

NASA MarsXR 2 Challenge

GEOLOGICAL SAMPLING WITH ACCOMPANYING VEHICLE

SUBMISSION: FREDERIC KREUTZER

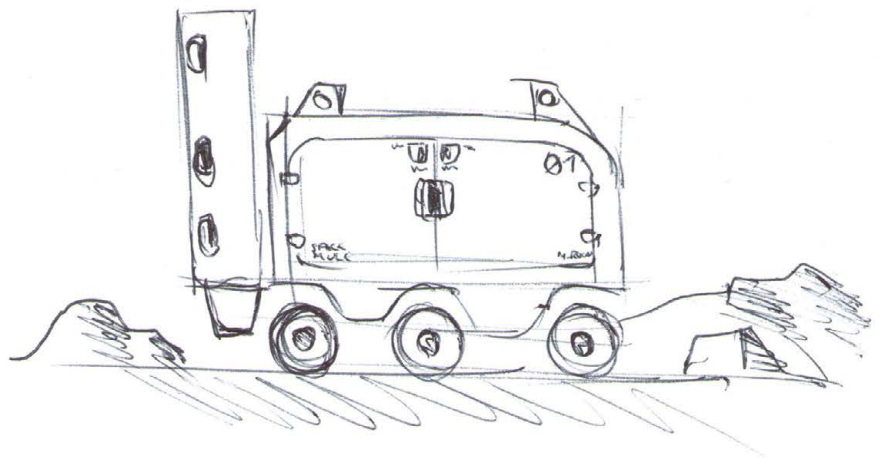
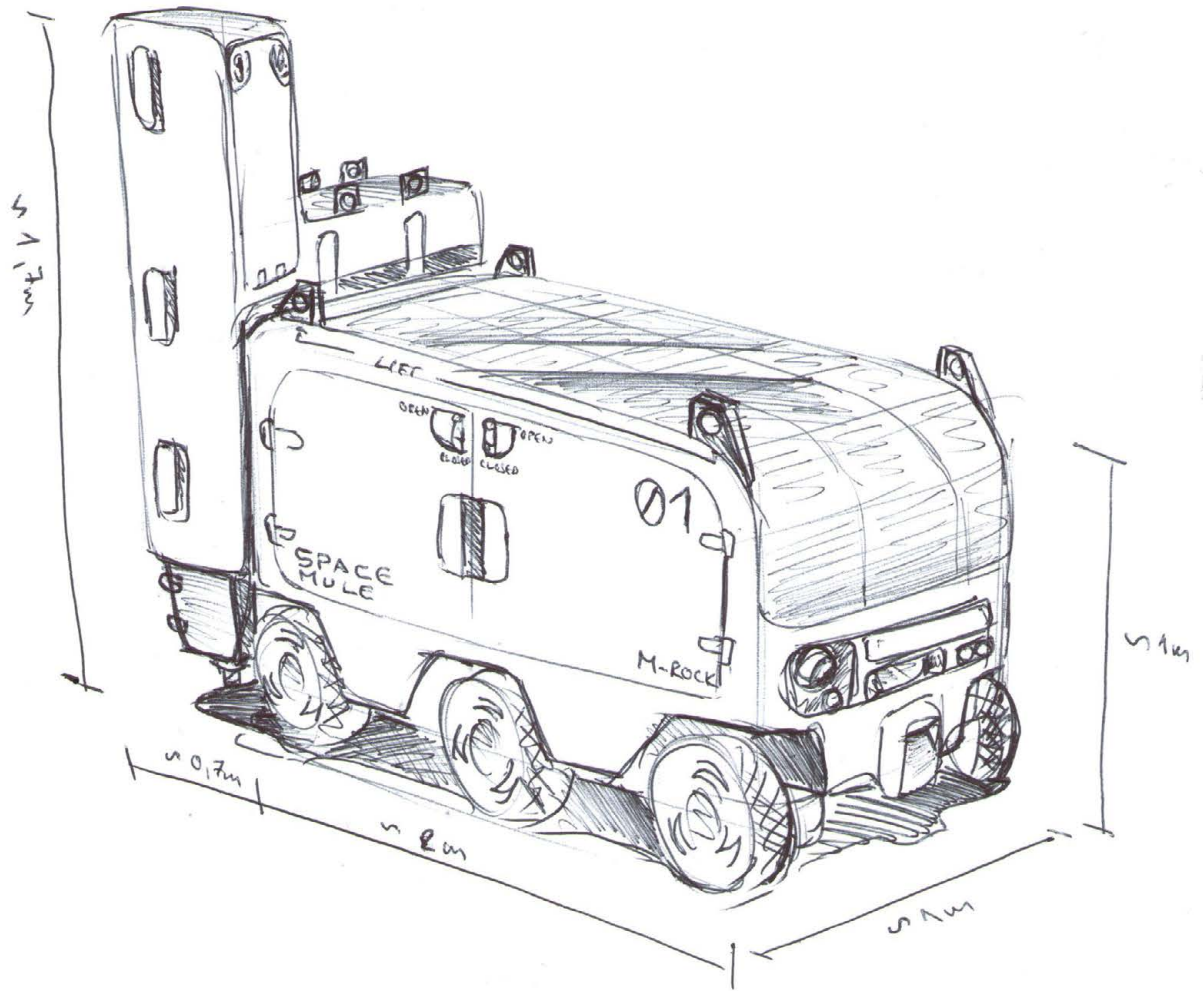
TRAINING SCENARIOS / TRAINABLE AND EVALUABLE VR-MISSIONS

MISSION 1 | GEOLOGICAL SAMPLING, PREPARATION, EXECUTION & SAMPLE PROCESSING.
(Investigation of the Martian rock for its geological properties & investigation of the borehole by means of a probe)

MISSION SUMMARY

The mission aims to geologically investigate an area in a grid-like manner. In this example a 25 sample grid with 5m drilling intervals is realized at a POI, so that an area of 625m² will be examined.

The mission is divided into three parts. In the first part, the mission is prepared and an accompanying vehicle is loaded and checked for its operational capability. The second step involves going to the POI along with the accompanying vehicle, preparing and carrying out the sampling. In the third step, we enter an airlock together with the accompanying vehicle, decontaminate ourselves, the accompanying vehicle and our equipment. Then we re-enter the geological laboratory where our mission started and perform the sample retrieval and pre-evaluation of the samples.



MISSION 1.1 | MISSION PREPARATION - GEOLOGICAL SAMPLING

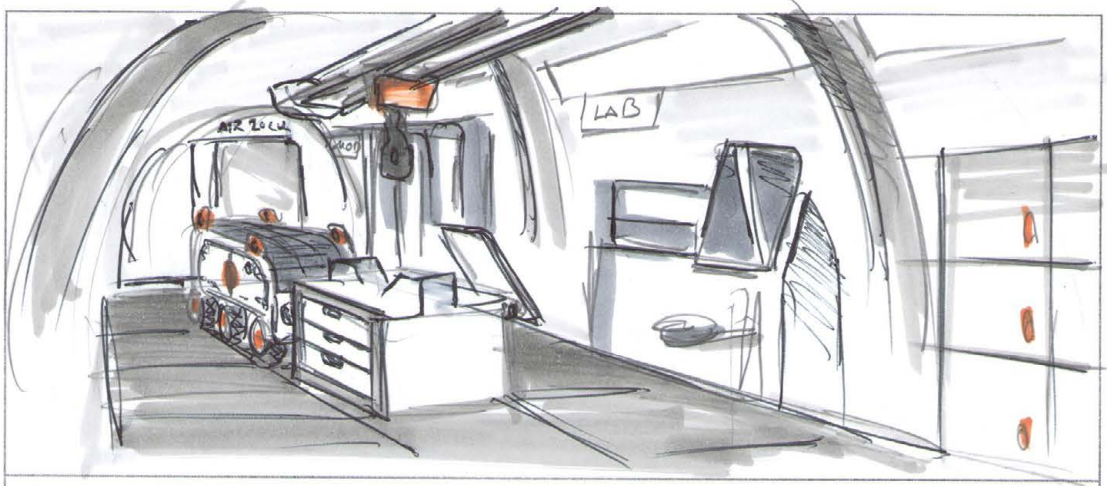
(Preparation and inspection of the accompanying vehicle, preparation of sample storage containers, functional testing and preparation of drilling equipment, loading of the accompanying vehicle)

1.1.x PREPARATION AND INSPECTION OF THE SUPPORT VEHICLE

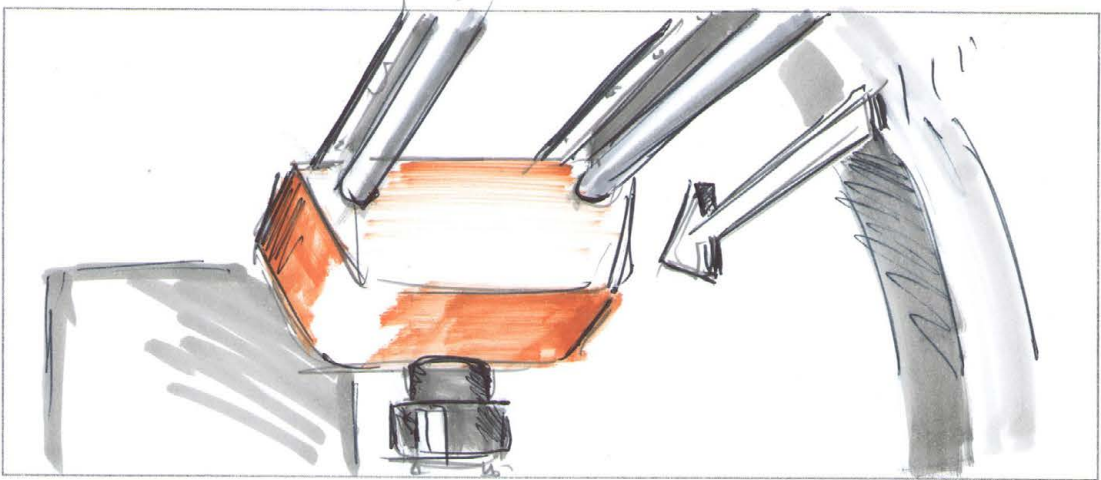
DURATION APPROX. 20-30mn

Section 1.1.1 (Work preparation) (~5-10mn)

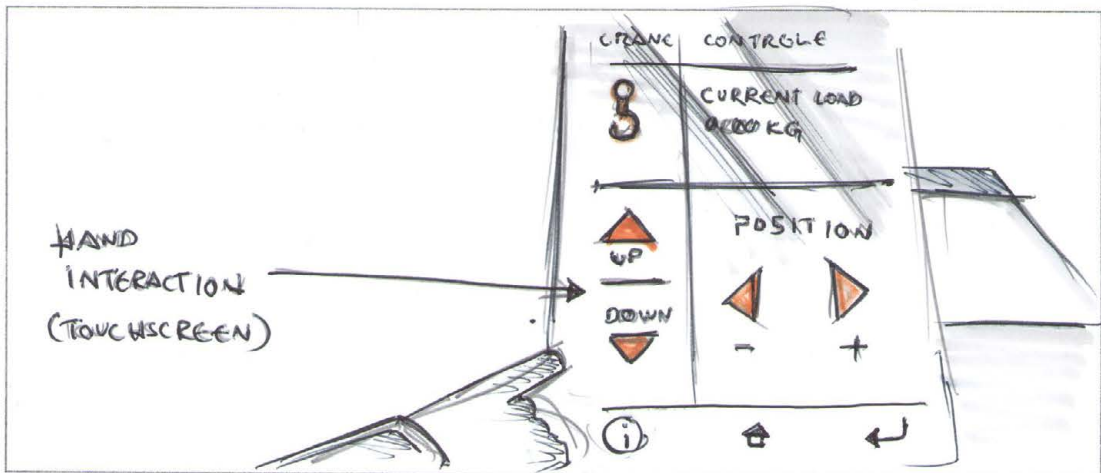
The Geological Support Vehicle is located on its parking place inside the Geological Module. In the first step, the user must drive the overhead crane in the module over the vehicle. The vehicle is now connected to the crane by means of ropes and four lifting points. The crane is then used to lift and move the vehicle and place it on a raised platform in the center of the module. The vehicle can remain connected to the crane so that it is additionally secured against falling from the working platform.



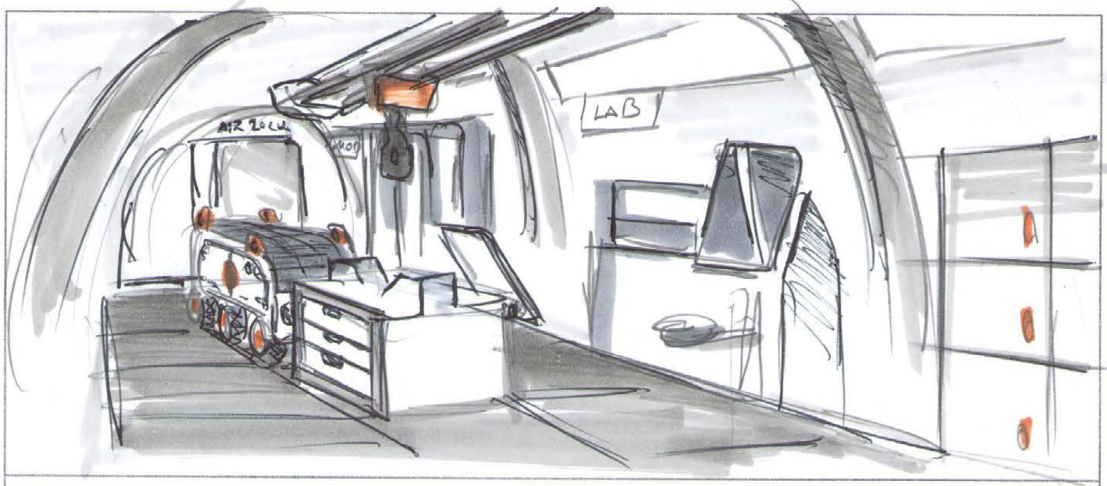
1.1.1 MISSION PREP. GEOLOGICAL MODULE



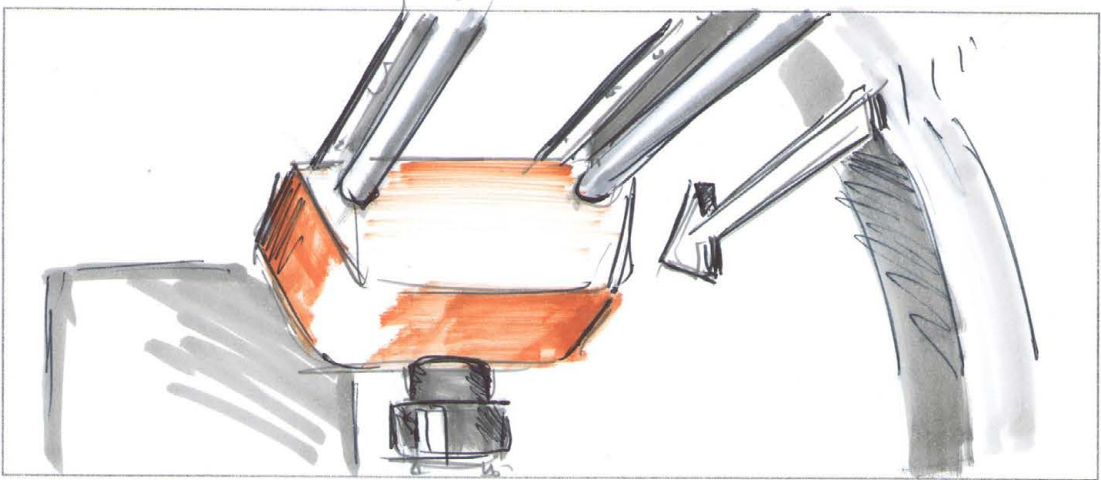
1.1.1 CRANE POSITIONING (CONTROL VIA TOUCHSCREEN)



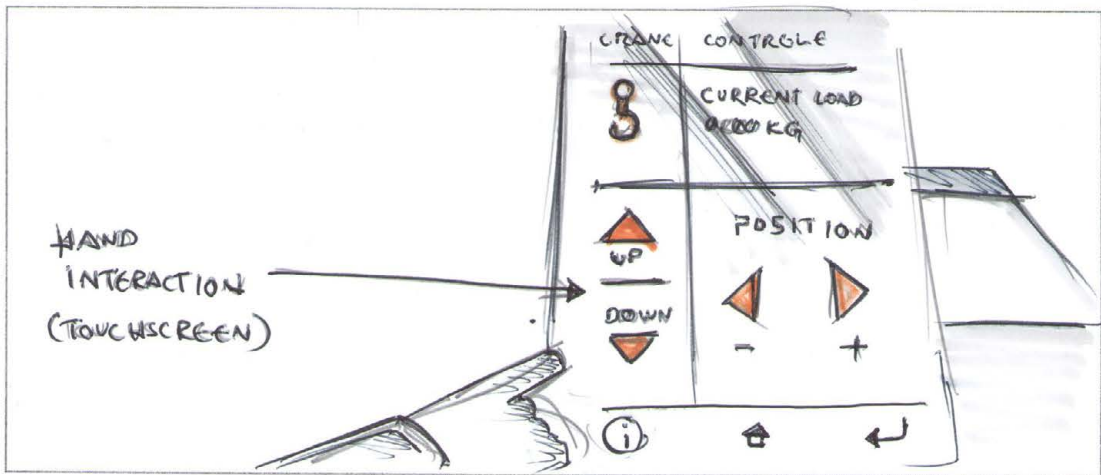
1.1.1. CRANE CONTROLLER



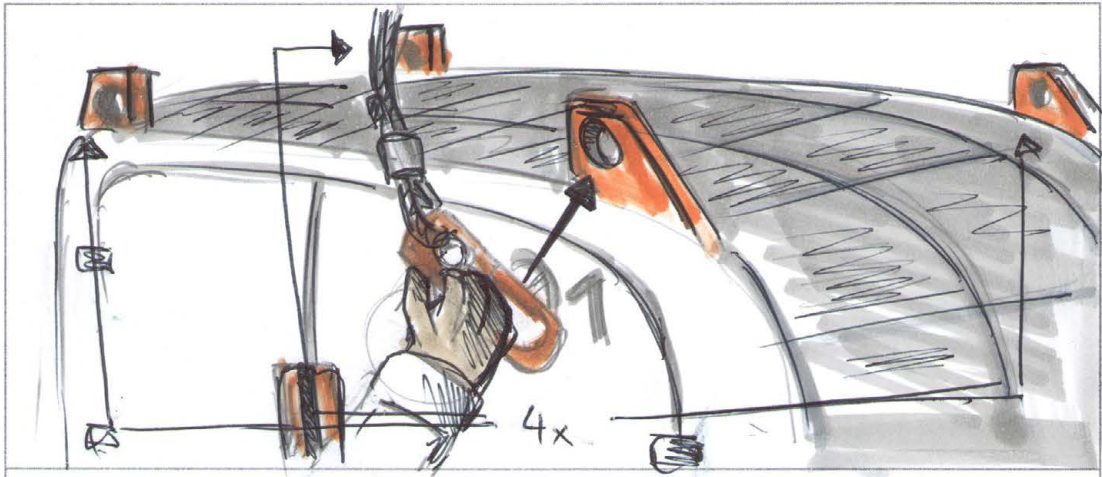
1.1.1 MISSION PREP. GEOLOGICAL MODULE



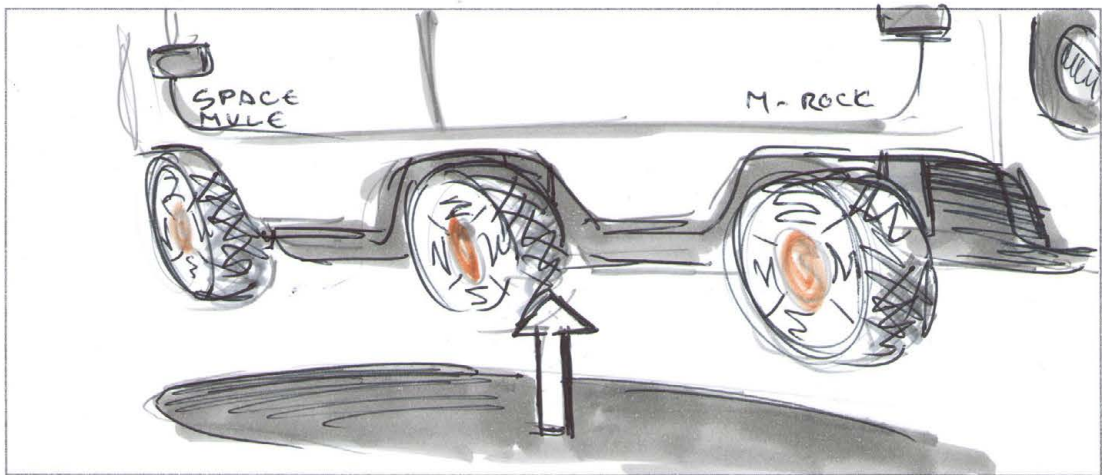
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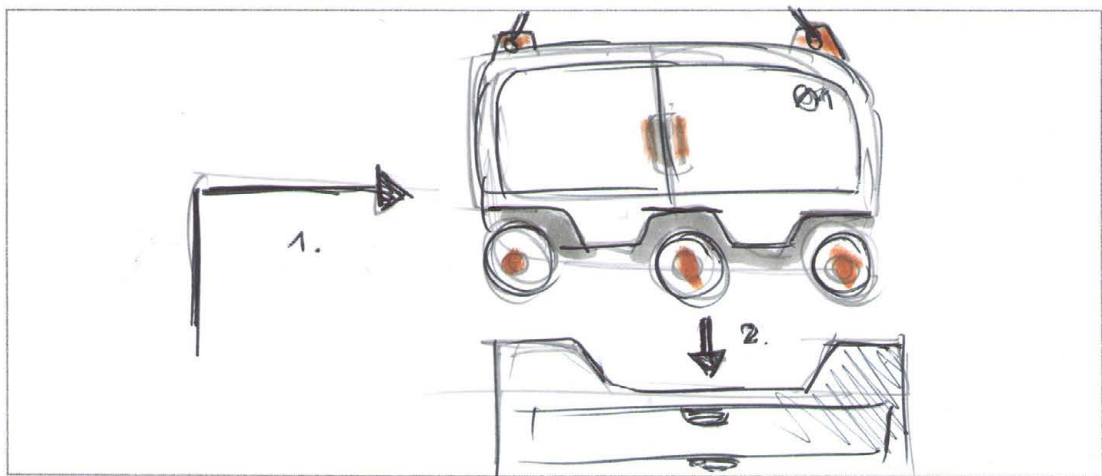
1.1.1. CRANE CONTROLLER



1.1.1 CRANE ATTACHMENT



1.1.1 VEHICLE LIFTING



1.1.1 VEHICLE TRANSPORT / DEPOSIT

Section 1.1.2 (Vehicle inspection) (~10mn)

The vehicle is now on the work area. Here, the test person first checks the exterior of the vehicle, looking at it from all sides and also from below at an angle to detect possible damage.

The vehicle might contain intentional scratches that are to be detected by the user. (Also other damages are conceivable e.g. missing screws or a not correctly closed cover.)

In this case, it would be conceivable that the user should photograph these with a camera on his suit or capture them via the controller trigger.

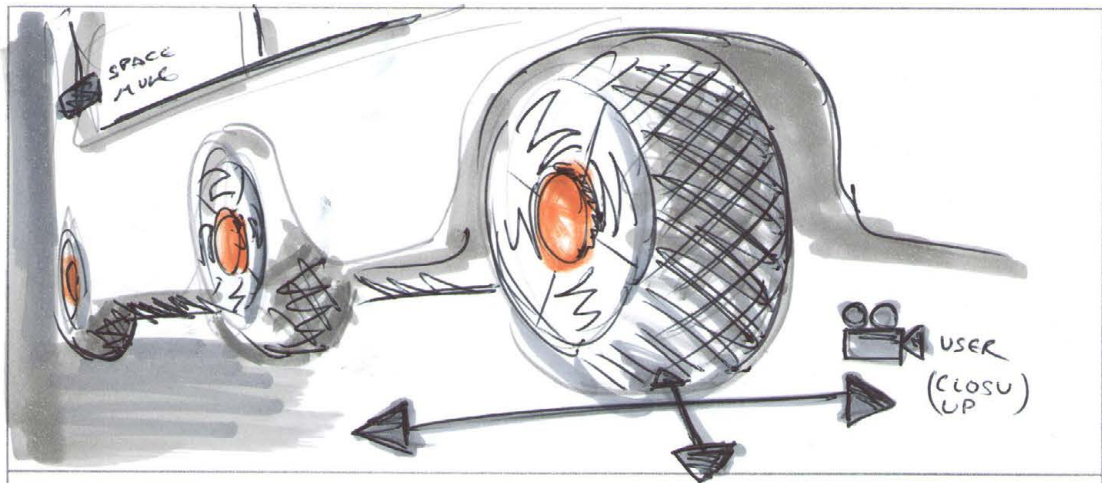
(Depending on the proposed damage, repairs are also possible in such a scenario. If realized the scenario can therefore be used as template for other spinn-off scenarios.)

In addition to the vehicle in general, the wheels and the drive mechanism in particular should be examined. Are there, for example, rock fragments that can influence the drive mechanism or the wheel steering? Is there any residual dust in the vicinity of rotating elements that could lead to abrasive effects? Or are the nitinol strands of the mesh wheels damaged so that they would have to be replaced or repaired?

The next step is to read the battery condition and storage data, the storage capacitor memory, the onboard diagnostics & the fault memory of the vehicle. All this data is obtained from the BMS of the battery and capacitor system. These parameters can be read out in the display terminal of the service station.

(At this point, scenario variations are possible, e.g. the change of a battery or capacitor module could also be trained at such a moment. In particular, changing a charged capacitor module represents a major electrical risk, which is why this task would be predestined for a safe training in VR)

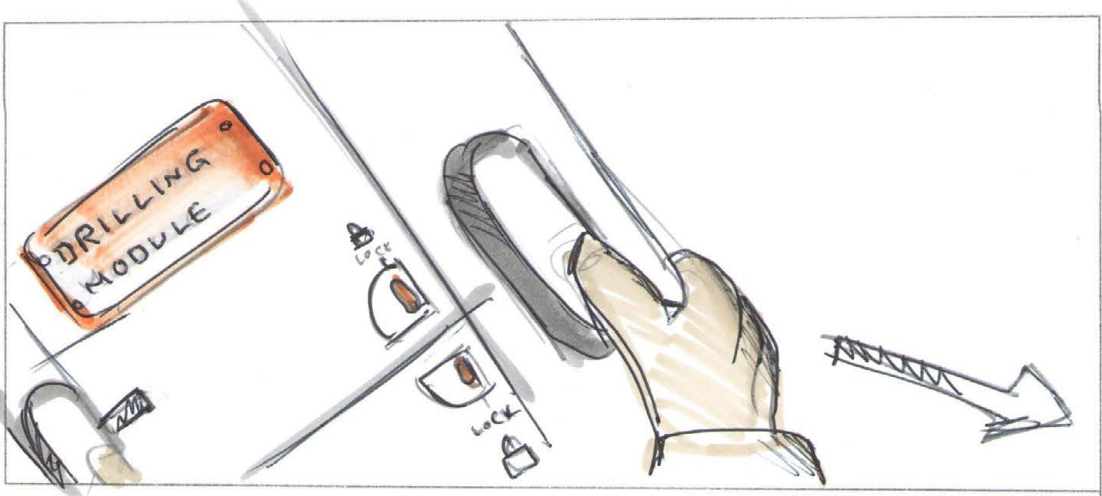
Once all the checks have been carried out, the training can continue in the next step with the loading of the vehicle. Once the inspection is complete, the vehicle is lowered by crane and the lifting points are released.



1.1.2 VEHICLE INSPECTION (VISUAL)



1.1.2 VEHICLE DIAGNOSTICS



1.1.3 RETRIEVING THE DRILLING MODULE

Section 1.1.3 (Tool preparation & loading of support vehicle) (~5-10mn)

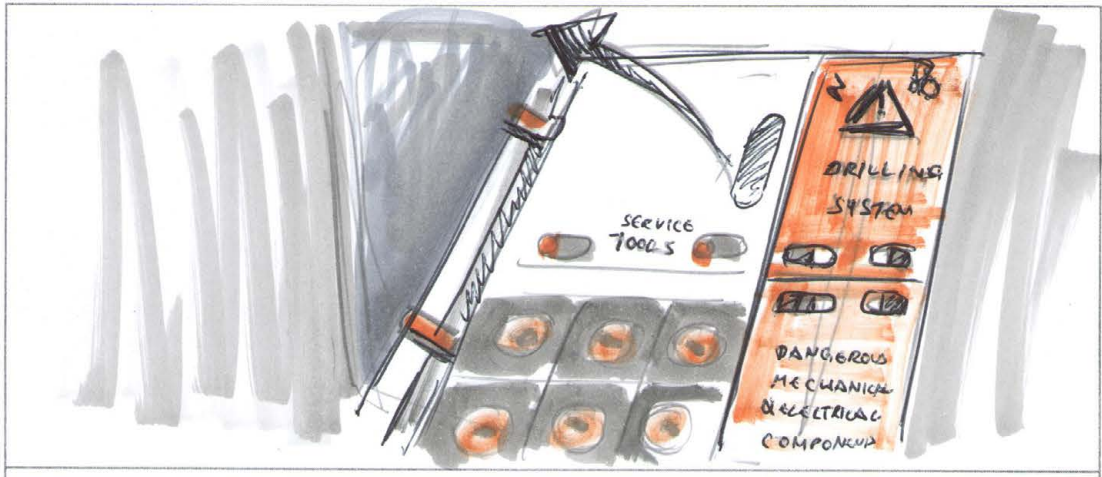
The drilling tool comes as a replaceable module that can be attached to the back of the vehicle like a backpack. The large energy storage unit in the vehicle is later also used to operate the tool.

The drilling module is taken from the module stock and placed in the designated location inside the geological module. (If the fully loaded module weighs less than 85kg, it could be carried two-handed by a single person on Mars. If we apply the factor 0.38x for the gravity on Mars, this would correspond to a load of ~32.3kg on Earth. If we apply a safety margin of 70kg as module weight, this would correspond to a load of 26.6kg on Earth, which should be acceptable for each crew member, at least over a short period of time.)

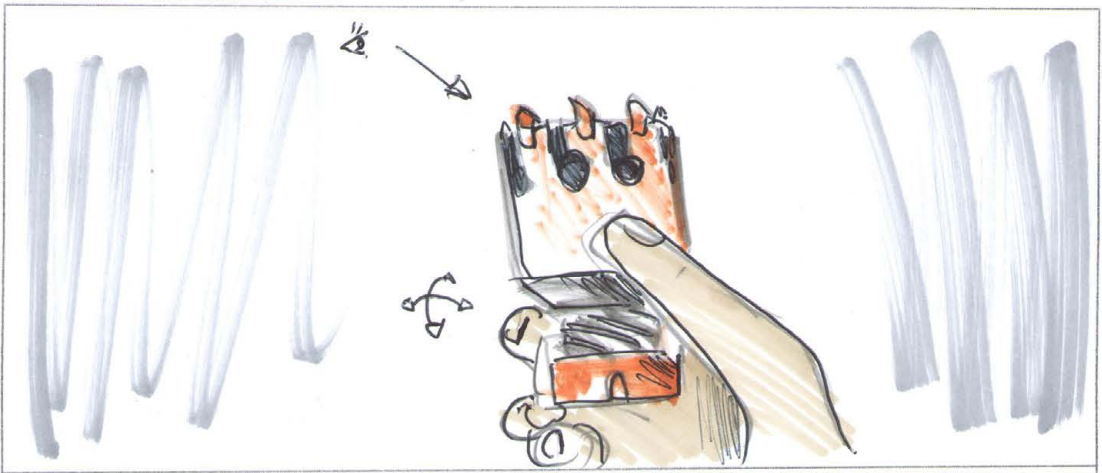
The module is opened at its service position, now the user checks the drill heads and checks the completeness of the service tool. He then loads the module with fresh sample tubes.

All sample tubes have individual QR codes & numbers so that they can be assigned to the borehole later. In addition, the module has a five meter long cable-connected probe, which is also checked by the user. Once the check is complete, the user closes the module and attaches it to the back of the vehicle. (The Tasks to be performed can be accessed on the monitors inside the Geology Module.)

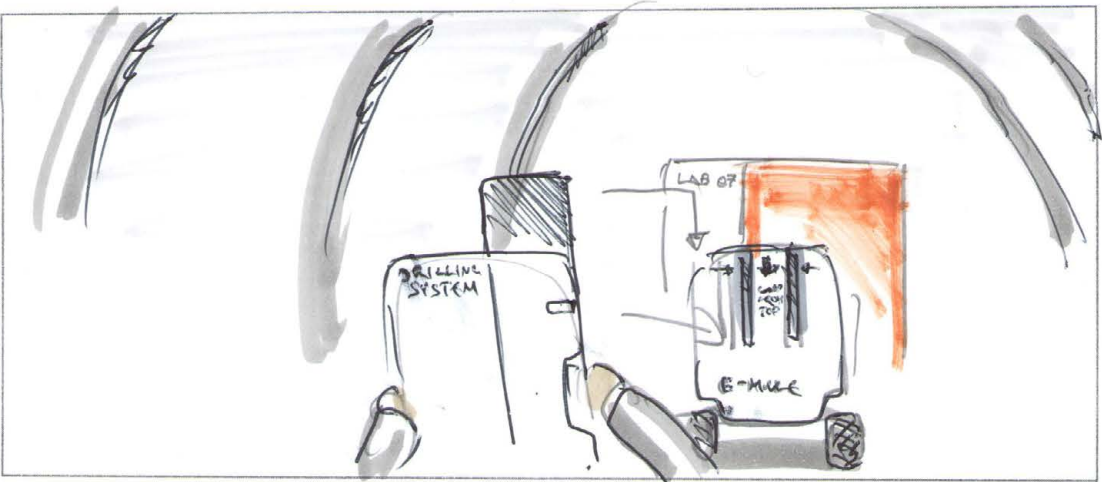
Once this task is completed, the user opens the side flap of the vehicle and loads it with hand tools, electric hand tools as well as borehole markers that later facilitate sample identification and sample allocation.



1.1.3 TOOL CHECK



1.1.3 DRILL HEAD INSPECTION



1.1.3 TOOL LOADING

MISSION 1.2: MISSION EXECUTION - GEOLOGICAL SAMPLING

(Reaching the POI where the sampling is to take place, performing the sampling, marking the boreholes)

1.2 CARRYING OUT THE SAMPLING AND RECORDING THE COLLECTION PARAMETERS DURATION APPROX. 80+mn

The execution of such a task does not necessarily have to be exciting, it is quite conceivable that many tasks that have to be performed during missions are repetitive and could therefore be perceived as tiring and boring. Here, a high number of repetitions was deliberately chosen in order to achieve fatigue effects and to see how conscientiously repetitive tasks are performed. For example, if errors occur because the focus on the task is reduced.

Section 1.2.1 (Reaching the POI) (~5-10mn)

The user continues his training outside the module's airlocks in the open air together with the assisting vehicle.

(In this section, it would be useful to use a VR add-on solution that allows the user to walk, for a more realistic training. Furthermore, it would be conceivable to put a movement restricting suit on the user to simulate the movement restrictions of a pressurized space suit)

The user moves continuously next to the accompanying vehicle in the direction of the POI. This environment and walking direction is shown on a segmented e-paper display on his arm. After about 5 minutes of walking, the user reaches the destination together with the vehicle. For the route, it would be conceivable to deliberately specify a route that does not consist of a simple straight line due to natural obstacles.

(In this section scenario variations are possible. An alternative scenario would be, for example, that the companion vehicle gets stuck and must be freed with the help of an integrated winch.)

Once the target area is reached, the next training section begins.

Section 1.2.2 (Drilling and logging) (75+mn / 25x 3mn)

Once the target area is reached, the drilling process begins. The module at the rear of the vehicle independently drills 1m deep holes. The drilling samples are automatically emptied into the sampling tubes. The drilling is done in several steps corresponding to the length of the sample container. Once this is completed, an e-paper display on the module outputs a QR code that is scanned by the user. The user takes a marker flag and places it close to the borehole. This also has a QR code that is scanned by the user. The vehicle moves to the next sampling point and the process starts again. Before departure, the probe can optionally be used to determine the interior of the borehole, whether this is necessary can be specified by the training scenario).

(Variations are possible in these repetitions, e.g. changing the drill head as a repair measure or as an adaptation to a different substrate.)

Section 1.2.3 (Optional scenario section/ return to base and decontamination of vehicle and suit.) (10-15mn)

It is conceivable that the user accompanies the vehicle back to the base. Once there, he opens the air locks after they have been drained.

In the next step, it is entered and closed. Now the user starts to decontaminate the vehicle with a compressed air system and a vacuum exhaust. The fine statically charged Mars dust is separated by an electrostatic filter system. In this process it is also possible to measure how thoroughly the vehicle has been cleaned by the user. A multi-stage cleaning is conceivable and probably useful. (Stage 1 Vacuuming to remove the coarse dirt. Stage 2 Cleaning by means of a brush and suction. Stage 3 Cleaning by means of compressed air and suction system. Stage 4 (Renewed) decontamination of the own suit in a designated air shower with dust extraction.)

1.3 CARRYING OUT THE SAMPLING AND RECORDING THE COLLECTION PARAMETERS DURATION APPROX. 80+mn

Section 1.3.1 (Sample extraction and data entry) (25-35mn)

Before taking the sample, the subject opens the drilling module and the sample collection container inside. In the next step, he prepares the sample terminal in the geological module for the input of the samples.

The samples are inserted cassette by cassette. In this example, each cassette contains five subsamples, with three subsamples corresponding to each borehole. Thus, 15 cassettes must be entered into the system.

For this purpose, each cassette is deposited in the corresponding opening in the geological module and its identification code is scanned beforehand.

Once all cassettes have been entered, the user checks the completeness of the inserted subsamples on the terminal. He also checks whether the collected data have been wirelessly transmitted from his suit to the geology module. Finally, he can start an automatic completeness check of the data set.

At this point, further connection points for scenario variations are possible. For example, it would be conceivable that the user inspects and maintains the deployed vehicle after the operation or that he performs further actions in connection with the data collection. For example, if a borehole was interesting and should be investigated further, it is possible that a deeper borehole should be drilled or other more specialized measuring instruments should be used at that location.

EVALUATION METHODS

**ANALYSIS PARAMETERS FOR
MEASURING TRAINING
SUCCESS & DATA COLLECTION**

VIEW, PROXIMITY & FOCUS

(Evaluation of the detection of important interaction points through eye tracking & viewing targets)

If a VR solution with eye tracking is employed, it can capture view targets by using ray casting of the visual axis and thus track whether the person being trained has looked at important key points in the training process.

The basic idea is that a Blueprint class is set up with two or three differently sized nested (spherical) collision objects. The innermost smallest collision object is the view target that represents the Immediate Interaction Point / POI. The second larger object serves as a close proximity object that detects whether the subject was basically looking in the right area. The last optional object is a rough proximity object that detects whether the subject has fundamentally looked into a very rough interaction area. (Example: If a button was looked at, If a whole control panel was looked at, If the correct object was looked at where the control panel is located).

For a more detailed evaluation, it is also possible to record the times of the individual collision events, so that it can be concluded later, for example, whether an interaction interface was designed in such a way that the test person could quickly identify the correct function. For an even more detailed evaluation, it would also be imaginable that alternative targets are set that do not correspond to the searched interaction point, whereby it would be possible to understand which alternative interaction possibilities were considered by the subject.

A general recording of the viewing targets can also run as an invisible checklist, in this way the user can be deliberately allowed to skip process steps of the training. The collision detection & time recording of interaction points can later provide information about whether these have been forgotten by the user or whether he has taken them into consideration without successfully executing those tasks.

HAND DETECTION / COLLISION DETECTION FOR THE EVALUATION OF RISK SITUATIONS

(Eradicating risk factors & potentially hazardous behavior when performing tasks such as installation or maintenance)

In Mars operations, many potentially dangerous situations and activities are conceivable. On the one hand, an astronaut's suit could be physically/mechanically damaged, resulting in a pressure drop and exposure to toxic materials and intense cold. On the other hand, hazardous activities could also occur inside station modules, e.g. supercapacitors could be used as energy storage devices with a significant risk of electric shock, or dusts of toxic material (e.g. untreated surface dust from Mars) could have to be handled.

The idea for monitoring these hazards is to create collision objects as a blueprint class that measures the proximity to and contact with hazard points. Hazard points as well as the hands and the head of the user could get two nested collision objects. The inner object describes the absolute point of contact, e.g. the user's hand or the immediate danger point. The outer one represents a proximity area. The proximity area for hands and head is static in terms of its size, while the size of the external collision object of the danger point can be adapted to the situation. In this way, hazard situations can be detected in several stages.

If both External Collision Objects overlap, the user's hand has approached the danger point, for example. If the outer collision object of the user overlaps with the interior of the danger point, it can be assumed that an immediate danger situation exists (imminent danger). If the two inner collision objects overlapped, a catastrophic hazard situation would have occurred that would have had serious consequences for the test person or possibly the entire mission.

In addition, variants are conceivable, for instance, if DC sources are handled, it would also be possible to determine whether one or more poles of the voltage source were touched. In another variant, a similar procedure could be used, for example, to detect short circuits and identify potential short-circuit situations (close calls).

HANDLING FORCES / MECHANICAL STRESS OF HANDLED OBJECTS

(Measurement of acceleration forces/ velocity and external forces acting on training objects manipulated by the user)

Modern VR systems have the ability to capture hand movements spatially in real time. This data can be used to calculate the acceleration and speed of the user's hands. With information such as the user's mass, it is also possible to roughly calculate impact forces, such as those caused by unintentional collisions with objects. (Similar metrics are used in vr fitness applications, for instance)

The forces calculated in this way can be put in relation to the properties of the manipulated objects. Thus, among other things, the weight and physical behavior of an manipulated object can be used to calculate whether critical forces have occurred to the object.

An example of this would be the installation of a cable, where it could be measured how strongly the user pulled on the cable and connector and whether critical mechanical forces occurred when joining the connection. These forces could be recorded over time, with critical events and exceeding of threshold values (with resulting damage) being logged.

At the same time, other factors could be taken into account, for example, if the scenario takes place at different times of the day (Sol), the outside temperature could have an influence on materials behavior and possible material failures.

VITAL PARAMETERS / STRESS & ENERGY CONSUMPTION

(Data logging of subjects' vital parameters using additional hardware to capture additional key data points)

Vital signs can provide valuable information about the subject's physical and psychological response to the training scenario. For example, an increased heart rate may be related to physical exertion or a stressful situation. Other parameters such as the blood oxygen and the external respiratory air can allow a better medical evaluation.

In this way, it can be determined whether subjects remain calm in an unanticipated dangerous situation or react nervously and unpredictably. In particular, with time-synchronized recordings of the complete training mission, conclusions could be drawn about the behavior of individual test subjects in extreme situations. At the same time, training effects can be evaluated; it would be interesting to see whether better prepared test subjects react more calmly to unforeseen situations when they are appropriately trained.

Another mission critical parameter that can be evaluated from these readings, as well as the acceleration and motion of the subject and their physical characteristics, is the caloric consumption of an operation. It seems plausible that the calorie supply of astronauts at the beginning of a manned Mars mission is one of the biggest challenges. Therefore, it can be an interesting planning aspect to know how the execution of different tasks by the subject would affect his calorie consumption during an actual mission.

CHECKLISTS CONFORMITY / TASK COMPLIANCE

(Monitoring the training sequence and protocol compliance of tasks to be completed)

In addition to the checklist visible to the participant or the tasks communicated to the user, a blueprint class runs in the background of the application and records whether and how partial steps of training tasks are carried out.

Typically, when assembling systems or maintaining equipment, it is possible to skip partial steps or even groups of steps with no immediately visible or noticeable effect on the short term result. In the long term, however, this can lead to considerable and avoidable problems. Especially in the case of maintenance and control tasks, this omission of duties can manifest itself with a considerable delay.

Imagine you are supposed to check the piping of a heating system for corrosion and you omit a certain area. Immediately, this has no effect on the function of the system as a whole, but in the long term, this area can develop an unnoticed leak that may cause a great deal of damage to the entire system and potentially even the entire mission.

This checklist conformity can be recorded on the basis of different events. Conceivable are: Interaction points and button presses on the controller (a function was activated). Collision detection between objects (was a component mounted). Viewing queries (was an object or area viewed and if so, for how long). Position queries (did the test person stand in a certain area). Other Blueprint events (was a task completed).

MICROPHONE / AUDIO RECORDING

(Evaluation of the sounds generated by the user as an aid to training evaluation)

Recording sounds from the headset can provide information about the breathing and audible responses to training scenarios that the subject unconsciously emits during training. If necessary, this data could be used to gain a better understanding of the behavior during training scenarios.