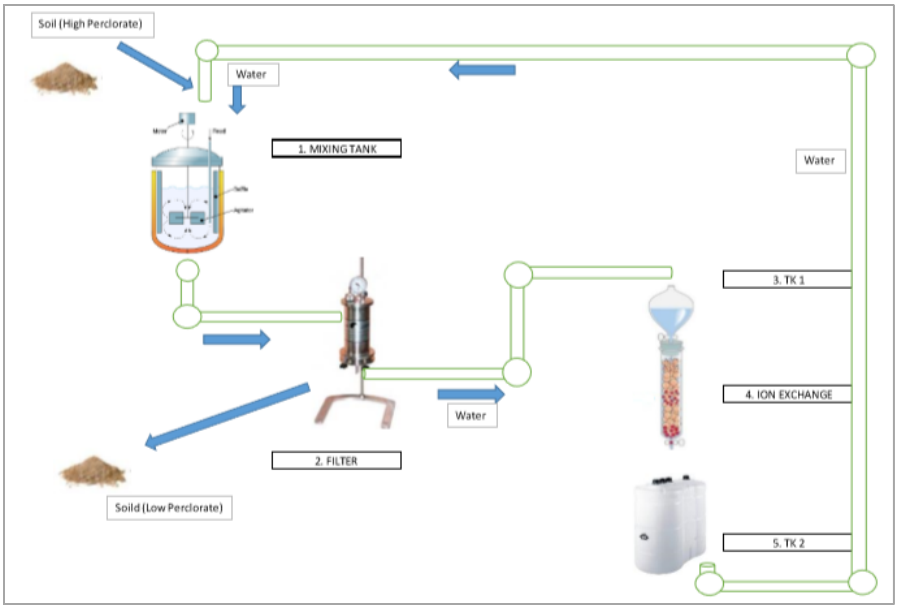


Figure 7.3.4: *Flowsheet Process*

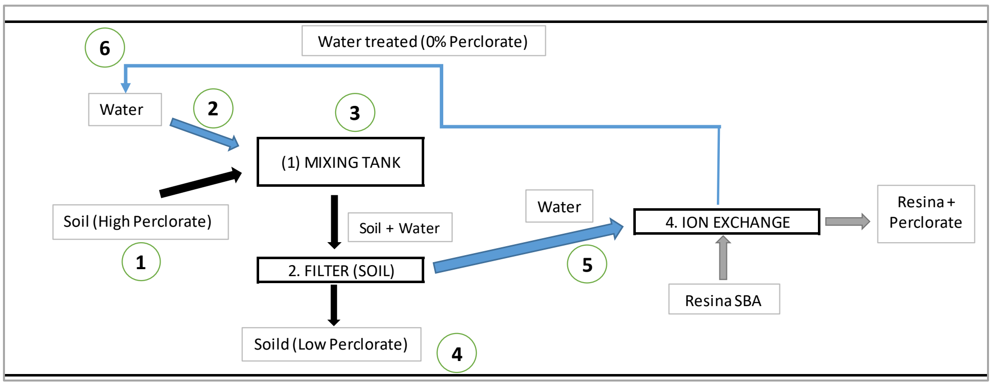


Figure 7.3.5: *Sampling Points*

	Dilution	pH	Time
Test 1	2	Natural	60
Test 2	4	Natural	60
Test 3	2	Natural	60
Test 4	4	Natural	60

Table 7.3.3: *Experimental Design*

Pulp sampling in the process	
Order	Stirring time
1	5
2	10
3	15
4	20
5	30
6	45
7	60

Table 7.3.4 : *Pulp sampling*

7.4 Human Factor

7.4.1 Psychology

PI - Principal Investigator: Caroline Pulfrey (EPFL, UNIL), Kim Lê Van (HESAV), Sophie Goemaere (University of Ghent, Belgium), Fabrizio Butera (UNIL)

Student in charge: Orane Valette (orane.valette@epfl.ch)

Description: We will study how individual values, motivations and crew need for satisfaction impact team functioning, task motivation and coping in the context of a space mission.

Expected results: More knowledge on how to improve the interaction between astronauts-astronauts, and astronauts-MCC and learn about what triggers bad mental state.

Methodology: Questionnaires before, during and after the simulation, analysis of video excerpts and logbooks, and finally semi-directive interview focusing on the experiences and situations of tension.

Requirements: It will take each astronaut 40 minutes a day (best at the end of the afternoon). Equipment needed: one laptop.

Protocol: Quantitative Data Collection-Questionnaires

Our team will collect quantitative data using questionnaires filled in by astronauts and Ground Support.

a) A first questionnaire will be filled in before the simulation. This will include measures of individual values, personality, motivation and task-related self-efficacy.

b) A set of quantitative and qualitative measures will be filled in on a daily basis, for the duration of the simulation flight. (psychological need satisfaction, self-regulation, work climate, team cooperation and cohesion, oppositional defiance and reaction to feedback). This will take approximately 30 minutes per day. Timing is flexible.

c) A post-simulation questionnaire will be filled in (individual values, motivation, task-related self-efficacy, team commitment).

We will also collect qualitative data using:

a) Relevant excerpts from the Asclepios video recordings. These will be analysed with a view to understanding how and why tensions among crewmembers or difficulties in communication (misunderstandings, misalignments, conflicts) arise.

b) A logbook filled in by each astronaut to collect feelings and emotions throughout the mission. This will be investigated to complete the information gathered in point a) using an inductive approach based on Grounded Theory.

c) A series of 5 open questions inviting astronaut feedback on the day.

d) Short (30min) semi-directive interviews with crew members, focusing on the experiences and situations of tension.

Measures:

Pre-simulation:

- Individual values (Schwartz et al, 2012)
- Hexaco personality inventory (Lee &Ashton, 2004)

During simulation – daily basis:

- Adapted version of Work Climate Questionnaire (Baard et al., 2004; Goemaere et al., 2019)
- Adapted version of Basic Psychological Need Satisfaction Scale (Gagné, 2003; Goemaere et al., 2019)
- Adapted version of Self-Regulation Questionnaire - Parental Rules (Soenens, Vansteenkiste, & Niemiec, 2009; Goemaere et al., 2019)
- Oppositional defiance questionnaire Adapted from Vansteenkiste, Soenens and Van Petegem (Vansteenkiste, Soenens, Van Petegem, & Duriez, 2014; Goemaere et al., 2019)
- Adapted version of Resentment Scale by Assor, Roth, and Deci (Assor, Roth, & Deci, 2004; Goemaere et al., 2019)
- Adapted version of Sport Climate Questionnaire (Delrue, Reynders, Aelterman, Vande Broek, & Vansteenkiste, 2017).
- Adapted version of the single item questions on stress, happiness, trust and performance
- A set of 5 open question (e.g.: "what was your best experience today?").

Qualitative data collection:

Stage 1: Video recordings. The Asclepios project plans to video record some steps of the space simulation. Excerpts showing tensions among crewmembers or difficulties in interpersonal communication (misunderstandings, misalignments, conflicts) will be extracted to constitute a video corpus. The latter will be used for two purposes: i) identify a trigger excerpt to use in the interview (see *Stage 2*), and ii) identify potential patterns of communication showing challenges, leading to collaborative tensions and communication fails.

Stage 2: Semi-directive interviews. 30 to 45 minutes, conducted with each of the crewmembers, after the week of simulation. The interview protocol includes 18 questions organised in five thematic dimensions: 1) Experience of collaboration, 2) narrative description of a video excerpt (a situation of collaborative difficulty experienced during simulation), 3) experienced difficulties and coping strategies, 4) participant's individual needs in collaboration, 5) perceived team's needs and difficulties in collaboration. With participants' agreement, interviews will be audio-recorded and fully transcribed verbatim. Participants will be informed in writing of the anonymity of the data and respect of integrity. Participation will be volunteer and unpaid.

Stage 3: Logbook. The Asclepios project plans to put in place a logbook filled out by each astronaut to collect feelings and emotions throughout the mission. For the purpose of this study, the logbook will be investigated to constitute a corpus of notes related to i) video corpus of situation of tensions and difficulties in communication, and ii) specific situations mentioned by participants during interviews.

Anonymity: We ensure that personal data will be anonymized into scientific publications. During the data collection we will pseudonymize the personal information.

Data storage: Data will be stored in EPFL data storage repositories.

Deception(false, objectively untrue information)**:** There is no participant deception in the psychology side of the simulation.

7.4.2 NASA Psychology project

PI (Principal Investigator): Dr Nathan Smith, Research Associate in Psychology, Security and Trust - University of Manchester

Student in charge: Elfie Roy (elfie.roy@epfl.ch)

Description: The aim of the study is to help validate NASA's standard health measures and explore some of the antecedents that might influence individual responses in challenging and demanding environments. The outputs of this research will feed into NASA's Human Research Roadmap for space and shape some of the health measures used on missions to the moon and Mars.

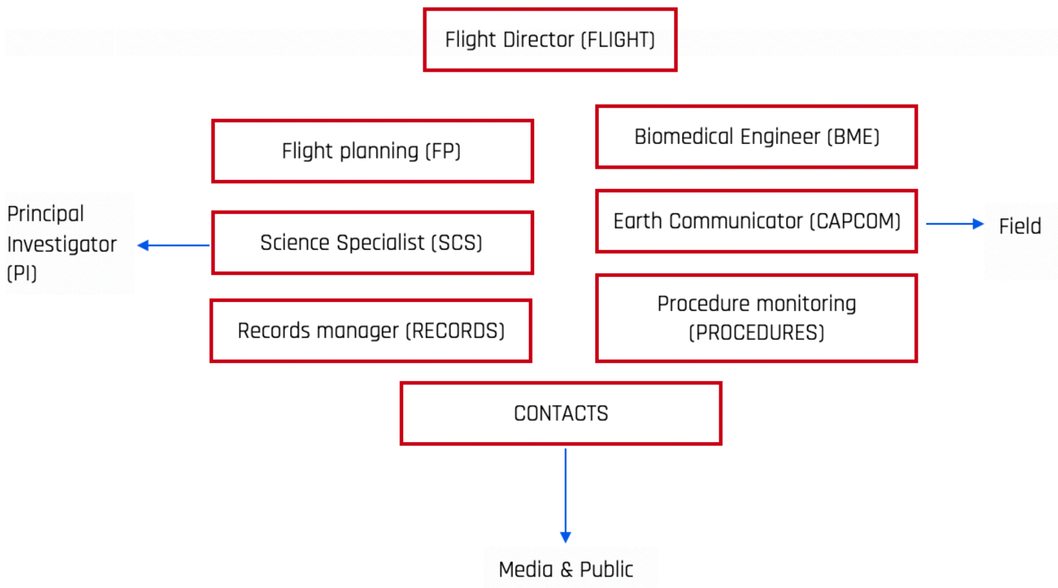
Requirements and methodology: The study is very straightforward and includes a pre and post-expedition online survey which takes around 40 minutes. The pre-expedition survey will have to be done any time within 2 weeks of commencement of the mission, and the post-expedition survey will have to be done between 2 and 4 weeks after the mission. A daily expedition diary will also have to be filled in by astronauts, which takes around 10 minutes a day. One section of this form will have to be filled in the morning and another in the evening, keeping the time roughly consistent: when they wake up and just before they go to bed.

8 Mission Control Center (MCC)

Mission Control Center represents a team, within the Asclepios project, with the following goals:

- The recruitment of analogue astronaut (first semester);
- The organization of the analogue astronaut's training;
- The writing of the procedures and flight planning;
- The monitoring and management of the mission and the dress rehearsal.

The following organigram represents the role and tasks of the Mission Control Center during the mission[2].



[2] The roles are subject to change

8.1 MCC organisation and positions

- **Flight Director:** Head of Mission Control Center.

The Flight Director (FLIGHT) is responsible for the overall ASCEPIOS-I mission operation. During the mission, he is responsible for ensuring that the resources of the MCC and the supporting operational ground segment were adequate to conduct mission operations. He has the final decision-making authority.

ASCLEPIOS-I Flight Directors	
	
Chloé Carrière	Marcellin Feasson

- **Earth Communicator (CAPCOM):** Head of MCC if FLIGHT is not in the room.

The Earth Communicator (CAPCOM) has the responsibility for coordinating the communications between the MCC and the field crew (via voice communications and chat). He should have gone through the astronaut training and know the crew very well.

- **Procedure monitoring (PROCEDURES):** Head of MCC if FLIGHT, BME and CAPCOM are not in the room.

The procedure monitoring position (PROCEDURES) maintains the compilation of the standard operating procedures as well as experiment procedures to ensure that the field crew and the MCC have access to the most recent editions. During the mission, PROCEDURES observes if the sequence of events is done according to the given procedures and informs FLIGHT in case any deviations (both time – or procedure-wise) that might endanger the operations occurs.

- **Flight Planning (FP):** Head of mission schedule.

The Flight Planning (FP) team schedules the activities to be conducted in the fields, based on the input from the Experiments team and the Communication Team. He/she/they is responsible for updating the schedule in real time during the mission in case delay, weather, etc.

- **Science specialist (SCS):** Head of the experiments to be performed.

The Science specialist (SCS) is responsible of the experiment to be performed on a specific day and therefore changes depending on the day of the mission. He/she/they is able to provide assistance to the astronauts if something doesn't go as planned and is responsible for storing the data in an appropriate hardware and sending it to the Principal Investigator (PI) of the experiment.

- **Records manager (RECORDS):** Responsible for the continuous log file of the mission.

The Records Manager (RECORDS) ensures continuous log file of what is happening in the field as well as in the Mission Control Centre. This position provides input on the progression of the experiments and to properly store the data. Biomedical and psychological recordings are NOT part of the RECORDS logfiles but are maintained by the BME due to their personal and sensitive nature.

- **CONTACTS:** Head of communication.

CONTACTS is responsible for all exterior contact including public, media and other. He/she/they is responsible for the coordination of media activities and the management of media inquiries. He/she/they generally handles the communication of the mission to the general public via social media channels and traditional press. He/she/they is also responsible for event planning.

The Mission Control Center ensures a constant monitoring (24/7) to make sure the mission goes smoothly in terms of security and data management. To do so, three shifts will be established during the one-week simulation: 6AM to 2PM, 2PM to 10PM and 10PM to 6AM (with a reduced shift by night). This brings a total of 20 to 30 people to support the field test. This number includes a Ground Support team which has for goal to secure the MCC building and to make sure everybody has enough to eat/drink and is on time for their shift.

8.2 Selection of ASCLEPIOS-I Analogue Astronauts

During the fall semester of 2019, the Asclepios Mission Control Center (MCC) held the responsibility of the design and implementation of a recruitment process to find the most eligible candidates for the astronaut positions in the mission.

As a preliminary to the set goal, a separate email and Google drive account were created in order to facilitate the receiving of documents from the applicants. This was necessary to ensure the clandestine nature of the recruitment process, as any discussions and meetings between the MCC members needed to stay private to maintain the fairness of all procedures. The identity of all candidates remains secret and only the MCC team has seen and evaluated the applications. The email that was created is the following: recrutement.asclepios@gmail.com. The website of the mission was launched as well containing all information about Asclepios including the selection process. In the Annex, the poster for the first part of the recruiting session which was advertised can be found.

In the following step, minimum eligibility criteria were negotiated and set, especially on our website (Asclepios.ch). These requirements were the following:

- students undergoing Bachelor/Master/PhD studies, in any domain;
- of adequate physical health to ensure the ability to undergo the astronaut training, a medical certificate to certifying ability to dive had to be procured;
- availability during the simulation period, which will take place from 21/02/2020 – 23/02/2020 and 07/04/2020 – 18/04/2020;
- commitment to 10 hours of work per week as of the spring semester;
- willingness to sign a consent form before enduring the various physical and mental tests during the training;
- providing a blank criminal record.

We have also made it mandatory that the applicants join Space@yourService association after the application process is over.

The selection process was divided into 4 parts, each of which was detailed and conducted as follows:

8.2.1 Part A

Asclepios required from each applicant, a CV, a personal statement explaining their motivation for applying, and their criminal record. The application process began on 28/10/19, where we started receiving the documents, and was open up until 10/11/19. We received a total of 194 applications that were divided into two groups in order to be read and assessed by the MCC, as well as the UK Analogue Missions members (UKAM) team. Elements we tried looking for aside from the minimum eligibility criteria are the following:

8.2.1.1 1. Motivation letter

Is motivation intrinsic or extrinsic, i.e. whether it is a personal reason or one that goes beyond themselves? Is it an opportunity for career progression? Do they see it as an opportunity for doing social good elsewhere? Does the letter include an awareness of others? Are they team players?

8.2.1.2 2. Resume

- Eligibility: student, good English
- Mixed-discipline team, variety of experiences
- Awareness of other cultures, sports experience
- Experience in Isolated Confined Environments

In total 29 countries were represented, and 11 EPFL sections were also represented among the applicants. The following figures give an overview of the applications statistics.

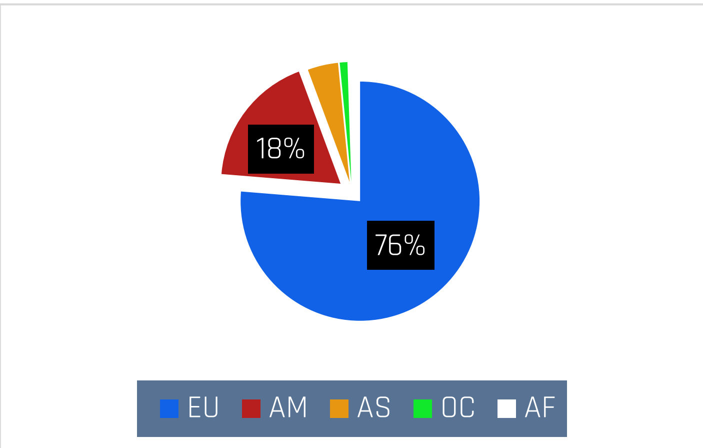


Figure 8.2.1*: Percentage distribution of applicants in the world*

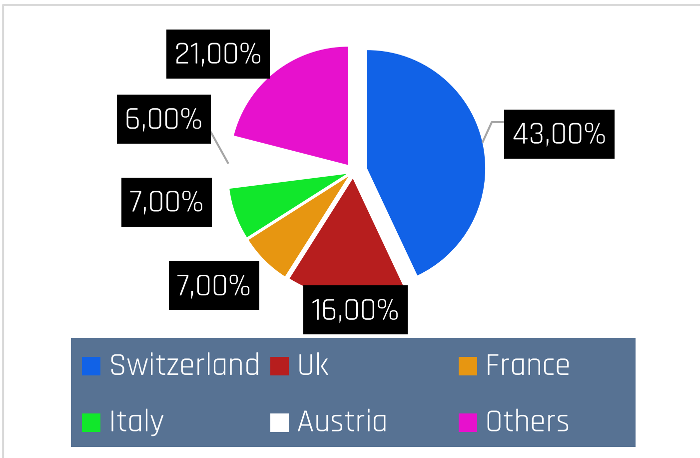


Figure 8.2.2: *Percentage distribution of applicants in Europe*

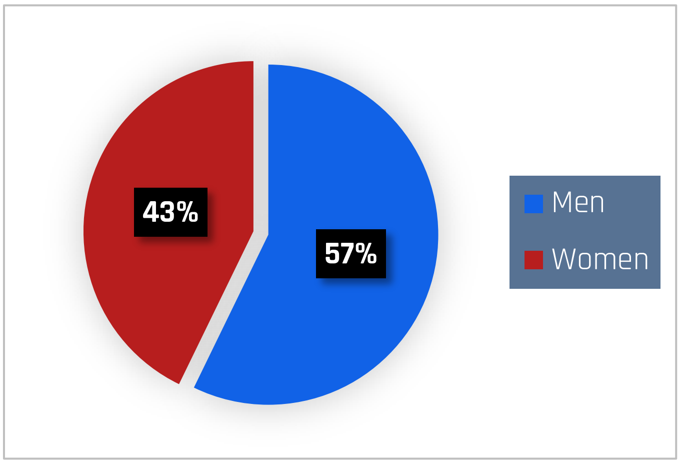


Figure 8.2.3: *Percentage distribution of the applicants between men and women*

We aimed for a mixed crew (ideally half women, half men), with interdisciplinary skills and a diversity in age and academic level.

8.2.2 According to what has been stated, 77 were chosen to proceed to the next part, and were informed by email on 15/11/2019, using the same email address (all participants were in cci and not cc to keep confidentiality).Part B

We required that the applicants send us a video of themselves answering a set of questions that we prepared. The instructions were:

1. The video should be approximately two minutes long (max 3 minutes);
2. You have to speak English the entire time;
3. Select two to three questions from the list below to answer as you see fit;
4. When you answer, be sure to state (orally or visually) which question you're answering;
5. Upload the video as detailed below;
6. Do so before the 22nd of November.

The questions were:

1. Why do you want to be an analogue astronaut?
2. What's your view on space exploration?
3. Will the Asclepios mission be useful for your professional life?
4. What does a crew represent for you?
5. How do you do with people?
6. Have you had prior experience of prolonged periods of isolation/indoor stay?
7. How well do you take orders?
8. How do you react under stressful conditions?

9. What is your favourite rocket?
10. What is your favourite space related quote and why?
11. Why would **you** be the best choice among all other candidates?

To make their video available to the MCC team, they went through this procedure:

1. Realize a video respecting the instructions above;
2. Upload the video on Youtube (for more confidentiality, you can either make your video private and give the access to " recrutement.asclepios@gmail.com " or make it unlisted);
3. Send the link to " recrutement.asclepios@gmail.com ".

The point of the video is to verify their level of English and to help us know more about their personalities. We prepared a consent form requesting the agreement to allow MCC to use, view, analyse, and possibly share the videos and other media provided by the applicants without any legal consequences (see Annex). The form was revised by the mission's legal team and was sent to the applicants to sign and email back along with the video. We received the videos starting 15/11/19 till 22/11/19 and provided them to the mission's team of psychiatrists to be analysed. The results were then discussed between MCC members to choose the applicants eligible to move on to the next step. We accepted a total of 35 and informed them through email.

The evaluation committee was composed of the MCC and UKAM teams as in part A.

8.2.3 Part C

We required that the applicants sit for a standard technical test that was designed using assessment questions used by the European Space Agency for the recruitment of their astronauts. The book used as reference for the questions is "The Astronaut Selection Test Book" by Tim Peake and the European Space Agency [24]. The test, held on 28/11/19 lasted an hour and a half and targeted the following reasoning areas: logic, perception/concentration, memory, decision making, technical knowledge, and human behaviour. Since not all candidates are present in Switzerland, or not locally in Lausanne, it was preferred that the test would be projected on PowerPoint slides, in which each question is timed and ran automatically according to the time allocated for each question. The applicants were also given an answer sheet where they had to place their answers, and which was later corrected according to the set answer key. The correction was done by FLIGHT, and MCC.

The test was broadcasted using Twitch to the applicants who were not present at EPFL for the test, and the answer sheet was shared with them using Google docs. Several members of Asclepios, as well as the MCC team, were then assigned to one member and had to monitor their behaviour on Skype, after asking the examinees to share their screens. The entirety of the procedure was designed to ensure that no cheating occurs, and that the candidates conform to the rules.

Some excerpts of the different sections of the exam, as well as a visual display of the remote test for the foreign candidates, is given in Figures 4 to 10. The results of the technical exam are given in Table 1.

Part I : logic and perception
Test I duration : 5 minutes

Logic, perception

Test I) Basic arithmetic : You have 30 seconds to read the instructions on your answer sheet.

a) 689 + 398 = ?
b) 1149 + 1992 = ?
c) 1912 + 646 = ?
d) 1358 + 1839 = ?

e) 1829 – 730 = ?
f) 1425 – 687 = ?
g) 1977 – 839 = ?
h) 1856 – 924 = ?

i) 11 x 15 = ?
j) 16 x 18 = ?
k) 12 x 14 = ?
l) 19 x 17 = ?

m) 34 / 11 = ?
n) 44 / 6 = ?
o) 94 / 8 = ?
p) 74 / 8 = ?

q) 13 x ? = 110.5
r) 79 / ? = 10

3

Figure 8.2.4: Example of a basic arithmetic question from the first section of the technical exam

Part I : logic and perception
Test IV duration : 4 minutes

Logic, perception

Test IV) You have a minute to take a good look at the following picture, before answering some questions.

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Figure 8.2.5: *Example of a question extracted from the first section of the technical exam*

Part II : concentration and memorization

Test IV duration : 2 minutes

Logic, perception Concentration, memorization

Test IV) Question 9) Question 10)

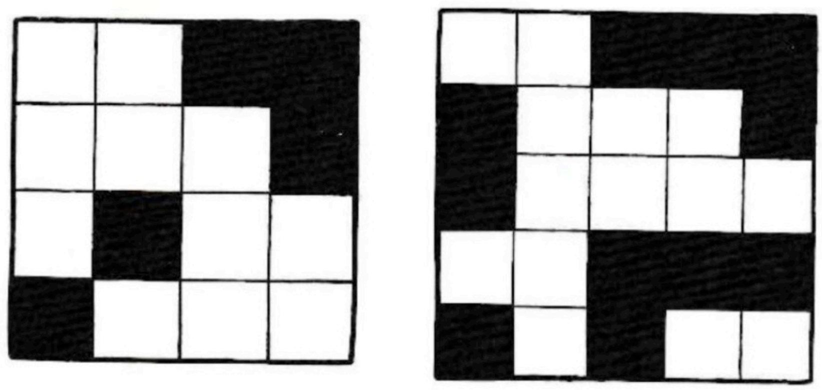


Figure 8.2.6: *Example of a memorization question from the second section of the technical exam*

Part III : Decision making

Test I duration : 20 minutes

Logic, perception Concentration, memorization Decision making

Test I) You are in a mission with 5 other explorers. During this mission, you are unfortunately separated from your group. Therefore, **you have now to walk back alone to the base camp**. You have no weapon, and your only means of communication is out of use. Besides, you have enough food and water for one whole day and your equipment is very rudimentary.

From the place where you are located, you notice that there are montains to the West, as far as you can see.
Moreover a lake, which you know is infested with crocodiles, prevents you to walk to the South.
You manage to see a dense and humid jungle to the East. Finally, you remember there is an ennemy camp based in the North.

Instructions : Suggest a realisable solution to return to your base camp and detail it.

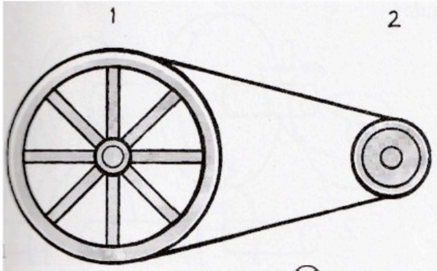
Figure 8.2.7: *Example of a decision-making question from the third section of the technical exam*

Part IV : Technical knowledge

Test I duration : 11 minutes

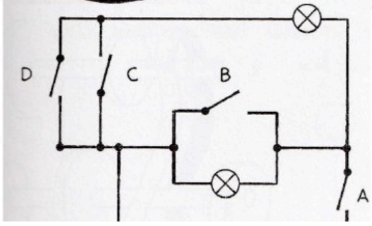
Logic, perception Concentration, memorization Decision making **Technical knowledge**

Test I) You have 40 seconds for the following 2 questions.



Question 7) Which one of these wheels rotates faster ?

a) Wheel 1
b) Wheel 2
c) They rotate at the same velocity
d) It depends if the propulsion system is located on the wheel 1 or on the wheel 2



Question 8) Which one of these switches have to be closed to allow the passage of electricity?

a) A
b) B
c) C
d) D

Figure 8.2.8: *Example of a technical knowledge question from the fourth section of the technical exam*

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Part V : Psychology

Test I duration : 12 minutes

Logic, perception Concentration, memorization Decision making Technical knowledge **Human behavior**

Test I) Read the instructions on your answer sheet.

Question 1) Performing a procedure of a scientific experiment, you realize that you have switched 2 steps. You are sure that the result can't be changed but there won't be any consequences. What do you do ?

a) You continue the procedure, and write to the mission control center a note about the steps which were switched.
b) You stop the procedure and inform the mission control center immediately about your mistake.
c) You continue the procedure as you believe the result won't be modified.
d) You ask one of your colleagues' opinion.

Figure 8.2.9: *Example of a psychological question from the last part of the technical exam*

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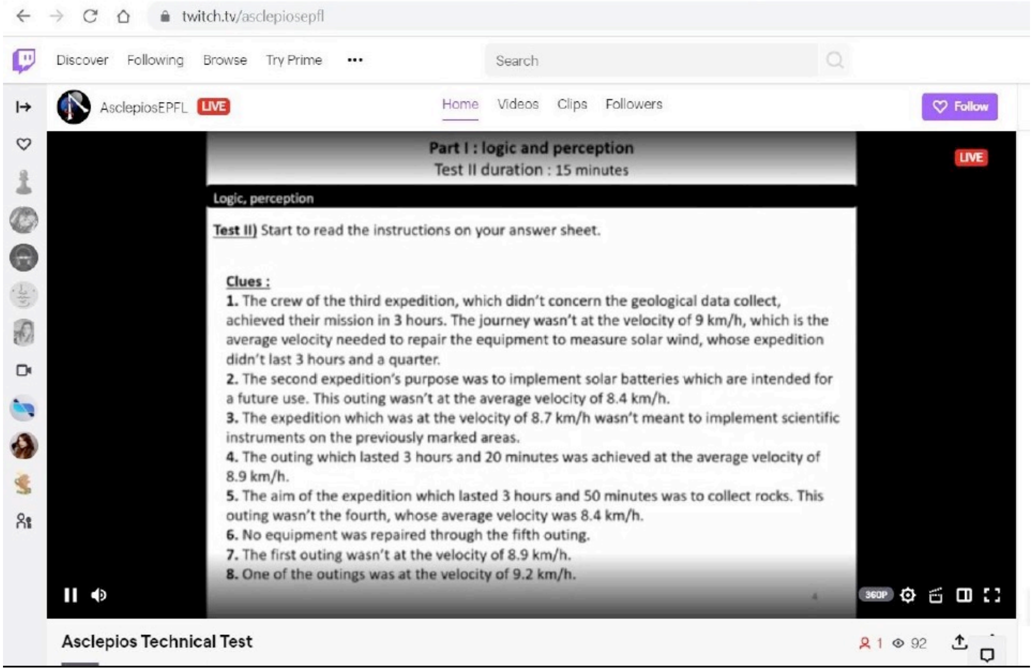


Figure 8.2.10: *Display of the remote test for non-local candidates*

Lowest grade	First quartile	Median	Third quartile	Highest grade
88/194	102.75/194	126.5/194	139/194	174/194

Table 8.2.1: *Final results from the technical test*

After evaluating the answer sheets, 14 candidates were chosen to proceed to the next step and were informed a week after the test was held. This choice was made by FLIGHT and UKAM specialists and was based on background, communication skills, score on the technical test and motivation.

8.2.4 Part D

A final interview with the remaining applicants was organized as the last recruiting part. The interviewers consisted of the psychologist Konstantin Chterev, FLIGHT, professional psychiatrist

Nicolas Belleux and Prof. Claude Nicollier. Prof. Nicollier is a crucial and a very prestigious element in the evaluation process, as he is the first Swiss citizen to become an astronaut as well as the first European Space Agency astronaut to perform space walks during his last space shuttle mission. He is currently a full professor of Space Technology at EPFL and assisted us in choosing the ideal final choices among the remaining candidates. The interviews were conducted at the Cabinet Nicolas Belleux in Lausanne, and at the Swiss Space Center.

The interviews took place as followed:

- 10/12: 15-minute interview with Swiss Astronaut Claude Nicollier;
- 16/12 and 17/12: 1-hour interview with FLIGHT, UKAM, Cabinet NB;
- 17/12: team exercise and social evening.

Here are some examples of the questions asked during the hour-long interview:

1. Share an experience you had dealing with a difficult person/situation.
2. An important part of missions in isolated/confined environments is humour; how do you think humour may be a positive or negative aspect to group dynamics?
3. Have you got to know any of the other candidates? Who can you see yourself on a team with?
4. If you were an animal, which one would you be and why?
5. What do your parents think of your application for Asclepios?

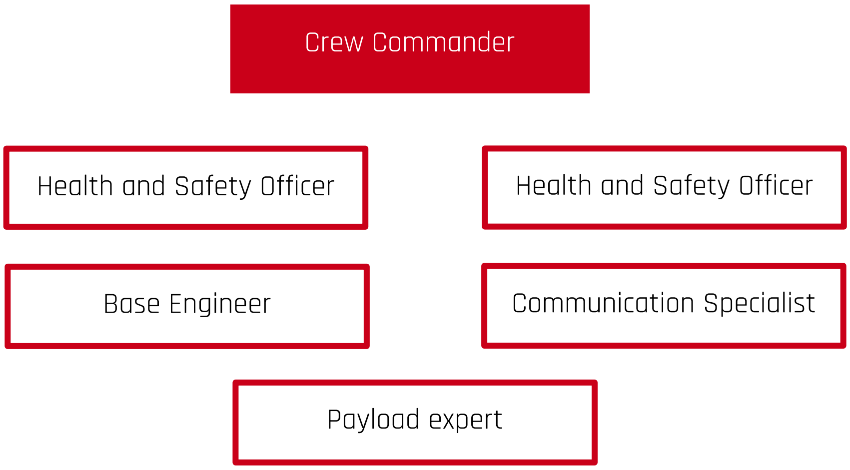
A teamwork exercise designed by NASA [23] was also conducted, to assess how well the individuals perform in a team. The exercise features a theoretical situation in which an accident happens in a Moon mission, and the teams are supposed to organize and prioritize the materials they are left with in order to ensure their return to base. The exercise can be seen in Annex.

The results of this phase concluded the recruitment process, having narrowed down the choices to the best possible candidates for the Asclepios analogue missions. Dr Nicolas Belleux attested the ability of the candidates to perform this experience: the letter can be found in the Annex. 8 candidates were selected at the end of the selection procedure. These include 6 crew members and 2 backups. The selected candidates will then undergo training.

8.3 Crew features

The eight analogue astronauts will go through an intense training to be ready for the field test in April 2020. It is important to note that the crew members are always free to drop out of the mission, even during the April simulation. They were informed during the interviews during the selection process and throughout the training. Everything is done on a voluntary basis.

The following hierarchy is considered:



The crew committed to 10 hours per week of training as for the spring semester. It will consist in the following:

- Workshop in extreme environment by Alban Michon, polar explorer, in Mid-February. It will consist in a night camping in the Alps and diving under the ice by night.
- Training to perform the experiments. It will be done by the experiments' team and will depend on the specific tasks of each astronaut.
- Theoretical courses by specialists in groups dynamics, space mission design and communication.
- Workshops for media interactions and outreach events by Space@yourService and EPFL Mediacom.
- One-month test of the workout and the vegan diet.

It is possible that crew members might take part in other field tests of the program Asclepios. Therefore, the selection process might not be done each year.

The selected analogue astronauts are the following:

- Aubin Antonsanti (Back-up)
- Christian Cardinaux (Back-up)
- Eleonore Poli – Crew Commander
- Julien Corsin – Communication Specialist
- Manuela Raimbault – Health and Safety Officer
- Sebasthian Ogalde Castro – Payload specialist
- Sophie Lismore – Base Engineer
- Willem Suter – Health and Safety Officer

They are all willing to go through the training on a voluntary basis and to perform their task during the mission in April. They can drop out at any time until the end of the campaign.

8.4 The Profiles

Name	Specialty	Age / Origins	Particularity	Gender
Aubin Antonsanti	Nuclear and Electrical Engineering	23 / France	Robotics and Astronomy specialist	Male
Christian Cardinaux	Mechanical Engineering	27 / Switzerland	Rocket team, theatrical impro, scuba diver, Private pilot Licence	Male
Eleonore Poli	Materials Science and Metallurgy	24 / Switzerland, UK, France and Italy	Ironman runner, Pianist	Female
Julien Corsin	Communication systems	20 / France	Programmer, Asclepios member	Male
Manuela Raimbault	Astrophysics	31 / France	Mountain guiding and paragliding	Female
Sebasthian Ogalde Castro	Astronomy and Electrical Engineering	25 / Chile	Scuba Diver, Private pilot Licence	Male
Sophie Lismore	Physics	20 / Switzerland and UK	Competitive skiing, Asclepios member	Female
Willem Suter	Automation and Control, Space Technologies	23 / Switzerland, Belgium and USA	PADI Divemaster	Male

Table 8.4.1: *Characteristics of our crew*

Figure 8.4.1: *Picture of Asclepios I astronauts before Crans-Montana workshop*

8.5 Astronauts' training

In order to be ready for the mission, the crew follows a training made of theoretical courses, workshops and prepares to perform the experiments. One of the key moments of the training was a workshop in extreme environment made by the French polar explorer Alban Michon in February. During this training period the crew also follows a one-month vegan diet and has a workout plan. A workshop of health and safety in the field is also planned in partnership with the Swiss Polar Institute and a fire training with EPFL (necessary to access la Dole).

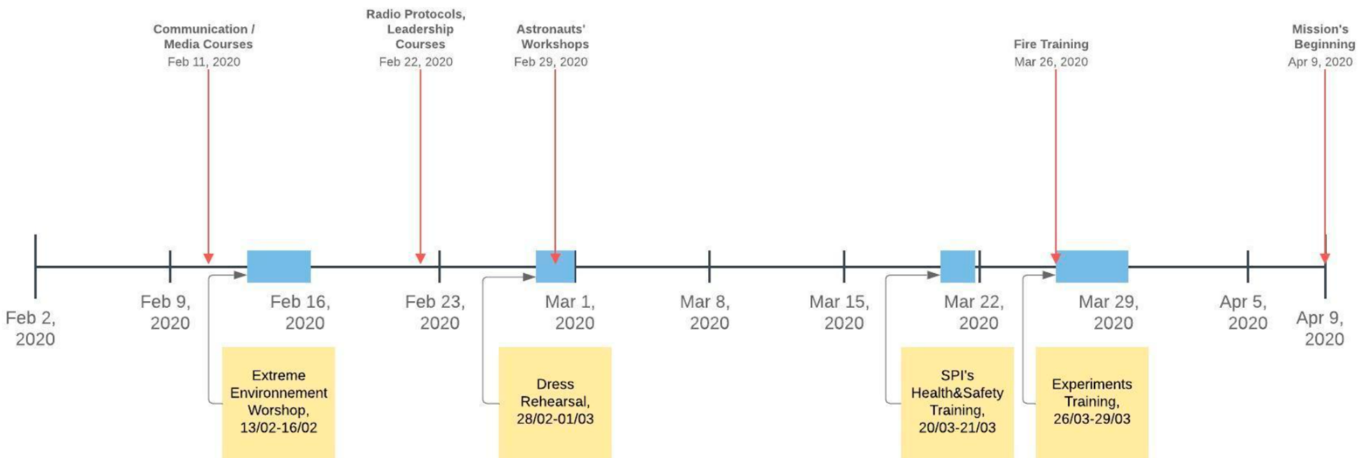


Figure 8.5.1: *Timeline of the astronauts' training*

8.5.1 Workshop in extreme environment by Alban Michon

The 13th to 16th of February 2020 were dedicated to an extreme conditions workshop. The astronauts along with Asclepios' leaders lived in a camp near Moubra's lake at Crans Montana, Switzerland. As previously mentioned, the workshop was designed and animated by the French polar explorer Alban Michon and his colleague Pedro. The goal of the workshop was to build a real team cohesion and to work on the stress management in extreme conditions.

8.5.1.1 Day 1: Thursday 13th February

Everybody met at EPFL to take pictures and then made their way to Crans Montana to meet with Alban Michon, his colleague Pedro and the head of "La promotion économique de l'Association des Communes de Crans Montana", Rafal Hys. Then it was time to start the building of the camp. The camp was swiftly built and well equipped with both small tents to sleep in and two large tents, one to live in and a storage. Team building started quickly by working together effectively. Alban then explained the base camp way of life so that everybody participated to the group's efforts. The meals shared were dehydrated food that Alban usually brings when he goes in a polar expedition.

Figure 8.5.2: *Camping at night in Crans-Montana*

8.5.1.2 Day 2: Friday 14th February

Figure 8.5.3: *Diving under the ice at night in Crans-Montana*

The first night was harsh due to a snowstorm blowing the whole night, covering the tents in snow. Tasks were allocated to everyone: thermos filling with water, weather measurements, physiological measurements, camp management. The morning was spent either performing physiological tests or preparing the flagship activity of the workshop. Those tests aimed to assess the fatigue felt by the explorers and would be extremely interesting on the long term. As the main activity of the workshop has been ice diving under the frozen Moubra's lake part of the crew went to the lake and start digging holes in the ice. Medias arrived and astronauts began giving their first interviews then dove in dry suits into the frozen lake. At night, ice diving proved to be even more magical. Switching off all lights was a very meditative and extremely beautiful experiences. It was -0.6

degrees Celsius in the evening after diving. Alban presented some of his expeditions, a wonderful time of touching and inspiring story telling.

8.5.1.3 Day 3: Saturday 15th February

After the second night, it was 4 degrees Celsius at 7h30 when the camp woke up to start the day. The group was given instructions to compete in two teams, for the building of igloos and collection of water without using lighters, gas, nearby houses. More people went diving in the morning and evening and the shelter/water competition started. Everybody then attended 3 activities. The first was a blindfolded walk in the forest, tied to a rope. It aimed at working on how to communicate, as only one person wasn't blindfolded and able to give instructions.

The second one was playing a game of holding a barrel on top of a makeshift crevasse. Two people, one per side of the crevasse, were progressively walking away from each other while holding the barrel. Once again, communication, team strategy and slow movements were crucial. The third activity was to dive in the water of the lake in swimming costume, not in diving suit, in order to work on stress management and breathing.

8.5.1.4 Day 4: Sunday 16th February

Most of the group slept much better during the last night, probably due to exhaustion creeping in and better planning on how to warm up. The morning was spent debriefing with the following five questions:

1) What did you like the most?

2) What did you like the least?

3) What lesson do you take out from this experience?

4) Would you go on an expedition?

5) With whom in this team would you go?

The group then had to progressively unpack the camp, while families were showing up for the open day visits, asking questions. The igloos were also criticized by Alban, who said that neither igloo was perfect. Both missed a cold air pocket, which should be at least 50 to 60 cm deep and 30 cm in diameter. One of the igloos was also too narrow, while the other could have been dangerous due to small branches sticking out. It was apparently comfortable enough to sleep in according to Manuela and Christian, which both spent the night in it. About 2.5 L and 4 L of water were produced by the teams. The main techniques tried were body warm and kinetic energy, although techniques such as sun reflection or using the lake's heat were tried.

In the end, it has been a truly bonding and unforgettable experience for everyone. The main thing that came out was that everybody trusted everyone to carry on with their job the best they could.

8.5.2 Theoretical courses

A set of courses has been designed to give a common ground to all the crew with the objective to learn basics in key topics for space missions. The crew already followed 3 courses and will have to go through at least one more.

The first one was a course given by head of MCC Chloé Carrière on communication. It aimed at giving advices, do's and don'ts on how to communicate with the medias and with the public, depending on what type of audience you face (children, teenagers, adults etc...). This course was given as soon as possible when the training started so that the crew was prepared for the forthcoming meetings with the public and press.

Before the Dress-Rehearsal, the crew and MCC assisted to two very important courses given by Theodore Bellwald focusing on the different types of leaderships and on standardized radio protocols. The leadership course was an insight on the advantage and inconvenient of the different types of leaderships (delegating, supporting, coaching, directing ...) and on how to give orders in order to keep a good group cohesion during the mission. The radio protocol course was designed to give everybody a clear protocol to follow to ease MCC/Base and Base/EVAs communications.

A course on group dynamics has yet to be organized in order to give the crew some knowledge of the behaviors and psychological processes occurring within a group.

8.5.3 Diet and workout

The astronauts started their one-month diet and workout prior to the mission on March 10th. They followed the program described in Section 6.3.5 and 6.3.9.

8.5.4 Astronauts' workshops

Each astronaut designed a workshop to be given to the rest of the crew during the Dress-Rehearsal. The goal was to make them share useful knowledge, learn how to communicate and strengthen the team cohesion.

Sebasthian came up with a Russian workshop. The objective was to give the crew a first contact with the Cyrillic alphabet and its pronunciation and to give knowledge of phrases to have a basic conversation.

Julien gave an introductory course on cryptography so that the crew learns about cryptography and the fundamental tools of cryptanalysis. It helped building an intuition about the different tools that can be used against an intercepted encrypted message.

Eleonore organized a "Wellbeing and communication" workshop so that everybody in the crew expresses about how they react to stress with the goal of helping to prevent escalation of tensions during the mission.

Manuela and Willem talked about their passion for mountain through a “Mountain and Survival skills” workshop. The objective was to make the crew able to plan a mountain expedition properly, to teach them the usage of basic tools and equipment used in mountain sports and to give tricks and techniques used for mountain rescue and survival.

Finally, Sophie discussed about the different methods for living a more sustainable life and gave information about the impacts of different everyday actions.

Figure 8.5.3: *Russian workshop given by Sebasthian*

Figure 8.5.4: *Survival workshop given by Manuela and Willem*

8.6 Flight Plan and procedures

Another role of Mission Control Center was to write and coordinate the Flight Plan and the procedures during the mission. It is necessary to have a thorough standardization to avid wasting time during the field tests. The Dress Rehearsal was used to test the way we do Flight Plans and the procedures.

8.6.1 Flight Planning

We used Microsoft Office Excel to make the timetable of the astronauts and chose to divide time into 30-minute blocks.

The first step was to establish the sleeping time and to take note of mealtimes. For our first mission, we thought astronauts would sleep approximately 8 hours per day and eat 4 times per day. We adapted the duration of meals according to the quantity to eat.

The second step was to find a half hour for the briefing and debriefing. We tried to keep a global rhythm for the astronauts through the mission.

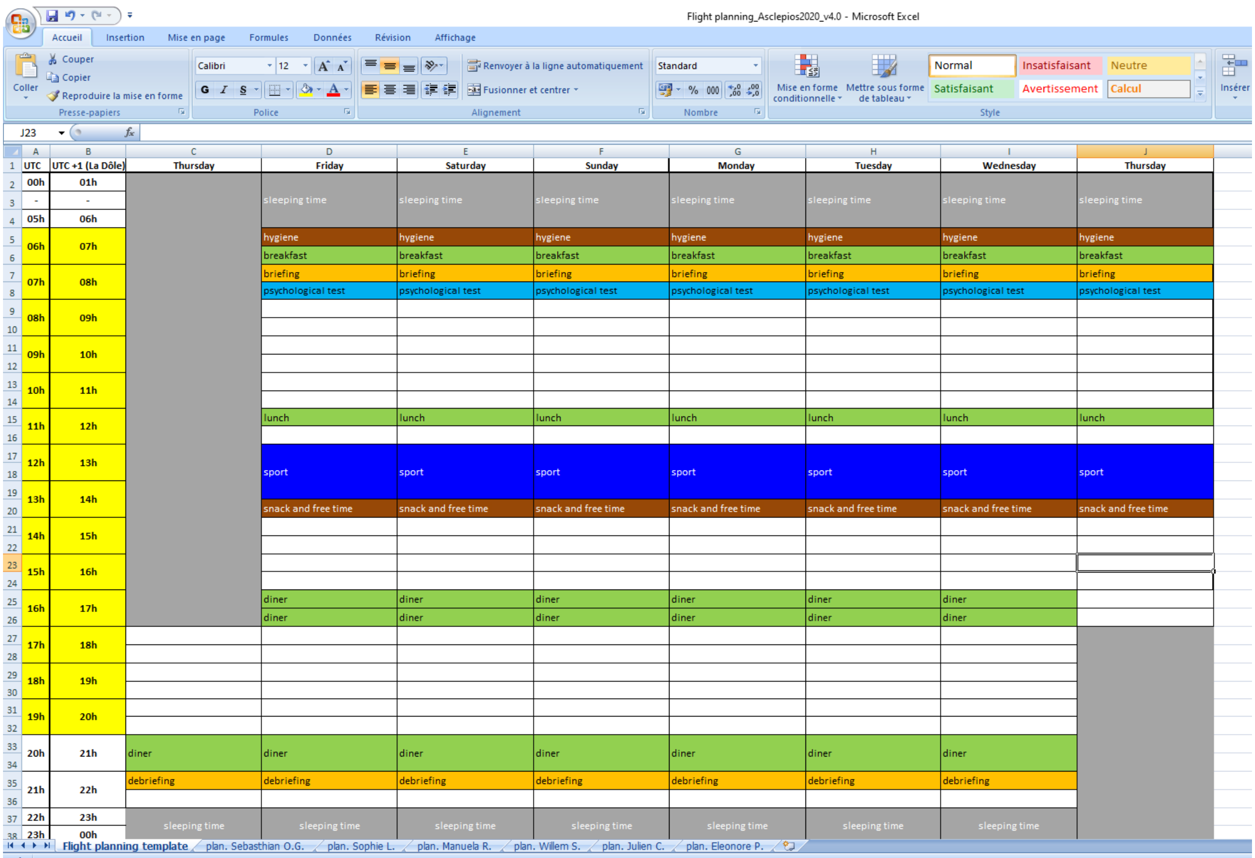
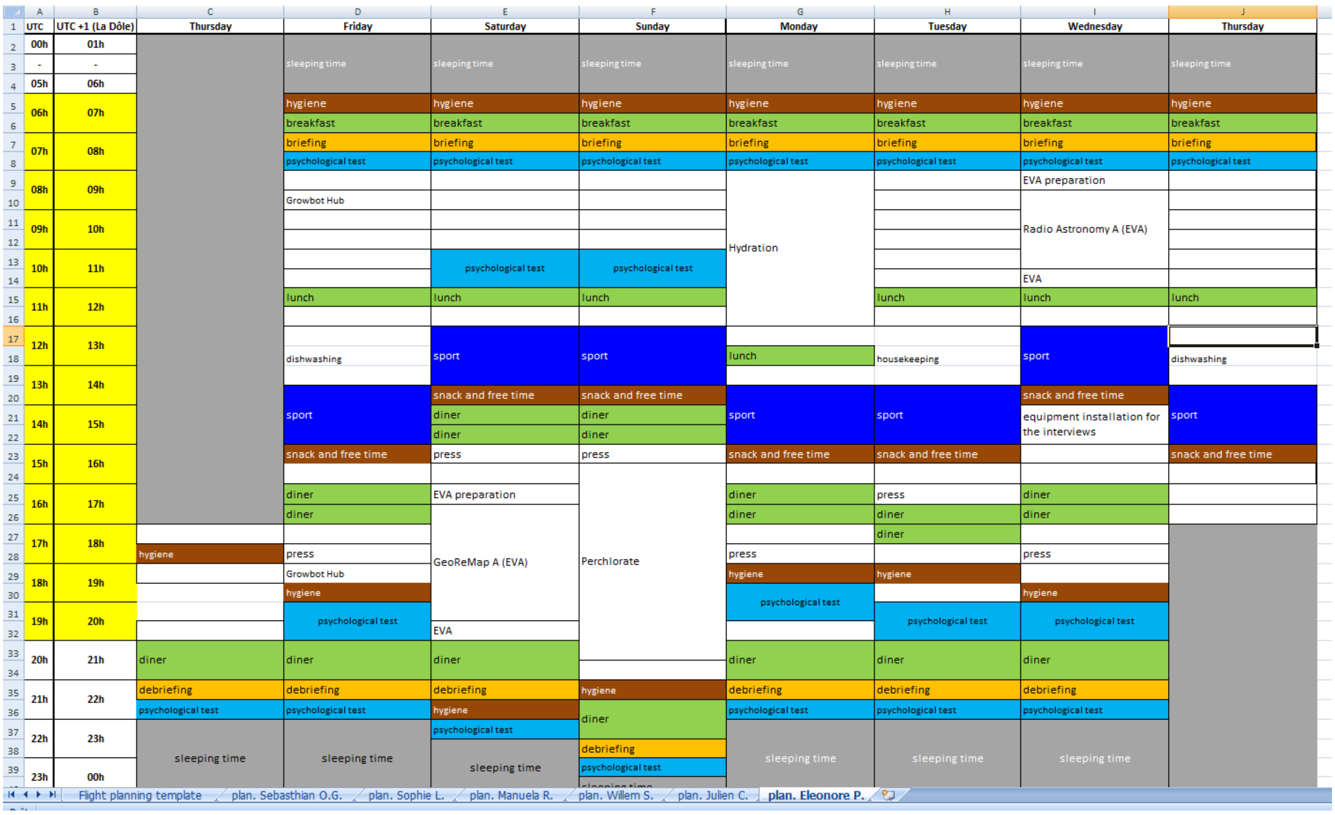


Figure 8.6.1: *Template of the mission's Flight Plan*

Then, we considered all the experiments and scheduled the EVAs at the evening (after 6 pm) or very early to avoid tourists. Generally, we managed to keep between 30 minutes and a quarter of hour between most of the tasks if ever astronauts were delayed. At this time, we divided astronauts into 2 groups of 3 people each day for sport because we hadn't the equipment for all of them to train at the same period. In addition, some experiments should have been done by several astronauts (at the same time), and we had to consider the time astronauts take to change clothes for EVAs. That's why we first reserved time for group experiments.

Afterwards, we introduced some time for press. We had a restrained time slot between 4 pm and 6pm 30. Consequently, afternoons and evenings should have been really busy. Two different astronauts should have tested the material for the interviews every day. If some time remained, we could have scheduled a group interview.

Finally, we put time apart for housekeeping (some minutes for 1 person per day) and hygiene every morning and evening. Some time had to be reserved for installation and tidying up at the beginning and the end of the mission. The last step, was to give free time to the astronauts.



	A	B	C	D	E	F	G	H	I	J
1	UTC	UTC +1 (La Dôle)	Thursday	Friday	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday
2	00h	01h								
3	-	-		sleeping time	sleeping time	sleeping time	sleeping time	sleeping time	sleeping time	sleeping time
4	05h	06h								
5	06h	07h		hygiene	hygiene	hygiene	hygiene	hygiene	hygiene	hygiene
6				breakfast	breakfast	breakfast	breakfast	breakfast	breakfast	breakfast
7	07h	08h		briefing	briefing	briefing	briefing	briefing	briefing	briefing
8				psychological test	psychological test	psychological test	psychological test	psychological test	psychological test	psychological test
9	08h	09h							EVA preparation	
10				Growbot Hub						
11	09h	10h							Radio Astronomy A (EVA)	
12							Hydration			
13	10h	11h			psychological test	psychological test				
14									EVA	
15	11h	12h		lunch	lunch	lunch		lunch	lunch	lunch
16										
17	12h	13h								
18				dishwashing	sport	sport	lunch	housekeeping	sport	dishwashing
19	13h	14h								
20					snack and free time	snack and free time			snack and free time	
21	14h	15h		sport	diner	diner	sport	sport	equipment installation for the interviews	sport
22					diner	diner				
23	15h	16h		snack and free time	press	press	snack and free time	snack and free time		snack and free time
24										
25	16h	17h		diner	EVA preparation		diner	press	diner	
26				diner			diner	diner	diner	
27	17h	18h						diner		
28			hygiene	press	GeoReMap A (EVA)	Perchlorate	press		press	
29	18h	19h		Growbot Hub			hygiene	hygiene		
30				hygiene			psychological test		hygiene	
31	19h	20h		psychological test				psychological test	psychological test	
32					EVA					
33	20h	21h	diner	diner	diner		diner	diner	diner	
34										
35	21h	22h	debriefing	debriefing	debriefing	hygiene	debriefing	debriefing	debriefing	
36			psychological test	psychological test	hygiene	diner	psychological test	psychological test	psychological test	
37	22h	23h			psychological test					
38			sleeping time	sleeping time		debriefing	sleeping time	sleeping time	sleeping time	
39	23h	00h			sleeping time	psychological test				

Figure 8.6.2: *Example of a Flight Plan for Astronaut Poli*

8.6.2 Procedures

Procedures are classified between the three work packages: Mission Control (Green), Design (Blue) and Experiments (Red). They are called Standard Operating Procedures (SOPs). The document begins with a specific number for the SOP and the number of revisions. The implementation date, review date and author are also indicated.

The content is described below:

- Purpose
- Scope
- Prerequisites
- Responsibilities
- Procedure
- References
- Definitions

Each part of the mission must be thoroughly described in these SOPs. The SOPs are present in the base and in the Mission Control Center. An example of a procedure used in the Dress Rehearsal is visible in Annex. Each work package has the responsibility of writing its own procedures and the astronauts must know the procedures almost by heart in order to save time during the mission.

	Asclepios **Asclepios 1 – Dress Rehearsal**	**SOP #**	101
		Revision #	1
		Implementation Date	26.02.2020
Page #	3 of 1	**Last Reviewed/Update Date**	27.02.2020
Workpackage	Mission Control	**Author**	Chloé Carrière

Figure 8.6.3: *Heading of a Mission Control SOP*

9 Communication & Media

The communication branch of the Asclepios project serves two purposes. Primarily, it is a tool used to recruit new members for the project's staff as well as attract the applications of astronaut candidates. Secondly, it carries the task of encouraging the wider public to learn about the space domain which is one of the project's main goals.

9.1 Communication team organisation

The communication of the Asclepios project is be based on two aspects: the mission and its subjects, hereinafter referred to as "astronaut", as well as on the project itself and its teams, hereinafter referred to as "the members". When it comes to the candidates for the position of astronaut, no name or image of their persons will be used without the prior signature of a consent form in order to guarantee the respect of their rights.

Tasks accomplished by the communication team are the following:

- **Social networks (one to two persons in charge):**
  Responsible for a large part of the project's image and communication outside of it. This position involves journalistic work that can express itself in all its usual forms such as written, audio or image.
  - Facebook
    - Broadcasting interviews with project members, researchers, astronauts
    - Report on the work of the project teams
    - Report on the history of the project
  - Twitter
    - Sharing facts about the project
    - Distribution of images of the project
    - Information on the status of the project
  - Instagram
    - Distribution of images of the project

- **Events (one person in charge):**
  Responsible for researching events related to the domains affected by project Asclepios. He makes sure to expose possible partners to the project. He must communicate with the sponsoring/finance team in order to have access to sponsorship proposals at events.
  - Search for events where the project could be presented
    - obtaining a presence at the said event (example: a stand, a display, the presence of communicators)

- Preparation of the necessary tools for the presence (example: roll-up for stand, communication with the project's *gear* manager)
- Preparation of a file with the sponsoring/finance team to present to potential partners during events.

- **Gears (one person in charge):**
  To carry out his task, the gear manager is in close communication with the graphic designer of the project and must contact suppliers able to produce the objects.
  - Creation of goodies in the colours of the Asclepios project
    - pens
    - badges
    - stickers
    - various accessories
  - Creation of clothing for the project staff and for the mission control centre

- **Communication with the press (one person in charge):**
  In charge of media relations in order to take advantage of their audience and so that they can communicate with the public.
  - Realisation of the press-kit, a page summarizing the main part of the project in order to give a sufficient overview to interest and popularize to the media the concept of Asclepios.
  - Contact the media to present the project and obtain their interest
  - Correspondence with the media, and transmission of dates or information that could lead to their involvement

- **Webmaster (one person in charge):**
  Using the tools at his disposal, the webmaster can manage the site without programming knowledge and thus take care of the information platform for candidates and the public.
  - Update of project information posted on the website
    - Advances of the project's teams
    - Dates of the events
    - Mission Partners
  - Make changes to the site organization according to immediate needs

9.2 Website

The Asclepios project has its own website: http://asclepios.ch/. This serves as a platform for information and visibility.

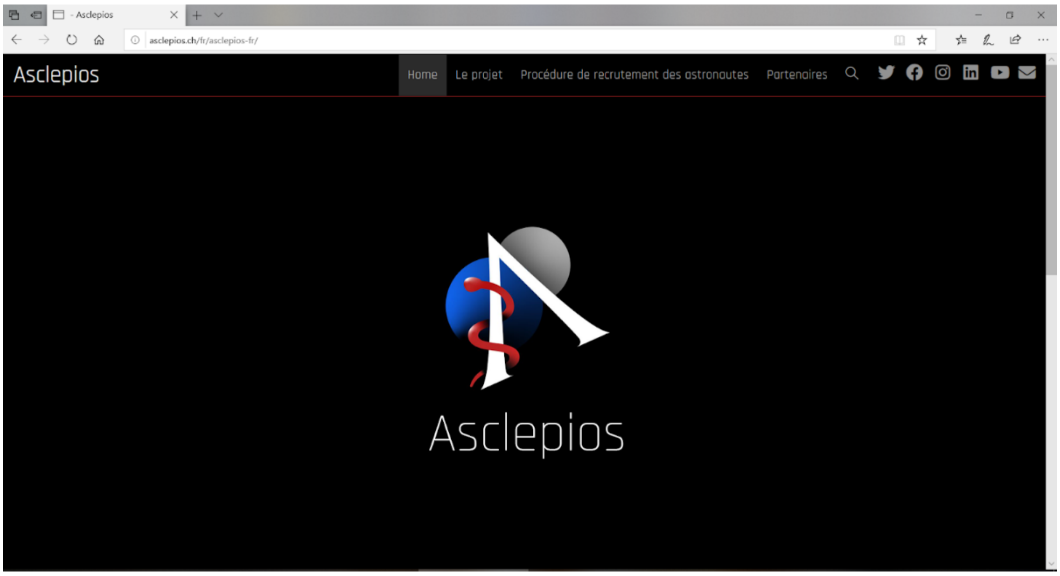


Figure 9.2.1. *Website view*

For candidates for the position of astronaut, it contains the information facilitating applications.

Figure 9.2.2. *Website view*

For the general public, it presents the Asclepios mission and its scope. It also serves as a showcase for the project partners, demonstrating the commitment of the project and the trust it has earned.

9.3 External Communication

For the sake of organisation, the following section will follow the following structure:

- **Item:**
  Description
  - Option 1
    - sub option 1

9.3.1 During the mission

- **Morning announcement of the day's activities:**
  In order to provide information on the daily lives of residents of a lunar base, the format of daily publication of activities necessary for the life of a base or requested by the organisms setting up such structures seems very much on point and particularly telling.
  - On the social networks of the Asclepios project
    - Dissemination of the experiments planned for the day
    - Dissemination of the specific activities planned for the day (example: off-base trip)
  - In traditional media, whether online or on paper
    - Dissemination of the experiments planned for the day
    - Dissemination of the specific activities planned for the day (example: off-base trip)

- **Interview with astronauts:**
  Having the opportunity to broadcast the words of an individual living under pseudo-spatial condition would be particularly telling for the wider public because of its authenticity. This would cement the seriousness of the project and the spatial endeavour in general in the viewer's mind.
  - By the Asclepios project communication teams for dissemination on the project networks and communication to the invited media with:
    - A video conference whose images could be broadcasted
    - An audio recording that can be broadcasted
    - A transcript of the exchange whose sentences could be broadcasted
  - By the invited media with broadcasting according to the modalities they would have chosen. The interview takes the following form:
    - A video conference whose images could be broadcasted
    - An audio recording that can be broadcasted
    - A transcript of the exchange whose sentences could be broadcasted

N.B: The present and future well-being of astronauts being the first concern of the Asclepios project teams, retaining only the first option would ensure that communication of the project would not harm any of the astronauts.

- **Interviews with members of the mission control centre:**
  Ground staff being a key component of a successful space mission, the promotion of this experience is just as necessary as the flight one. However, since the members did not sign a consent form, those wishing to be interviewed must submit to it.
  - By the communication teams of the Asclepios project followed by a diffusion:
    - on the social networks of the Asclepios project
    - in traditional media, whether online or on paper
  - By the media invited by the communication teams of the Asclepios project followed by a broadcast according to the modality of these media.

- **"Outreach day."**
  The outreach day would be a day before the simulation when individuals could come up in the base and interact with the astronaut in the environment that will be their base in order to present the experience in a "palpable" way. Astronauts being trained communicators, they would have been trained for this kind of occasion. The visit to the mission control centre would also provide an opportunity to discover this unknown world and potentially test communications between the base and the centre.
  - Visit of the base
    - Media, in order to show them the conditions of the mission like the base and allow them to take more meaningful photographs for the public
    - Sponsors, in order to show the use that has been made of the resources provided
    - Schools, as part of a field trip to introduce the subject to a young audience that could be inspired by the field
  - Visit to the mission control centre
    - Media, in order to show them the conditions of the mission like the control centre and allow them to take more meaningful photographs for the public
    - Sponsors, in order to show the use that has been made of the resources provided
    - Schools, as part of a field trip to introduce the subject to a young audience that could be inspired by the field
  - Experiments:
    - Carrying out an experiment similar to that of the mission. It would be an entertaining and meaningful opportunity.
    - Testing the communication methods between the control centre and the base

9.3.2 After the mission

- **Interview with astronauts:**
  In order to establish a feedback for the public, these final interviews would give the opportunity to conduct a before/after interview and give a voice to people with a great deal of experience resembling the future of the candidates selected for the position of astronaut, the real one.

  - By the communication teams of the Asclepios project followed by a diffusion:
    - on the social networks of the Asclepios project
    - in traditional media, whether online or on paper
  - By the media invited by the communication teams of the Asclepios project followed by a broadcast according to the modality of these media.

- **Distribution of photographs of the mission:**
  Photographs being a powerful vector of information and emotions, they would clarify the reality of the Asclepios project.

  - On the social networks of the Asclepios project
    - From the daily life of astronauts
    - Experiments carried out and their experimenters
    - Exceptional activities on the base
    - Mission control centre teams during their daily work
    - Mission Control Centre teams during exceptional situations
  - In traditional media, whether online or on paper
    - From the daily life of astronauts
    - Experiments carried out and their experimenters
    - Exceptional activities on the base
    - Mission control centre teams during their daily work
    - Mission Control Centre teams during exceptional situations

- **After-movie:**
  The after-movie is a film about the edition of Asclepios that has just been concluded. It is as much a promotional tool as a reward for members, tracking the work done as well as the project highlights. It allows everyone to review their work and its consequences but also the work of the other teams.

  - Making a film in the "making of" format
    - Including interviews
    - Including images of the simulation (centre and base)
    - Including public presentations
    - Including images of team meetings
  - Distribution on social networks of the Asclepios project

9.4 Communication examples

As part of the communication plan of the Asclepios project, the communication team got to follow the project's advancement which include the following production, showed here as relevant example of the application of the principles laid above.

9.4.1 Coverage of the extreme environment workshop at Crans-Montana

As part of the astronauts' training, the polar explorer Alban Michon gave a four days workshop where the astronauts were tasked with sleeping under tents in the snowy environment of Crans-Montana, diving under the ice by day and night as well as the general handling of their base camp. The communication team's involvement in this endeavour was to handle the overall press coverage of the event as well as the recording of footage meant to serve in the after movie and future communication material.

To offer the widest possible cover of the project's activity, the communication team contacted several scientific media and worked with the project's sponsor for this event, the economic promotion service of the Crans-Montana towns association which issued a press communiqué. Overall, over fifteen different media outlets wrote about the event as documented on the project's website.

Figure 9.4.1: *RTS's 19h30 in Switzerland*

9.4.2 Project members' interviews

As per its aim to offer glimpses of space science and every aspect of a space centric project. The communication team began producing and broadcasting interviews of the project's members starting with the founders Marcelin Feasson and Chloé Carrière. They were met with great enthusiasm on the project's social medias, toping most of the regular project post in terms of views and public interactions. They offer both technicality and a brief history of the project ranging from its origin to its most recent developments.

Figure 9.4.2: *Marcellin Feasson's interview*

Beyond the usual transmission of information that those videos engage in, they also allow the public to see the faces behind the actions. The project is as much about organizing an analogue space mission as allowing its members to learn. The interviews do justice to a somewhat invisible aspect of the projects: the little hands making it a reality.

10 Dress Rehearsal

The Dress Rehearsal took place on the EPFL Campus between February 28 and March 1, 2020. The goals of the Dress Rehearsal were to test the procedures and some of the design choices for the mission in April, but also to learn our weaknesses and aim to fix them. It was a great way to train the Mission Control and our astronauts for behaviours in the base and in MCC too. We could observe and confirm crew's working dynamics.

The base was located into the local PPB 918, which is quite isolated on campus with a low frequentation area (especially during weekends). MCC was located in CM in an exercise room, about 200 meters away from the base. The proximity reduced logistics costs and allowed to have a better efficiency. The base has a surface of 80 m^2 with access to drinkable water and toilets. Astronauts slept on inflatable mattresses.

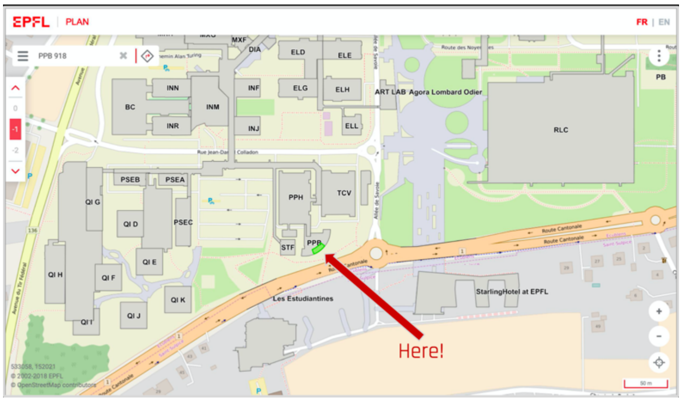


Figure 10.1: *Map of EPFL Campus*

Figure 10.2: *Photo of the Base for the Dress Rehearsal*

- Concerning the Design work package, the following things were tested: water quantities, communications, hygiene and procedures (videos, wakeup music, etc.).
- Concerning the Experiment work package, the following things were tested: the radio-astro experiment and procedure and the workout.
- Concerning the Mission Control Center work package, the following things were tested: roles in MCC, shifts, Flight Plan, procedures for briefing, debriefing, behavior inside MCC.

The shifts within MCC were the following:

Tasks	6h-14h (Purple Team)	14h-22h (Green Team)	22h-6h
FD	Marcellin Feasson	Chloé Carrière	Contact: Marcellin & Elfie
CAPCOM	Aubin Antonsanti	Christian Cardinaux	
PR/FP	Louis Kunz	Matthieu Leydier	
EXP/RC	Elfie Roy	Sonali Mayani	

Léonard Freyssinet was also present from 9AM until 5PM as Contact.

FLIGHTPLAN

DRESS REHEARSAL

BEGINNING 7:00

INTERVAL 60 (minutes)

HEURE	Friday	Saturday	Sunday
7:00		Breakfast	Breakfast
8:00		BRIEFING	BRIEFING
9:00		WATER PROT	WATER PROT
10:00		Survival WS	Russian 101
11:00		Survival WS	Russian 101
12:00		Lunch	Lunch
13:00			Crypto WS
14:00		RADIO ASTRO	Crypto WS
15:00			SPORT
16:00	SET UP	Well-being WS	SPORT
17:00		COMM PROT	Sustainability WS
18:00	LAUNCH	SPORT	RETURN To Earth

Figure 10.3: *Example of an astronaut's Flight Plan*

The Flight Plan was made using excel with one-hour-increments. The astronauts woke up at 7AM and went to bed at 10PM. The lunch is planned at noon and dinner at 8PM. Each day there is a briefing right after breakfast to make sure the astronauts can see what the planning of the day looks like. Before dinner at 7PM, a debriefing takes place to update the next day's flight plan and check on the astronauts' state of mind. The rest of the day is divided between experiments, astronauts' workshops and workouts.

To communicate with astronauts, MCC had several channels:

- First channel was through TeamSpeak (also used for communication between the members of MCC). Only Capcom could speak directly to the astronauts, but everybody could hear them.
- Second channel was a monitoring camera, but it was not always active (battery issues).
- Third channel was through walkie-talkies in case contact through TeamSpeak was lost.
- Finally, slack was used as a last resort in case of loss of communication, but also for video briefings.

The Asclepios google drive was used as a way to communicate files such as planning and resources sheets from MCC and videos and photos from astronauts.

The briefings and debriefings between the two teams took place in the following way:

"The next steps must be followed to guarantee an efficient (de)briefing:

1. *Members present to the meeting shall be presented.*
2. *State location and time on both sides.*
3. *Presentation of the Agenda of the meeting.*
4. *Feedbacks on the last night or day (positive and negative points).*
5. *Recommendations for next day.*
6. *Flight Plan presentation for the day / evening.*
7. *Validation process.*
8. *Specific reclamations.*
9. *End of meeting, greetings (good news for moral).*

RECORDS shall take notes for future mission reports. CAPCOM shall be the only MCC member talking directly to the crew. The agenda might change due to unforeseen circumstances. Each (de)briefing must be prepared by MCC half an hour before the planned time."

All the material in the base was classified into an index so it would be easy to make a checklist every day. For instance, the equipment for the Radio-Astro experiment was indexed as RAX, kitchen equipment as KIX and sport equipment as SPX. The astronauts were allowed to take personal belongings that fit into a bag pack and a guitar as a special case. The phones were turned off and computers were used only for the workshops.

Figure 10.4: *Photo of Mission Control Center*

Figure 10.5: *Photo of the astronauts in the base*

In terms of media, the dress rehearsal was held as a private event. A few pictures and short videos were posted on social media and on the website's blog.

The Dress Rehearsal was a critical point for the Asclepios project and many lessons were learned from this experience. Here are a few examples:

- A procedure for the wakeup music is needed;
- Precise and standardized shortcuts for MCC;
- Responsibilities must be given to specific astronauts per day (food, water, dishes, communication);
- A plastic basin could have been good to keep the water from the pasta for instance;
- Having a "water tank" so the astronauts can grasp more easily the amount of water they have consumed and the remaining amount for the day.
- Everything takes much more time that one could think (especially for MCC);
- Procedure to establish link checks in MCC when shifts switch;
- Three people for MCC is not enough;
- Merging Procedures and Flight Plan is not a good option;
- A google sheet for resources budget should be used by the astronauts to control consumption;
- Logbooks should be done each day by astronauts;
- Use Poseidon computers that remain in MCC is better to avoid problems with CAPCOM;
- The camera used was not the best fit (battery always low);
- Buying IP cameras
- Prepare the briefing in advance;
- Plan lunch for MCC;
- Think of toilet time;
- A can opener was missing;
- Amount of water planned was not completely used;
- Find a way to make astronauts more autonomous;
- When Go/No go demands are asked, make sure they've understood the answer.

We believe this step was necessary for the mission to process correctly. Some members of MCC are now trained and the astronauts know each other better.

A general meeting with the rest of team will be organized mid-March and a "Life-size" test in la Dole will be done by the Design team to test communication between la Dole and Chéserex.

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11 Risks Identification and Mitigation

11.1 Single points of Failure

Single points of failures are key aspects of the mission, that if they fail, would lead to the mission's failure. It is therefore essential to have at least two redundancy to mitigate these points. Three Single points of failure have been identified:

1) Location is unavailable
2) Communication failure during the mission
3) Missing Astronaut

To mitigate these aspects the following was put in place:

1) A contract was signed with Skyguide, the organism that owns the location at La Dôle to ensure they will still agree to let us use it in April. A secondary location is available at Chéserex in the Bunker that will be used by the Mission Control Center.
2) A precise protocol for communication between astronaut and mission control was written as well as a protocol to fix minor communication failures. One Astronaut knows all communication systems and can fix them in case of problem. Tests during the Dress Rehearsal and a "life-size" test between La Dôle and Chéserex in March to prepare for potential failures. In case of Urgent communications or severe communication failure, a fixed telephone line is in the skyguide habitat.
3) Two Backup Astronauts have followed the same trainings as the main crew in case one astronaut is sick or has another severe issue during the April mission.

11.2 Other risks

11.2.1 Allocated budget is insufficient

Mitigation: Multiples sponsors instead of one big sponsor. Having multiple income sources ensures the project does not depend on a single person/company's decision. We also have the possibility to adapt Experiments and Design according to the allocated budget. Finally, we have a 30% margin in the allocated budget.

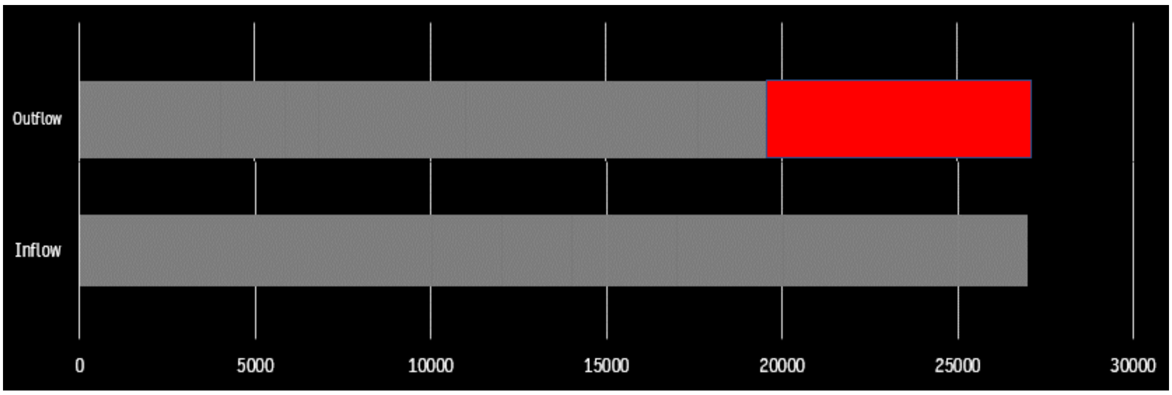


Figure 11.2.1: *Inflow and Outflow with margins (in red) in CHF*

11.2.2 Items are not delivered according to schedule

Mitigation: Margin in schedule for delivery of items that are needed for the mission. Potential other suppliers for critical items. In case one item is knows to be late on the delivery we can order it somewhere else.

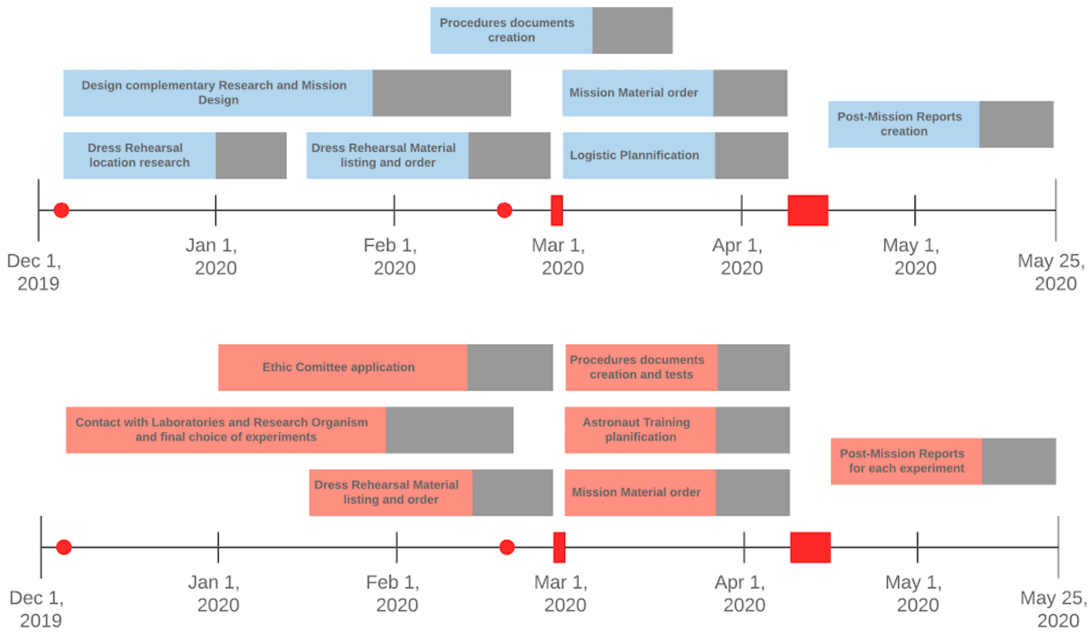


Figure 11.2.2: *Design and Experiment Timeline with margins (grey). PDR,CDR, Dress Rehearsal and Mission in red*

11.2.3 Not everyone can come to assure the MCC

Mitigation: Shifts are organized in advance and include people's availabilities. The number of shifts is limited for each person. Shifts are regular and a minimal rest time is fixed between two shifts. Backup shifts in case someone is not ready for their shift (sick or other reason) another person is already designated as their replacement and is available.

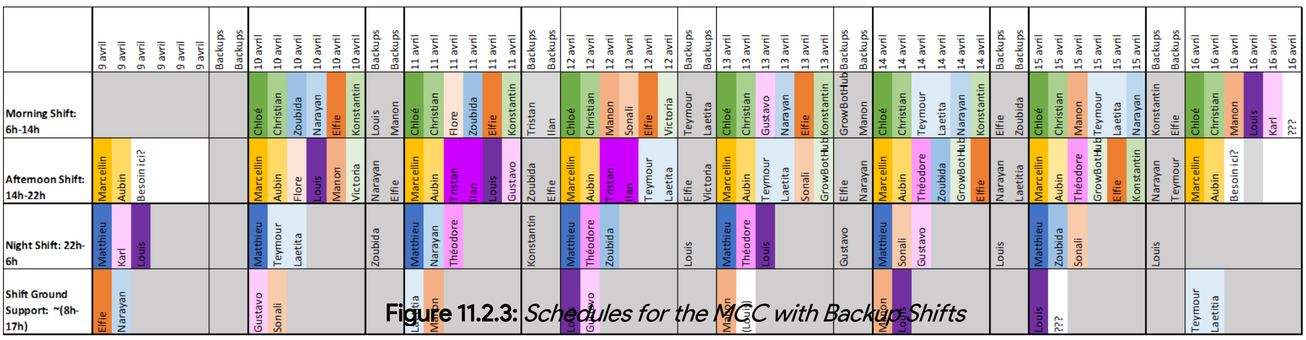


Figure 11.2.3: *Schedules for the MCC with Backup Shifts*

11.2.4 Set up/pack up is not ready according to schedule

Mitigation: Margin in set up and pack up schedules are planned. Outreach days will be shortened if needed.

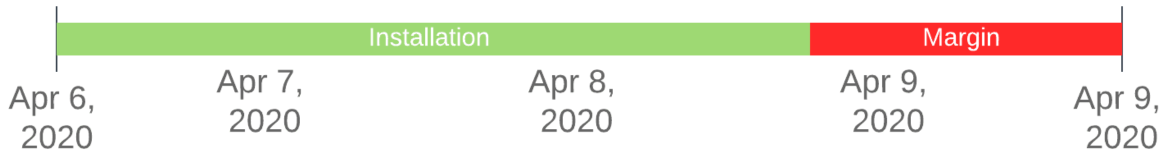


Figure 11.2.4: *Installation Timeline with margin for the April mission*

11.2.5 Ethics committee does not clear all experiments

Mitigation: Only a few experiments necessitate the approval of the ethics committee. The large number of Experiments allow the Mission Science objective to be completed even if some experiments are not cleared by the ethics committee

11.2.6 Isolation compromised during the mission

Mitigation: A procedure of emergency containment of the astronauts is written to ensure that even if the isolation of the base should be broken the isolation of the astronauts (in a smaller room) is maintained. Careful planning of the EVAs (at night, early or late) to avoid human presence that could be near La Dôle. Contact with the next by towns, to try discouraging hiker or skiers to come close to the base during the mission. Constant contact with skyguide to preventthe astronauts from seeingskyguide employees that might have to be around the base.

11.2.7 Equipment is missing

Mitigation: List of material and schedule of material collection is carefully written prior to the mission. The list is reviewed by multiple persons and there is always a possibility to access non-critical material at the last minute (things that can be bought in supermarkets or shops in Lausanne). Most critical equipment will be identified during the dress rehearsal and missing equipment will be added to the list.

1	Requirement	Equipment	Quantity	Cost (CHF)	Subtotal (CHF)	Provider	Notes	Link
2	**Data Connection**							
3	WiFi network, 10 Mbps	WiFi router	1	0	0	La Dôle		
4	Router for restricted subnet	Raspberry Pi kit	1	56	56			https://www.digitec

Figure 11.2.5: *Example of Equipment list needed for the mission*

11.2.8 Transportation problem to the location in La Dôle or Chéserex

Mitigation: Logistics' precise planning will be done in a document accessible to everyone in the team. Private vehicles of member can be used in case of problem. The travel time to the MCC location is only 30 minutes.

11.2.9 Security issues

Mitigation: Two astronauts followed the health and safety training and an emergency fixed phone line is available. The location is also accessible by the Rega. The Base entries are not locked in case of urgent situation astronauts can get out. In the same spirit the crafted wall is easily breakable. The astronauts will follow a first aid and fire training by EPFL. Skyguide's base at La Dôle follows the standard safety requirements.

11.2.10 Light injuries compromising the mission

Mitigation: A first aid kit will be easily accessible to the astronauts. At least two astronauts will or have followed a first aid formation. In case of light sickness, the astronaut schedule can be adapted to let them rest. The Mission control centre will be in contact with a professional of medicine for advice and remote consult.

11.3 Risk Matrix

RISK	PROBABILITY(1-5)	CONSEQUENCES(1-5)	SEVERITY	MITIGATION
Bad weather conditions	4	2	8	Flexible planning
Lost communication between MCC and Astronauts	3	2	6	Back up line, trained astronaut
System failure (heating, electricity)	2	3	6	Testing and working with Skyguide
Material not delivered or problem with Material	3	2	6	Careful planning of material order and second supplier for critical items
Psychological problems	1	5	5	First aid kit and training
Severe physical problems	1	5	5	Urgence procedure to extract Astronaut from simulation
Failure in one of the experiments	4	1	4	Follow procedure for each experiment
Light physical problems	3	1	3	First aid kit and training
Transport of the experiments	1	3	3	Centralisation of logistics

Figure 11.3.1: Mission's Risk Matrix

12 Outcomes

12.1 Expected Results

From the 7-day mission that will occur, we expect to obtain results from the different experiments conducted, to learn from the Mission Control to Astronaut communication (stress, delay, etc.) and to observe results linked to the astronaut's isolation from society. We also expect for the first iteration to teach the Asclepios team lessons useful for improving the next mission.

Asclepios is carefully defining the conditions in which the experiments will be conducted, for laboratories to access meaningful results for future experimentations. Scientific papers are also expected to be published under or in collaboration with Asclepios. A presence in both the general media and scientific publishing will participate in establishing the project's reputation.

Finally, we expect the project to promote space interest in public through the Space@yourService organization, the communication by the project's team and conferences, such as the International Astronautical Congress (IAC).

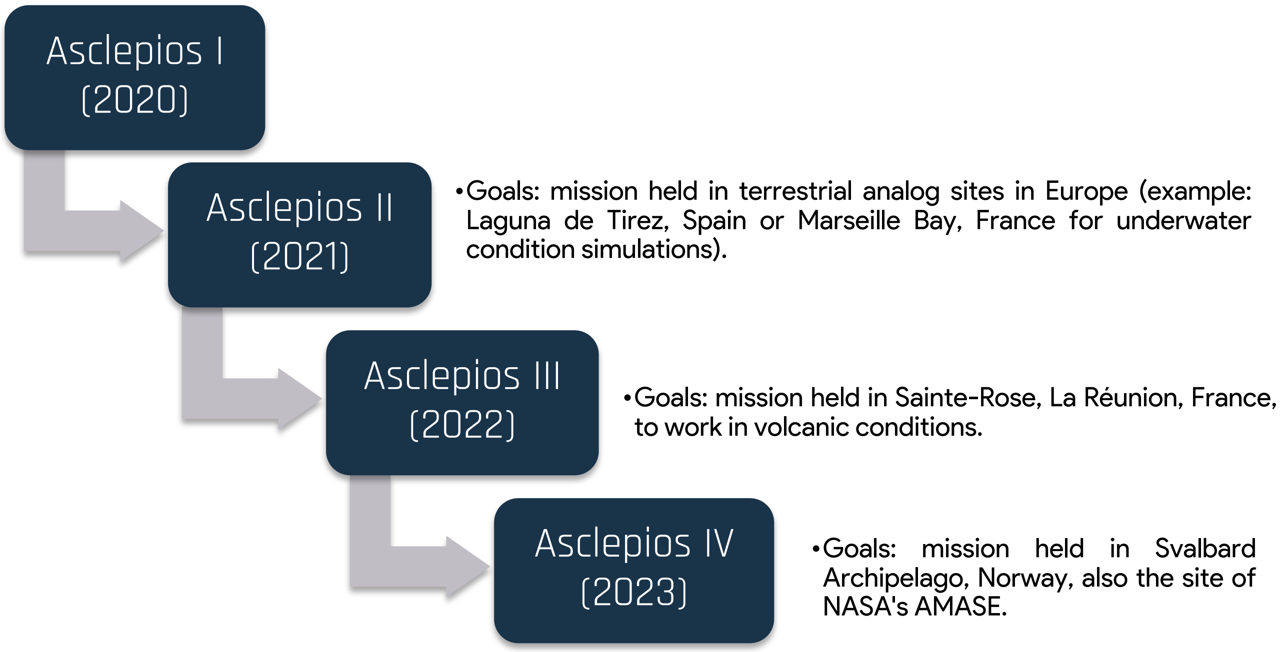
12.2 Educational Outcomes

The project is also expected to have an educational impact. Members will not only learn project management and development skills, but will also work alongside laboratories, start-ups and larger compagnies. Experiment team members might be cited as co-author in scientific papers. Furthermore, ETC Credits will be obtained by some members or other EPFL students using the project as a platform for their Master Thesis, laboratory projects, etc. Students doing a minor in Space technologies might also find an interest in Asclepios, as it is an interdisciplinary project directly related to their field of interest. As for the general public, the project aims to open a discussion on the benefits of analogue missions and trigger space enthusiasm.

Figure 12.2.1: *Project Promotion at EPFL*

12.3 Future missions

Asclepios aims to be a yearly recurring mission. The team expects to learn from the first iteration to develop and adapt experiments, design and logistics for the next missions. Collaboration with other missions (MDRS ISAE-SUPAERO, OeWF, HI-SEAS, etc.) is also an objective the mission could fulfil. Realism will be improved each year in term of location, material, duration, experiments and design.



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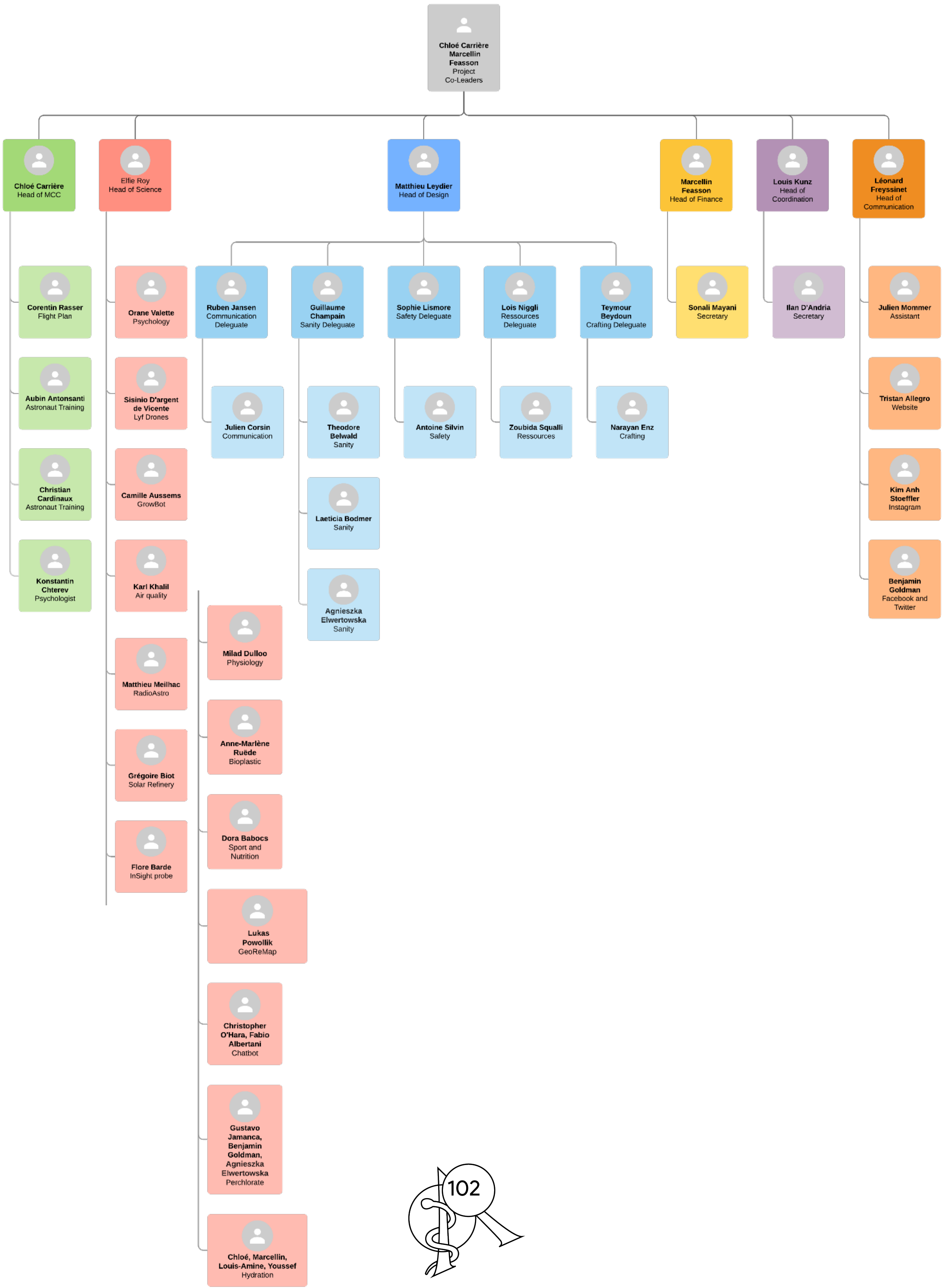
14 Appendix

14.1 Organigram



14.2 GeoReMap Protocol

Training:

The astronaut training will take one day and will consist of three parts:

1. Introduction to alpine geomorphology: alpine landforms, geographical scales.
2. Introduction to mapping methods: remote sensing, field work, required information for creating a map.
3. Practical training for GeoReMap: how to use the instruments, practical simulations.

Pre-Mission Phase:

1. Remote scouting of the area around the base camp, done by Google Earth.
2. Determine the investigation area (landscape scale) and save as satellite image.
3. Import the not-georeferenced satellite image to ArcGIS.
4. Identify landform classes by visible surface properties and topography, name each determined landform.
5. Determine the POI (Points of interest) where the astronauts have to collect the required geographic information. One point for each landform (max. 20 POI's).
6. Determine the VP (Viewpoints) near the border of the investigation area, where the astronauts have to take landscape images (max. 5 VP's).
7. Export the not-georeferenced satellite map.
8. Determine in which order the POI's and VP's have to be investigated during the EVA's.

During-Mission Phase:

- **EVA:**

1. Astronauts prepare themselves for the field work:
    a. Discuss the procedure of EVA.
    b. Check the equipment.
    c. Leave the base camp, note time.
2. Go to investigation area.
3. POI_01:
    a. Use the not-georeferenced satellite map and the GPS handheld tracker to find POI_01.
    b. Go to POI_01.
    c. Check if you are in the right position. If both astronauts agree, go ahead.
    d. Note time of begin POI_01.
    e. Astronaut 1: record coordinates and height, then put GPS handheld tracker on the ground.
    f. Astronaut 2: take surface image, use the GPS handheld tracker as scale.
    g. After data collection: mark POI_01 in the not-georeferenced satellite map as "done" and note the time when you have finished POI_01.
    h. Go ahead.
4. Same procedure for each POI.
5. VP_01:

    a. Use the not-georeferenced satellite map and the GPS handheld tracker to find VP_01.

b. Go to VP_01.
c. Check if you are in the right position. If both astronauts agree, go ahead.
d. Note time of begin VP_01.
e. Astronaut 1: record coordinates and height, use the compass to determine the direction in which the landscape image will be taken.
f. Astronaut 2: take landscape image.
g. After data collection: note in the not-georeferenced satellite map in which direction the landscape image was taken and time when you have finished VP_01.
h. Go ahead.

6. Same procedure for each POI.
7. If time of 2h is over / all data collected: go back to base camp.
8. Note time when arriving the base camp.

- **EVA data processing and evaluation:**

1. Astronaut 1:
    a. Note time of beginning.
    b. Transfer data from GPS handheld tracker to the laptop.
    c. Import data to excel file.
    d. Name each POI and VP, add time of beginning and ending.
    e. Save file as .csv (Comma Separated Values).
    f. Note time of ending.
2. Astronaut 2:
    a. Note time of beginning.
    b. Transfer images from camera to the laptop.
    c. Name each image (for example): surface_poi_01 / landscape_vp_01.
    d. Note time of ending.
3. Evaluation of EVA:
    a. Astronaut 1: fill out the evaluation sheet for EVA.
    b. Astronaut 2: fill out the evaluation sheet for EVA.
    c. Discuss your experiences and write a short report.

- **End of the day:**

1. Create folder: eva01.dataset.
2. Import all collected data of EVA.
3. Create folder: eva01.evaluation.
4. Import evaluation sheets and reports of EVA.

- **End of the mission:**

1. Check if information is complete.
2. Send all data to Mission Control Center.

<u>Post-Mission Phase:</u>

The data processing, map creating, and evaluation of the experiment will be done by the PI in Basel, without having any contact with the astronauts.

1. Reclass landforms by image analysis:

  a. Analyse each surface image.
  b. Describe surface properties.
  c. If possible: measure sizes of stones and particles with ImageJ.
  d. Define new landform classes by similar surface properties.
  e. Add landform classes to point data file.
2. Creating topographic map:
  a. Open not-georeferenced satellite map with ArcGIS.
  b. Turn it georeferenced.
  c. Determine coordinates of marked points.
  d. Import point data file from EVA to ArcGIS.
  e. Show points and compare the locations of marked and measured points.
  f. Create DEM (Digital Elevation Model) by interpolation of height information.
  g. Export 2D-topographic maps.
  h. Go to ArcScene, create 3D-model for EVA.
  i. Export 3D-model.
3. Creating landform map:
  a. Show landform classes of each POI.
  b. Determine the borders of each landform by the landscape images, if possible.
  c. Determine the area of each landform by drawing polygons in ArcGIS.
  d. Export 2D-landform map.
  e. Go to ArcScene, create 3D-model.
  f. Export 3D-landform map.
4. Results:
  a. Compare landform classification of pre-mission phase with the new landform classes.
  b. Analyse the evaluation sheets of the astronauts.
5. Evaluate the impact of wearing a space suit:
  a. How much time did the astronauts exactly need for the field work?
  b. At what points did difficulties arise for the astronauts?

14.3 Consent and Release Form

Without expectation of compensation or other remuneration, now or in the future, I hereby give my consent to Asclepios, its affiliates and agents, to use my image and likeness and/or any interview statements from me in its publications, advertising or other media activities (including the Internet), in relation with the mission. This consent includes, but is not limited to:

1. Permission to interview, film, photograph, tape, or otherwise make a video reproduction of me and/or record my voice;
2. Permission to use my name, in the cases already mentioned above;
3. Permission to use quotes from the interview(s) (or excerpts of such quotes), the film, photograph(s), tape(s) or reproduction(s) of me, and/or recording of my voice, in part or in whole, in its publications, in newspapers, magazines and other print media, on television, radio and electronic media (including the Internet), in theatrical media and/or in mailings for education and awareness.

This consent is given from the 22nd of November 2019 to the 31st August of 2020, for all the events in relation with Asclepios, and does not require prior approval by me.

Name:

____

Address:

____

____

Date:

____

Signature:

____

14.4 NASA Exercise: Ranking Survival Objects for the Moon [25]

14.4.1 NASA Exercise Instructions

(This part is for the examiners, and won't be included in the answer sheet)

Group members should be instructed to rank the objects individually (~10 min) and then in groups (15 min.). In the group part of the exercise, all groups should be instructed to employ the method of group consensus, which requires each group member to agree upon the rankings for each of the 15 survival items before the item becomes a part of the group decision. Instructors should ensure that students interact only within groups and no cross-talking occurs between groups.

After revealing the correct answers and allowing teams to calculate their scores, record the team score and the lowest individual score from each team. Subtract the team score from the individual score; this provides the "synergy" score. Ask the students in the teams with negative synergy scores why they think their team performed as it did. Then ask the teams with positive synergy scores why they think their teams performed well. Listen for evidence of good collaboration in the teams with positive synergy

14.4.2 NASA Exercise Handout

Candidates, you have just crashed on the Moon. With two other crew members, you were supposed to go to the Lunar base. Unfortunately, a technical issue forced you to land 50 kilometers away from the base. The Moon landing damaged the spacecraft and material damages are numerous. You now need to decide what will be vital to reach the Lunar base. Good news: lunar gravity allows you to walk at 5 km/h. Bad news: your space suit's autonomy is limited to only 8 hours.

Here is a list of 15 objects still intact in the spacecraft: which ones will be helpful to reach the lunar base? Classify them by order of importance, the most essential being first, and the most useless at the end.

Step 1: Without communicating with team members, rank each item in order of importance. Place the number 1 by the most important item, the number 2 by the second-most important, and so on through number 15, the least important. Record these in the column labelled "Step 1." You have 10 minutes for this step.

Step 2: Now, as a team, reconsider the items and come up with a new set of rankings. Record these in the column labelled "Step 2." You have 15 minutes for this step.

Step 3: The answer key will be projected in order to compare your answers. Please record them in the column labelled "Step 3" (Expert's Ranking).

Step 4: Take the difference between the answers in "Step1" and "Step3" i.e. the difference between your individual answers and expert's ranking. Place the answers in the column labelled "Step 4". Please include your answer in absolute value.

Step 5: Do the same for the answers in "Step 2" and "Step3".

Items	**Step 1 Your Ranking**	**Step 2 Team Ranking**	**Step 3 Expert's Ranking**	**Step 4 Difference* between Step 1&3**	**Step 5 Difference* between Step 2&3**
- Box of matches					
- Portable GPS receiver					
- 15 meters of Nylon rope					
- Three rescue batteries for space suits					
- Parachute canvas					
- Three rescue bottles for carbon dioxide evacuation for space suits					
- One portion of dehydrated food					
- Three rescue oxygen tanks for space suits					
- Stellar map (of the moon's constellation)					
- Self-inflated survival raft					
- Magnetic compass					
- 20 liters of water (potable thanks to the device in the space suits)					
- Two little mirrors					
- First-aid kit (medical adhesive tape, scissors)					
- Solar-powered receiver-transmitter FM					

TOTALS					
				Individual Score	Team Score

Table 14.4.1: *Candidates' sheet*

14.5 Recruitment Poster

Figure 14.5.1: *Recruitment poster*

14.6 Insurance certificate

la Mobilière

Mobilière Suisse
Société d'assurances SA
Direction Affaires Courtiers
Chemin de la Redoute 54
Case Postale 1333
1260 Nyon 1

Téléphone 022 816 17 60
Téléfax 022 816 17 89
courtier@mobiliere.ch
mobiliere.ch

La Mobilière, Affaires Courtiers, Case Postale 1333, 1260 Nyon 1

EPFL
VPRHO
Station 7
1015 Lausanne

Votre interlocuteur
Emmanuel Pache
Téléphone 022 816 17 655
emmanuel.pache@mobi.ch

Nyon, 07.01.2020

ATTESTATION

Nous soussignés, Mobilière Suisse, direction affaires courtiers, confirmons que l'EPFL, à Lausanne est au bénéfice à compter du 1er janvier 2017, d'une assurance responsabilité civile entreprise, police n° 501 402430.002, fondée sur les dispositions légales en matière de responsabilité civile (risques d'installations, d'exploitation et du fait des produits).

Cette couverture est valable pour des dommages survenant dans le monde entier, y compris les Etats-Unis et le Canada.

La somme de garantie s'élève à CHF 50'000'000.- par événement et par année civile, pour l'ensemble des dommages corporels et matériels.

La franchise s'élève à CHF 100'000,- par événement dommageable, pour les dommages matériels.

Avec cette confirmation, la Mobilière n'a pas l'obligation d'orienter le destinataire de cette attestation des changements du contrat (résiliation de la police, changement de l'étendue de l'assurance, non-paiement des primes, etc.). Cette attestation va à notre preneur d'assurance.

Validité de l'attestation jusqu'au 31.12.2020.

Avec nos meilleures salutations

La Mobilière
Direction Affaires Courtiers

Emmanuel Pache
Responsable courtiers

A. Weissflog
André Weissflog
Spécialiste souscription choses & tech.

Une entreprise de la Mobilière Suisse Société Coopérative

14.7 Psychological Attestation

CONSULTATION
CONSYL&BELLEUX SA
Cabinet de psychiatrie et de psychothérapie

Rue du Midi 2 / 1003 Lausanne
Tél : 021 312 47 60
Fax : 021 312 47 62

Lausanne, le 18 décembre 2019

Attestation

Par la présente, je certifie avoir effectué une évaluation de tous les candidats sélectionnés pour le projet « Mission Asclépios ».

Les évaluations ont eu lieu au sein de ma consultation et tous les candidats ont été vus une fois.

A l'issue de ces entretiens uniques, je ne retiens aucune contre-indication médicale pour la participation des candidats à ce projet.

Dr Nicolas Belleux

Médecin Psychiatre FMH

14.8 Example of SOP

	Asclepios Asclepios 1 – Dress Rehearsal	SOP #	1
		Revision #	1
		Implementation Date	23.02.2020
Page #	1 of 1	Last Reviewed/Update Date	23.02.2020
Workpackage	Design	Author	Louis

Standard Operating Procedure : Template (official Name of procedure)

1. Purpose

Describe the process for <official name of SOP>.

Describe relevant background information.

2. Scope

Identify the intended audience and /or activities where the SOP may be relevant.

3. Prerequisites

Outline information required before proceeding with the listed procedure; for example, worksheets, documents, IFAS reports, etc.

4. Responsibilities

Identify the personnel that have a primary role in the SOP and describe how their responsibilities relate to this SOP. If necessary, include contact information.

5. Procedure

Provide the steps required to perform this procedure (who, what, when, where, why, how). Include a process flowchart.

6. References

List resources that may be useful when performing the procedure; for example, Admin policies, Municipal Code, government standards and other SOPs.

7. Definitions

Identify and define frequently used terms or acronyms. Provide additional and/or relevant information needed to understand this SOP.

Figure 14.8.1: *Example of a SOP for Design*