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Mars exploration simulation in the Petites Dales cave

28th of May 2016

(Docs. J. Barbier/I. Ebran/Gargouille Productions)

Content

Executive summary

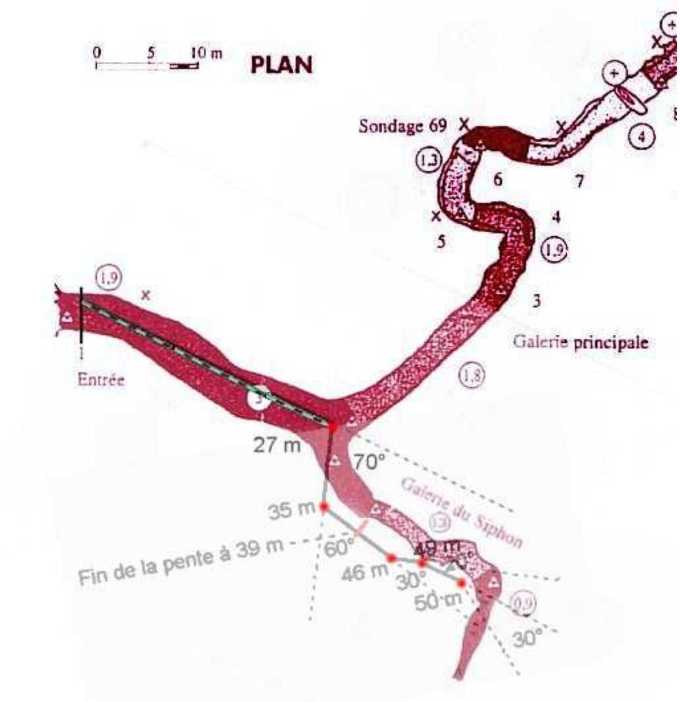
This second simulation carried out by the Planète Mars association in France has achieved the majority of its objectives.

The scenario unfolded consisted in the exploration and recognition of a cave a priori unknown. APM had already participated with the Cliff Reconnaissance Vehicle in the cave exploration simulation organized by the Austrian ÖWF in the Dachstein ice cave. But in the latter case it was more a question of carrying out scientific or technological experiments in the cave than to place oneself in the perspective of an unknown cave recognition.

This document first part is mainly a chronological description of the simulation with photos and including comments on the main results (§4 p 13). The helmet camera is mandatory to be able to describe all the operations and give an accurate chronology. After a short recapitulation of the simulation different phases, the last part (§ 6 p 186) presents the results by themes (Cliff Reconnaissance Vehicle utilization, cave cartography, behavior of simulation spacesuits and operations difficulties when wearing these suits).

It was also in this Petites Dales cave the first APM simulation with two people wearing the two association simulation spacesuits. Of course, many association members participated also in simulations in the USA (Mars Society MDRS station in Utah - see in particular reference 1 - or University of Hawaii HI-SEAS station) and in Canada (Mars Society FMARS station). There was also participation, but only as an experimenter, in the Austrian space forum ÖWF simulations in the Dachstein cave in Austria (2012), in Morocco in the Erfoud region (2013) and on the rock glacier of Kaunertal in Austria (2015).

The simulation in the Petites Dales cave has shown the possibility of crudely mapping the cave even if more sophisticated means than those carried could also be used.



Cave cartography (doc. J.P. Viard + APM indications)

It has also been shown the usefulness of a reconnaissance vehicle sent as a scout in a sloping passage before sending human explorers there. This experiment could be extended with a self-propelled vehicle for flat areas (or with rovers designed for slopes operations)

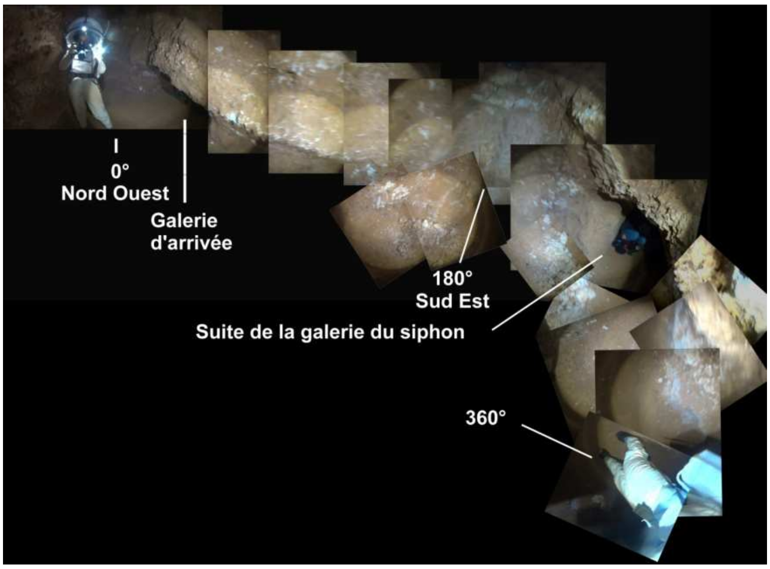
The Cliff reconnaissance Vehicle used to scout a slope before the experimenters descent in simulation spacesuit (docs. J. Barbier/I. Ebran/Gargouille Productions - A. Souchier)

After the CRV scouting, a descent could be engaged, using a rope and descender in a spacesuit (docs. J. Barbier/I. Ebran/Gargouille Productions-helmet camera)

As usual in these simulations, it has been verified that, despite the wearing of simulated spacesuits, quite complex operations can be carried out, even if the level of clumsiness and the duration of operations are increased. It has been shown that the volume of the spacesuit (more than the weight knowing that it is intended to recreate the equivalent Martian weight) increased the difficulty of progression in delicate passages. The experimentation of progression in a narrow passage was planned but not over a distance as long as 17m. The increase in distance traveled in the narrow passage was justified by the possibility of accessing a fairly large cavity, cavity 46, which served as a studio for interviews by one of the video teams. The crawling progression that was necessary to access to this cavity and return was not so useful for representing the capabilities of actual spacesuits in this domain, as for finding the weaknesses of the current APM simulation suits and possible improvements. The time spent for access and return from cavity 46 most likely limited the mapping operation in the main tunnel.
It was possible to show with photographs with a separating power of one tenth of mm that precise measurements were possible despite the wearing of the suit.

Photo from a video taken in spacesuit showing details in thin sedimentary layers (Sony HDR GW 55 camera, Alain in sim)

The helmet camera not only gives information on the simulation operations and chronology, but also may be used to reconstruct a landscape providing the head motions may not be too rapid.



A 360° crude "mapping" of cavity 46 built from the helmet camera pictures. A ruler bigger than the one used for sedimentary layers macro pictures, would have been useful to give a dimension reference. (Helmet camera)

As for all exploration simulations, wearing a simulation spacesuit, with a back pack and thick gloves increases the level of clumsiness and thus operations duration. But at the same time it is confirmed that rather complex operations can be conducted. The operations duration increase was not measured during this simulation. During the previous "Black Cows" simulation in 2014, a duration increase coefficient of 3,4 was identified for delicate operations as replacing a battery or microcard in the cameras. The Austrian Space Forum has more deeply worked on this question in the "Delta" experiment, which was conducted during the Morocco 2013 simulation, where the increase in operations duration is studied versus the operations complexity.

For progression in different situations the simulation spacesuit adds a notch in difficulty. Where people in normal outfit progress in a leaning mode in low ceiling passages, the spacesuit obliges to progress on knees. Where people in normal outfit progress squatting or on all fours in very low passages, the space suit obliges to shift to a crawling mode.

The descent into the Siphon passage in "normal" outfit on the left at the time of the cave recognition in 2014 (doc. A. Souchier), and in simulation spacesuit on the right (doc. J. Barbier/I. Ebran/Gargouille Productions)

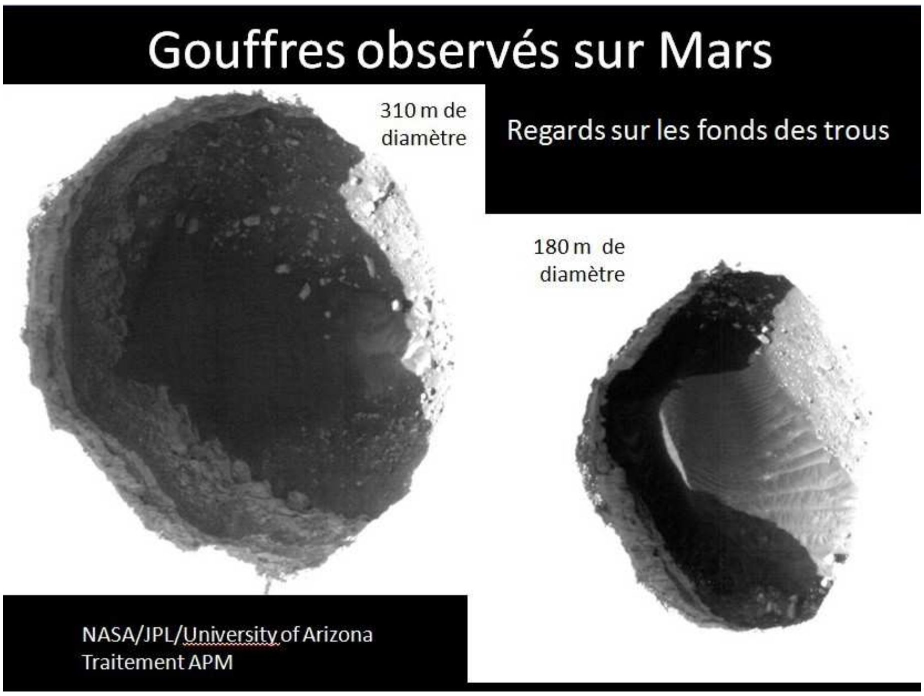
The progression in the passage to cavity 46, in "normal" outfit on the left, and in simulation spacesuit on the right (helmet camera)

1 Introduction

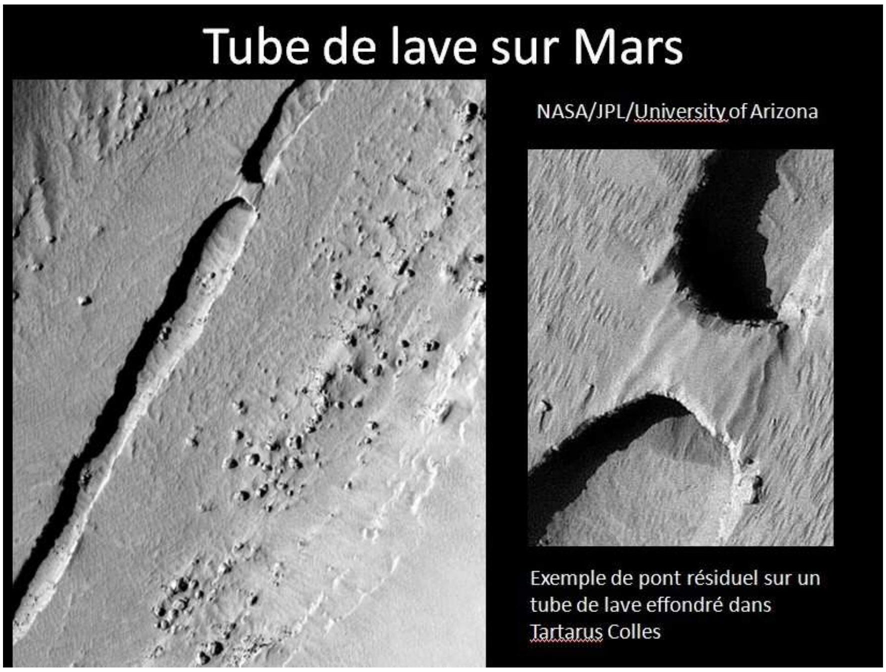
The Planete Mars association, french chapter of the Mars Society, has conducted, on the 28th of May 2016, its second simulated EVA (« Extra Vehicular Activity") with the analog or simulation spacesuits developed by Armande Zamora and Patrick Sibon in 2012 (http://planete-mars.com/les-troisiemes-rencontres-spatiales-de-saint-maximin/). One of the spacesuits was already used on the field for the first time in an area called "Black Cows Cliffs" in Normandy in March 2014 (http://planete-mars.com/une-premiere-simulation-deva-avec-le-scaphandre-analogue-de-lassociation/). This time the simulation was conducted with two people, Lucie Poulet and Alain Souchier, and the location was a cave close to the town of Fécamp, in St Martin-aux-Buneaux: the Petites Dales cave. After a first reconnaissance visit of this cave, which is only rarely open to public, the 19th of august 2014, a Mars cave exploration scenario was elaborated (see reference 6)

The operation was finally conducted the 28th of May 2016, the cave being opened specially by Jean-Pierre Viard who is in charge of the cave exploration and preservation. Two media teams were involved, one under leadership of Youki Vattier for a documentary to be broadcasted end of 2016 during the mission of astronaut Thomas Pesquet to the ISS, and the other one under the leadership of Jonathan Barbier, belonging to Planete Mars association, with the help of Isabelle Ebran from the Gargouille Productions media company.

Mars caves exploration will be interesting to search for organic molecules traces sheltered from the UVs and cosmic rays which in the long term destroy these molecules till a depth of 1 m. And it cannot be totally excluded to find extremophiles organisms still alive in particular close to or inside ice layers. On Mars lava tubes and large holes (300m in diameter and 160 m deep) have been detected, without knowing the underground extensions of these structures.



Two large Martian holes in the Tharsis area. These are volcanic features which have no similarities with some holes on Earth which are linked to limestone dissolution by water.



A collapsed lava tube in Tartarus Colles, excepted in one area where a bridge is remaining

In 2012, the Austrian Space Forum, ÖWF, had already worked on a cave exploration in the area of Salzburg, in the Dachstein ice cave, during a 4 days simulation and experimentations. Planète Mars association participated with the Cliff Reconnaissance Vehicle (CRV also nicknamed cliffbot) which was in particular used to explore large holes. However the Dachstein simulation was more oriented to conduct scientific and technological experimentations in the cave than conduct a first exploration of an unknown cave. The 28th of May Petite Dales cave exploration was mainly designed as the exploration of an unknown Mars cave.

The Cliff Reconnaissance Vehicle during the 2012 simulation in the Dachstein ice Cave (docs. ÖWF J Neuner/APM A. Souchier)

2 Main objectives

The exploration scenario which was executed in the cave is explained in reference 6. This document was prepared before the simulation.
The objective was to conduct an exploration in different phases which would highlight the various difficulties which could be encountered in a cave EVA with the penalties imposed in operations by analog spacesuits
The different planned phases were:
-Cave dimensions and lay out measurements (distances and angles between roughly linear sections)
- Utilization of the Cliff Reconnaissance Vehicle as a pathfinder in a slope (Siphon passage) before climbing down. This CRV use was peculiar because normally the vehicle is designed to study the slope or cliff ground (looking behind) whereas in this case it was oriented to look ahead. In the Dachstein cave, an intermediate situation was encountered where the vehicle was used in the Tristan hole suspended to its rope and swapping horizontally 360° by rotation
-Demonstration of a rope utilization with a rope descender in analog spacesuit in the Siphon slope
-Attempt of progression in a narrow low ceiling tunnel
-Macrophotos of sedimentary water deposited layers

This operation was also a test of the Planete Mars simulation or analog spacesuits in far more difficult conditions than the ones encountered during the preceding simulation in the 2014 Black Cows simulation (see reference 2).

3 Hardware used in the simulation

This was the first simulation conducted with the association two simulation spacesuits. These suits, which aim at bringing difficulties and constraints in the operations, mimicking as much as possible true spacesuits, are described in reference 7. The main handicap comes from the gloves, but also from a reduced visibility, from the feeling of being trapped in the helmet and also from the back pack volume. The weight is also to be taken into account but the weight of these suits between 12 and 15 kg is purposely small in order not to overload the wearer during a simulation under one g on Earth. On Mars the gravity is only 0,38 g and the terrestrial weight of the wearer plus the simulation spacesuit on Earth is already equal to his Martian weight wearing a spacesuit of around 150 kg. This is to be compared to the 85 kg of an Apollo spacesuit and the 130 kg of an ISS spacesuit.

Outside of the spacesuit, the hardware carried in the simulation was the following:
-A spool of Ariadne's thread carried by Lucie
-A belly bag carried by Alain with :
    -A Canon EOS 7D photo camera
    -A Sony HDR GW 55 video camera
    - A laser Vortex Ranger 1000 range finder
    -Two 20 cm cardboard rulers
    -A set of small plastic signs numbered 1 to 12
    -Two little boxes for samples
    -A modified protractor with spikes in order to measure angles between linear segments of the cave

-A safety flashlight with manual dynamo

-A side bag carried by Alain with a 15m rope, a Petzel descender and another redundancy 10m rope.

–A mountain harness carried by Alain.

The Ariadne's thread spool with 252 m of thread inside and the protractor in a configuration explaining the angle measurement process.

The belly bag showing the Canon EOS 7D camera location (empty), the laser range finder and the Sony HDR GW 55 video camera in the lateral small bag. The bag operator side is the upper one, thus the video camera is on the operator right side.

Front pocket content: the marking signs, the protractor, the safety flashlight. As for previous simulations the zippers have been modified adding large tapes (silver squares) to improve handling when using the thick gloves.

Content of the bag lower pocket : two boxes for samples and two 22 cm rulers in cardboard

The laser Vortex range finder and indications as they appear in the viewfinder : distance and inclination ; but this range finder does not give indications under 10 or 9 m.

The harness and descender during a rehearsal

To these pieces of hardware were also added the Cliff Reconnaissance Vehicle (CRV) or Cliffbot as well as its video reception box (see reference 8)

The CRV in its Petites Dales simulation configuration. Owing to the narrowness of the Siphon gallery, the vehicle is equipped with only two half length anti roll rods (50 cm) and not the full length of one meter. The two outer halves of the anti roll rods normally fitted to the vehicle are presented along the wall.

The « Martian » flag red, blue, green and its flagpole in two parts were also carried as well as a small Planète Mars association logo.

<u>4 Simulation events chronology</u>

<u>4-0 Time measurement</u>

One simulation objective being to detect and describe the difficulties encountered during operations, time measurement, either for short and simple operations or for longer ones (CRV preparation,

crawling in a tunnel) is important. Time is given primarily by the Sony HDR ASW 15 helmet video camera. This camera operates in principle continuously. On the recorded SD microcard however, the recording is segmented in 35mn 23s sequences (with no laps of time between the sequences). Thus the simulation is recorded on a first 35mn 23 s followed by another 35mn 23s sequence. The third sequence was accidently stopped at 34mn 16s. A fourth sequence during the camera manipulations lasts only one second. The fifth sequence lasts again 35mn 23s and the sixth and last sequence has been limited at 17mn 09s by the camera battery depletion. The total duration recorded amounts to 157mn 35s practically in a continuous way (excepted between end of sequence 3 and beginning of sequence 5).
The absolute time is given by recalibration on the Canon EOS 7D photo camera which has an internal clock.
The time taken as zero in the following events chronology is the time were the two operators crossed the cave entrance door. In absolute value, time is then 3h 04mn pm and the camera time 2mn 12s. This last value has been subtracted from the events camera time to give only the duration after the entrance door crossing.
By comparing the time given by the first Canon camera photo in the Siphon gallery slope and the last photo taken in the cavity 46, the correlation between photo camera time and video camera time is very good: the photo camera gives a 59mn 59s laps of time and the video camera gives 59mn 57s. To restitute the duration during which the video camera was stopped in the end of the 3rd sequence, a calibration on the photo camera time before and after the interruption has been conducted. It appears that the camera was stopped during 27s. This correction has been introduced in all the events time given by the camera after the interruption.

4-1 Preparation and preliminary activities

This phase includes the hardware transfer to the Siphon passage entrance, the Mars flag deployment, a first distance measurement and a short trip in the main tunnel beyond the Siphon passage entrance for the video shooting needs.

End of preparation in front of the cave entrance. On the helmet left side on the ground is fixed a Sony HDR AS 15 camera (field 120°, 1920x1080 pixels picture). This camera has been in operation continuously during the simulation excepted for a 27s interruption and for some minutes at the simulation end, the battery being depleted. The simulation events times are given by the camera clock. (Doc. J. P. Viard)

First entrance in the cave shortly after 3 pm. Lucie Poulet on the right carries the Ariadne thread (yellow spool) which is 252 m long and the CRV video reception box. Alain Souchier on the left carries the CRV. The hardware is deposited at the cave entrance. (Doc. J. P. Viard)

The following pictures which describe the operations, are extracted from the Sony HDR AS 15 camera on Alain helmet, from the video shot by the team Jonathan Barbier/Isabelle Ebran/Gargouille Productions and from the Canon EOS 7D photo camera carried by Alain (photos by Alain or Lucie indicated "in sim ") and few photos extracted from the video camera Sony HDR GW 55 carried by Alain. Two photos are from Jean-Pierre Viard. Every time the pictures sources are indicated.

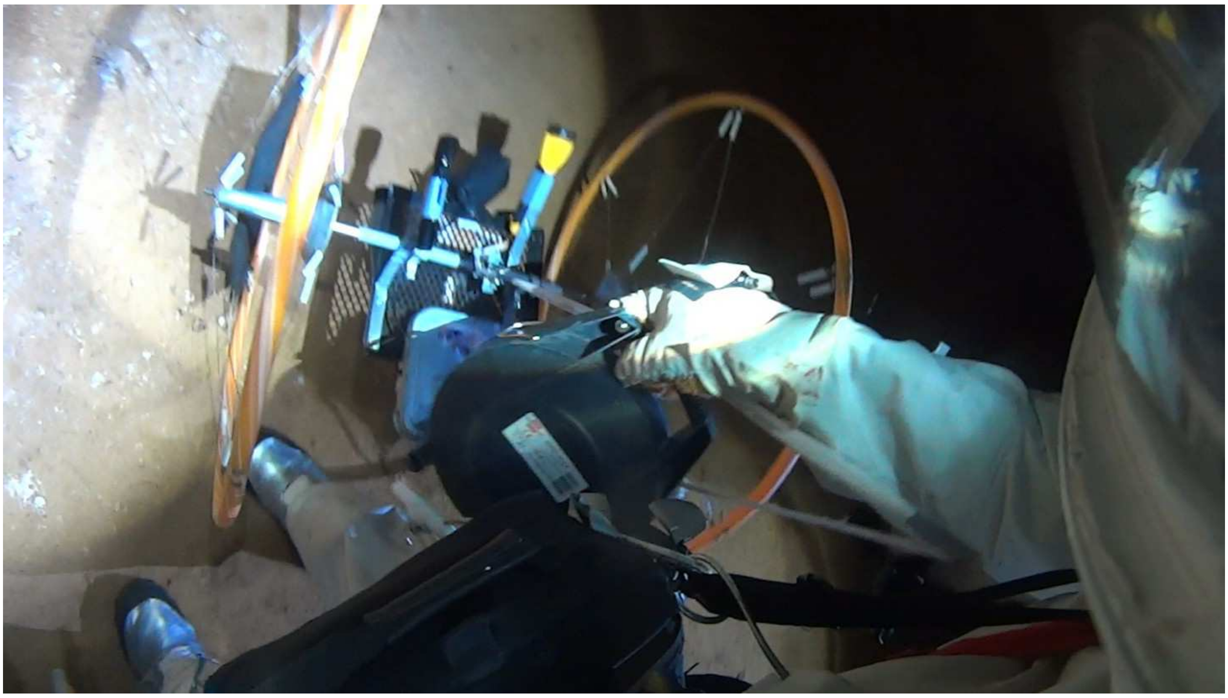
Second entry after hardware deposition at the cave entrance (doc. J. Barbier/I. Ebran/Gargouille Productions)

(Doc. J. Barbier/I. Ebran/Gargouille Productions)

The Ariadne thread which is also used for distance measurements is tied to the cave entrance gate, which is the starting point. This gate crossing time is taken as the zero reference for the EVA time measurements. The events are located in time from the time indication in the Alain helmet camera. The entrance gate was crossed at 3h 04mn pm. Lucie has tied the Ariadne thread at 0 mn 33s. (Doc. J. Barbier/I. Ebran/Gargouille Productions)

At 1mn 04s Alain takes the CRV in the right hand after taking the 4 half anti roll rods, the safety pole and the hammer in the left hand (helmet camera)

Carrying the CRV, the Mars flag and the CRV video reception box from the cave entrance to the Siphon passage inlet. Lucie carries the Mars flag, the flag poles, the flag horizontal supporting rod and the CRV video reception box. Alain carries the CRV. (Doc. J. Barbier/I. Ebran/Gargouille Productions)



1mn 51s after crossing the entrance gate, the hardware is deposited at the inlet of the descending Siphon passage, at 27 m from the cave entrance (helmet camera)

Then the (unofficial) Mars flag is deployed (red, green blue from the Kim Stanley Robinson science fiction trilogy, Red Mars, Green Mars, Blue Mars).The flag is leaning on the cave wall, left of the Siphon passage entrance. (Helmet camera)

Lucie puts in place the horizontal rod which keeps the flag deployed (doc. J. Barbier/I. Ebran/Gargouille Productions)

(Doc. J. Barbier/I. Ebran/Gargouille Productions)

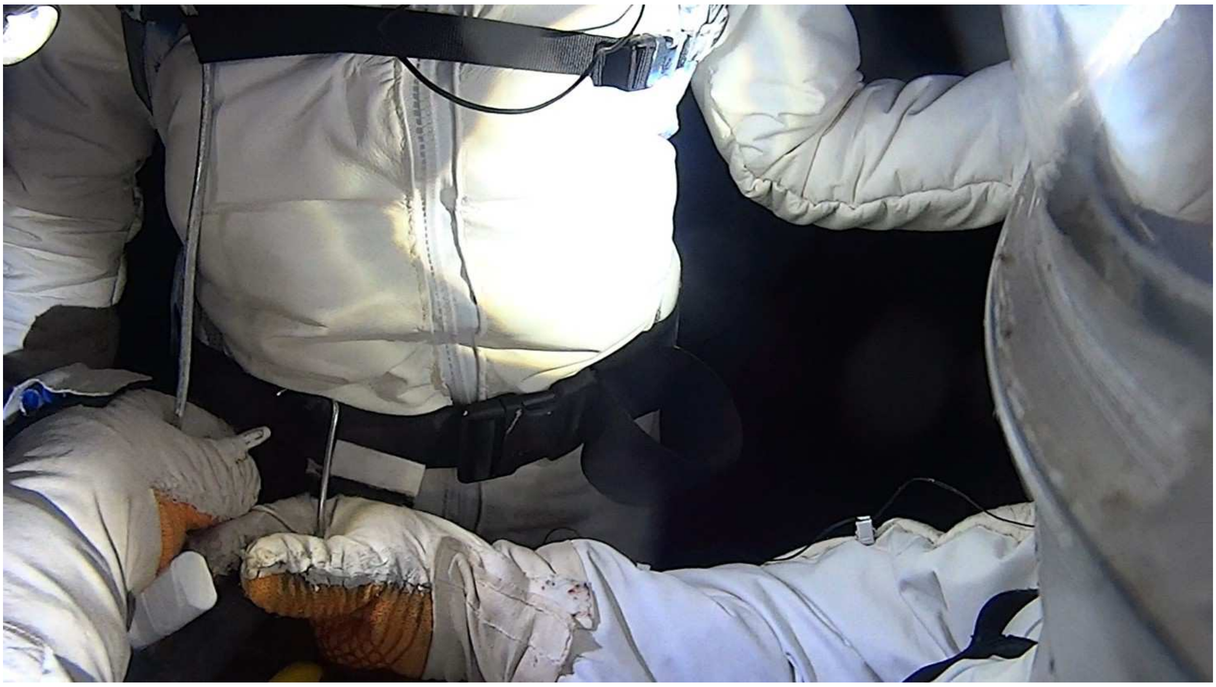
Distance measurement from the cave entrance to the Siphon passage inlet which is out of the field of view on the right. The main tunnel going to the depths of the cave is located to the left of Lucie. (Doc. J. Barbier/I. Ebran/Gargouille Productions)

The main tunnel is located behind Alain (doc. J. Barbier/I. Ebran/Gargouille Productions)

Between 3mn 26s and 4mn 50s, the distance from the cave entrance is measured (doc. J. Barbier/I. Ebran/Gargouille Productions)

The measurement process implies to unroll the thread to 30 m (where the value is indicated) and roll back by 3 m. Here at 3mn 58s Lucie is stretching the thread. (Helmet camera)

Alain has taken the thread container from Lucie's belt and is unrolling till the 30 m marking at 4mn 18s followed by a roll back to define the left side of the siphon passage as being at 27 m from the cave entrance. (Helmet camera)



At 4mn 48s Alain hooks back the container to Lucie's belt. This operation can hardly be made by Lucie because the down visibility is limited by the helmet. At 5mn 16s after a discussion about the uselessness to carry the thread container during the short excursion in the main tunnel requested by the media, Lucie unhooks the container from her belt without help and places it on the ground. (Helmet camera)

At 5mn 28 Alain gives the protractor to Lucie to measure the angle between the cave sections. Two attempts are needed to open the bag side pocket in spite of the tapes which enlarge the zips. (Helmet camera)

Markers extraction at 5mn 34s. The marker 1 is located on the ground at 27 m. Then a short trip to the first tunnel bent is conducted to fulfill the media request. (Helmet camera)

A short trip of some tens of meters in the main tunnel is conducted from the Siphon passage inlet in the main tunnel for the media needs. Departure at 5mn 59 s, turning at 6mn 35s and back at the Siphon passage inlet at 7mn 13s. (Doc. J. Barbier/I. Ebran/Gargouille Productions)

The preparation and preliminary activities phase (hardware transportation to the Siphon passage entrance, flag deployment, distance measurement from the cave entrance, trip in the main tunnel for the media,) has lasted 7mn 13s.

4-2 Cliff Reconnaissance Vehicle preparation phase

At 7mn 31s in front of the way down in the Siphon passage after sizing the CRV safety pole and the hammer. The flag pole may be seen on the far left and to its right the marker 1 indicating 27 m from the cave entrance. The Siphon down passage is on the right slightly above the CRV. (Helmet camera)

At 7mn 56s Alain hooks back the thread container to Lucie's belt (helmet camera)

Alert: the helmet ventilation is accidently stopped. Back to on at 8mn 11s. (Helmet camera)

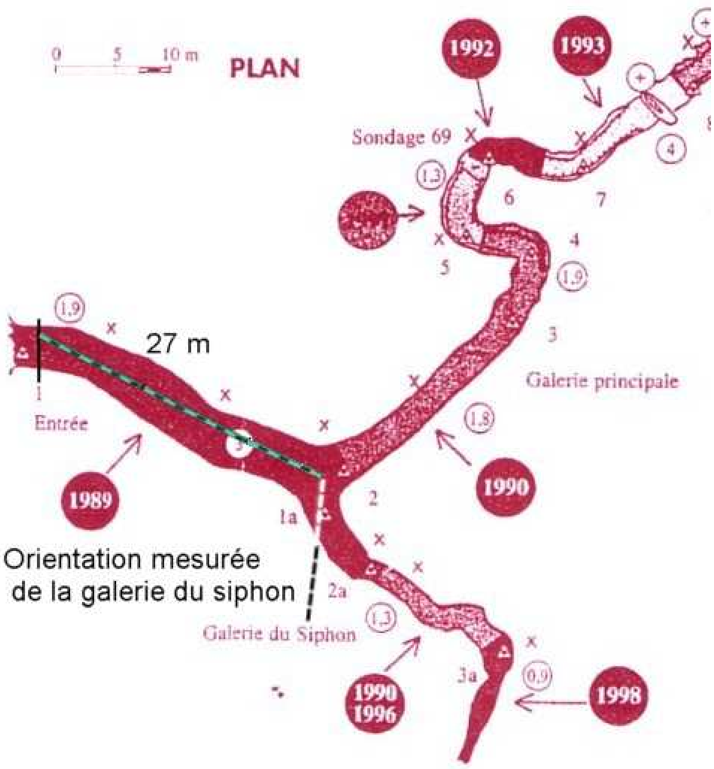
Preparation to stick in the ground the CRV safety pole. Lucie holds the Ariadne thread and the protractor in order to measure the angle between the entrance tunnel and the Siphon passage. (Doc. J. Barbier/I. Ebran/Gargouille Productions)

At 8mn 53 the CRV safety pole is planted in only 13 s and 24 hammer blows. Preparation for this operation has started at 8mn 22s. On the left Lucie is measuring the angle between the main tunnel and the Siphon passage. (Doc. J. Barbier/I. Ebran/Gargouille Productions)

The CRV preparation starts at 9mn 13s. Here the second anti roll rod is installed at 10mn 05s followed by the turning on of the 4 flashlights. (Helmet camera)

Lucie measures the angle between the entrance tunnel and the Siphon passage (doc. J. Barbier/I. Ebran/Gargouille Productions)

Lucie measures the angle between the entrance tunnel and the Siphon passage and announces "70° on the right" at 9mn 58s. (Doc. J. Barbier/I. Ebran/Gargouille Productions)



Measured distance from the cave entrance reported on a map as well as the angle of the Siphon passage. The 70° value seems too high and should have been closer to 45°. But the Siphon passage being in the dark and turning, the orientation given may be the first meters orientation. (Doc. J.P. Viard + modifications APM)

CRV wheel rotation to find the hole to hook the anti roll rod safety fixation (doc. J. Barbier/I. Ebran/Gargouille Productions)

Turning on the first flashlight: two unsuccessful attempts with the right thumb on the lateral switch at 10mn 51s (helmet camera)

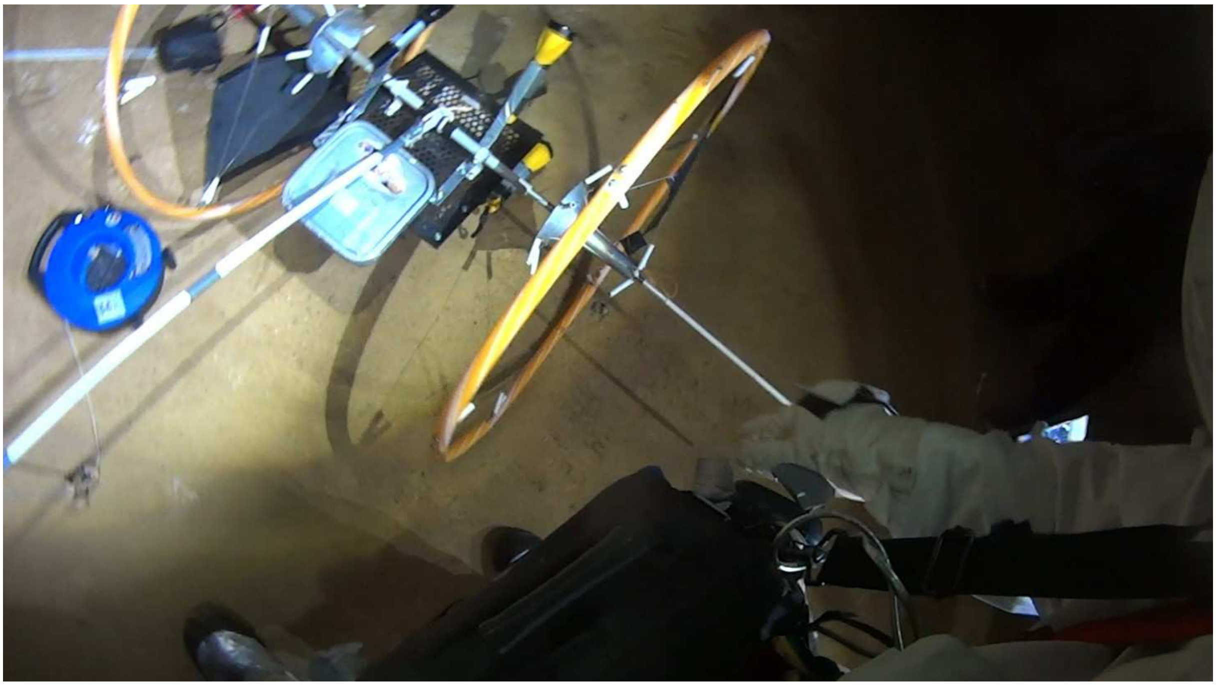
And success using the spike or lug on the left hand index. These spikes are used to fix a small prolongator « dexterity improvement" but by themselves they can be used for a simple action as this one. (Helmet camera)

Views of the two sides of the left glove with the spikes used to fix prolongators. These prolongators stored and fixed by Velcro on the upper part of the glove, under a protective clothe, were not used during the simulation. (Doc. A Souchier)

Four left hand index spike actions are then needed to turn on the second flashlight (rear push switch) towards 11mn 08s but a fifth action (why ?) shuts it off. At 11mn 18s the third flashlight is turned on with only one thumb push on the lateral switch. The fourth one is then turned on at 11mn 22s with one thumb push on the rear switch. On this picture at 11mn 23s, the two lower flashlights are visible as well as the Sygonix Hazcam fixed on the Bescor + ou – 170° sweeping mechanism. Then 20 s are needed to set on the Bescor. The Gargouille Productions video shows that the activation was obtained with the thumb without use of any spike. The Bescor switch is relatively small (5 mm by 3 mm width and protruding only by one mm). It has to be slid laterally to activate the sweeping mode. (Helmet camera)

Returning the CRV plate to initiate the Bescor operation (doc. J. Barbier/I. Ebran/Gargouille Productions)

The Bescor is started without needing a finger spike (doc. J. Barbier/I. Ebran/Gargouille Productions)



Walking around the CRV at 12mn 22s to set on the two video box emission (grey square) switches (helmet camera)

At 12mn 30s activation of the video emission box first switch with the right hand spike. At 12mn 33s the second switch is activated in the same way. (Helmet camera)

At 12mn 51s attempt to open the reception box with the right hand index and medium fingers without success (helmet camera)

A second attempt is conducted with two fingers ending with an attempt to use the RCA spike at 12mn 52s which causes the spike pull out because it is not designed to operate under a lateral force (helmet camera)

At 12mn 53s the excessive lateral force has pulled out the RCA spike. Two new attempts with the right hand medium finger and one with the right hand medium finger and thumb are then conducted without success before succeeding at 13mn 18s with three fingers of the left hand. Thus 5 operations and 27s were needed to open the box. (Helmet camera)

At 13mn 19s the reception box is opened. Alain gives the receiver to Lucie in order to set it on (helmet camera)

At13mn 34s Alain connects the 12V on the TV monitor in two attempts. Lucie indicates that there is no "on" light on the receiver. Two attempts on off are then conducted unsuccessfully. At this time the yellow video connector is not yet connected but the activities shift from « CRV preparation » to « failure mode search ». (Helmet camera)

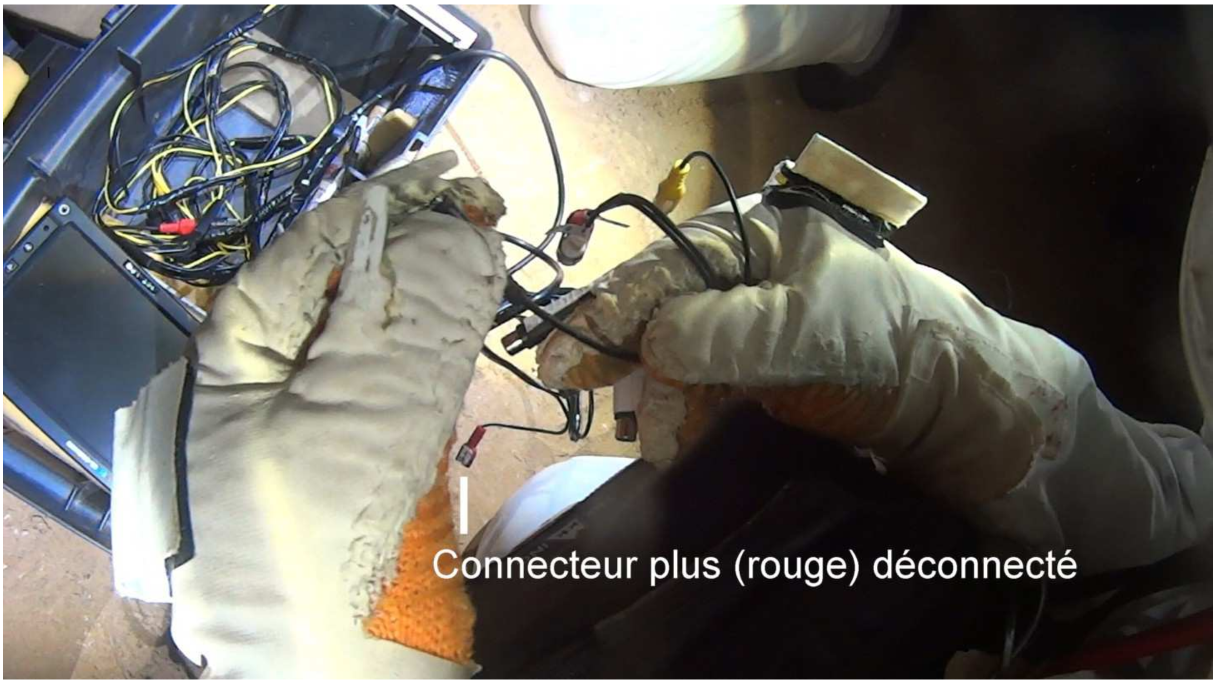
The CRV preparation has lasted 5mn 12s, including the hammering of the safety pole. The total duration of phase 2 is 6mn 21s.

4-3 Video failure origins search

At 13mn 44s first attempt "off on" by Alain using the RCA spike on the right glove. The receiver switch is activated by lateral motion. (Helmet camera)

At 13mn 49s Lucie starts a "off on" cycle. The failure is already visible on this picture (white arrow); only the black connector (-) is connected to the 12 V battery. The red connector (+) is disconnected. (Helmet camera)

The failure origin is already visible on these pictures from 12mn 57s and 13mn 13s. But the anomaly will only be discovered when returning from the Siphon passage and cavity 46 exploration. The CRV will be sent back in the slope to show on the video monitor the lower part of the Siphon passage as initially planned. (Helmet camera)



The red connector (+) appears clearly disconnected on this picture at 13mn 26s (helmet camera)

At 14mn 03s connection of the video reception line to the video monitor on the first attempt (helmet camera)

And naturally at 14mn 10s no picture appears on the screen. Diagnostic at 14mn 18s: « no 12 V ». The diagnostic is right but Alain interprets too quickly that the 12V battery has been accidently depleted during the transport. The disconnection at the battery level is not a known failure mode. A new attempt of setting "on" the video monitor is conducted. The video connections V1/V2 and 12V PM1/PM2 on the monitor are checked. A third attempt "on" on the monitor is conducted. Unfortunately a multimeter as used during the hardware checks was not available. With a multimeter a right diagnostic could have been elaborated. The battery voltage check is conducted either at the battery interfaces (where the disconnection would have been seen) or at the charging interface where a zero voltage would have been measured. When the battery is depleted there is always a small voltage remaining and a zero value would have indicated a disconnection somewhere. At 15mn 13s Alain says that the CRV test will be conducted only checking that the vehicle is not falling in a hole at the end of the slope. This situation would be detected on the rope

tension. Naturally, it is already known that there is no hole at the Siphon slope end. (Helmet camera)

The video failure search phase was rather short : 1mn 49s

4-4 Siphon passage reconnaissance by the CRV

This phase starts at 15mn 23s by carrying the Cliff Reconnaissance Vehicle, the CRV, to the upper part of the Siphon passage slope. The Petites Dales cave has the general configuration of an horizontal tunnel in zigzag, being a former underground river. But its geometry (not the geology) could be assimilated to a lava tube. However, close to the entrance (at 27 m) starts a slope on the right which has been designated the « Siphon passage ». The slope is not steep but a rope has been installed to help visitors going down or up. The slope end is not visible from the upper part because the passage is turning to the left. The exploration scenario was thus to send the CRV in the slope in order to check that the slope was not getting steeper and steeper, ending in a hole, before sending the explorers in this slope.

The CRV operation was the 124th use or test of the vehicle. The last tests were conducted in Utah during the MDRS 164 simulation around the Mars Society habitat in February and March 2016.

At 15mn 31s Lucie stores again the protractor in the lateral pocket of Alain's bag (helmet camera)

At 15mn 56s the vehicle is in front of the Siphon passage slope which may be seen on the right (helmet camera)

The CRV ready for the Siphon passage reconnaissance. Descent is started at 16mn 20s. First Alain's comment a 16mn 26s: « I am not sure we shall be able to pull it back" (because of the turn at the slope end). And also despite the passage narrowness, the vehicle has been equipped with two anti roll rod halves (50 cm on each side) in order to avoid a tipping over on the wheel side which would be a delicate situation. The counterpart is that the anti roll rods may contact the passage sides, blocking the vehicle when going down or up. (Doc. J. Barbier/I. Ebran/Gargouille Productions)

The CRV as seen from a spot down slope. The CRV is going down camera and lights oriented downward which is the opposite of the normal use where we aim at observing the slope or cliff wall. There we are aiming at looking at what is in front of the vehicle. As indicated in the previous § the video is not operating and the test aims only at checking that the vehicle does not fall in a hole. (Doc. J. Barbier/I. Ebran/Gargouille Productions)

Some meters in the slope (doc. J. Barbier/I. Ebran/Gargouille Productions)

(Doc. J. Barbier/I. Ebran/Gargouille Productions)

Descent monitoring. The safety pole has been placed as far as possible on the right because of the slope turn to the left. (Doc. J. Barbier/I. Ebran/Gargouille Productions)

The slope inclination to the left is visible on this picture. It is going to deviate the CRV trajectory to the left. (Doc. J. Barbier/I. Ebran/Gargouille Productions)

At 16mn 47s the 5 m mark on the rope is reached. At 17mn 00s when the distance reaches 7,5 m two small 40 cm pulls are conducted to free the vehicle. Comment: « Askew, no, no more! ». At 17mn 13s new comment : «it is very askew » with, at 8,5 m distance, two new 40 cm pulls. At 17mn 19s : « It is going to tip over" with one 80 cm pull at 9 m distance. At 17mn 25s: "It is stuck" with a pull from 9,5 m to 8,2 m. (Helmet camera)

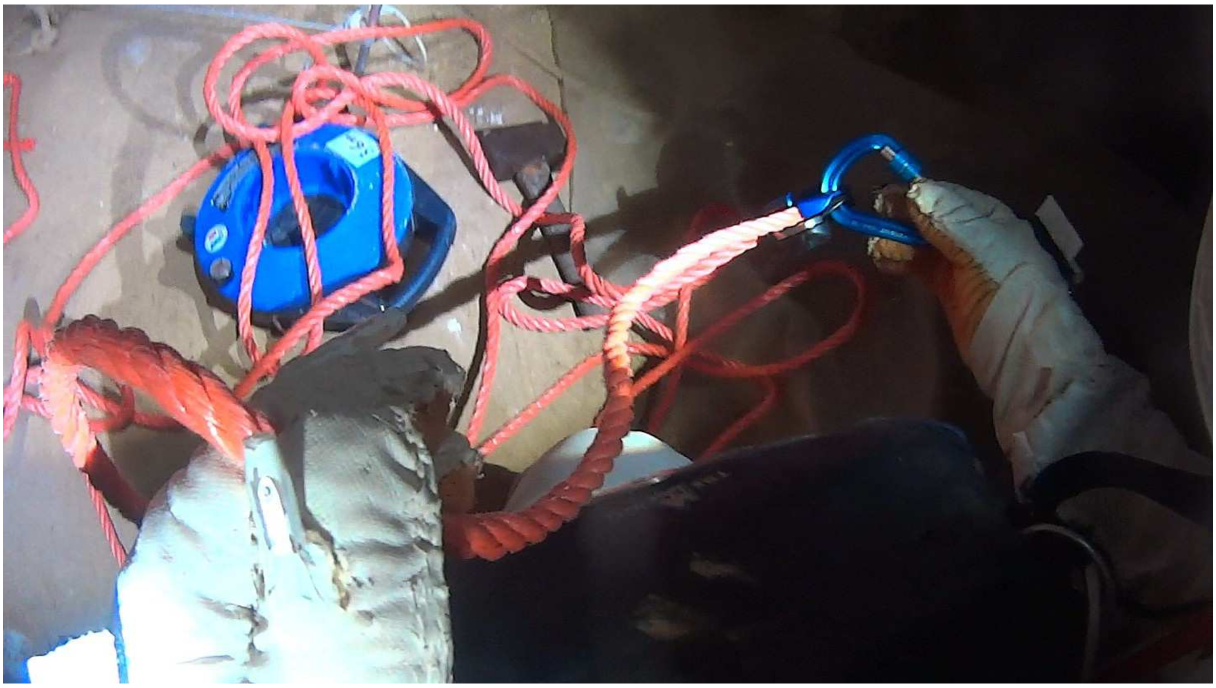
At 17mn 35s the 10 m mark is reached. At 17mn 38s: "It looks stable" with a pull back from 10 to 9,3 m. (Helmet camera)

At 17mn 43 crossing again the 10 m mark then pull back to 8,2 m: "let it go again". (Helmet camera)

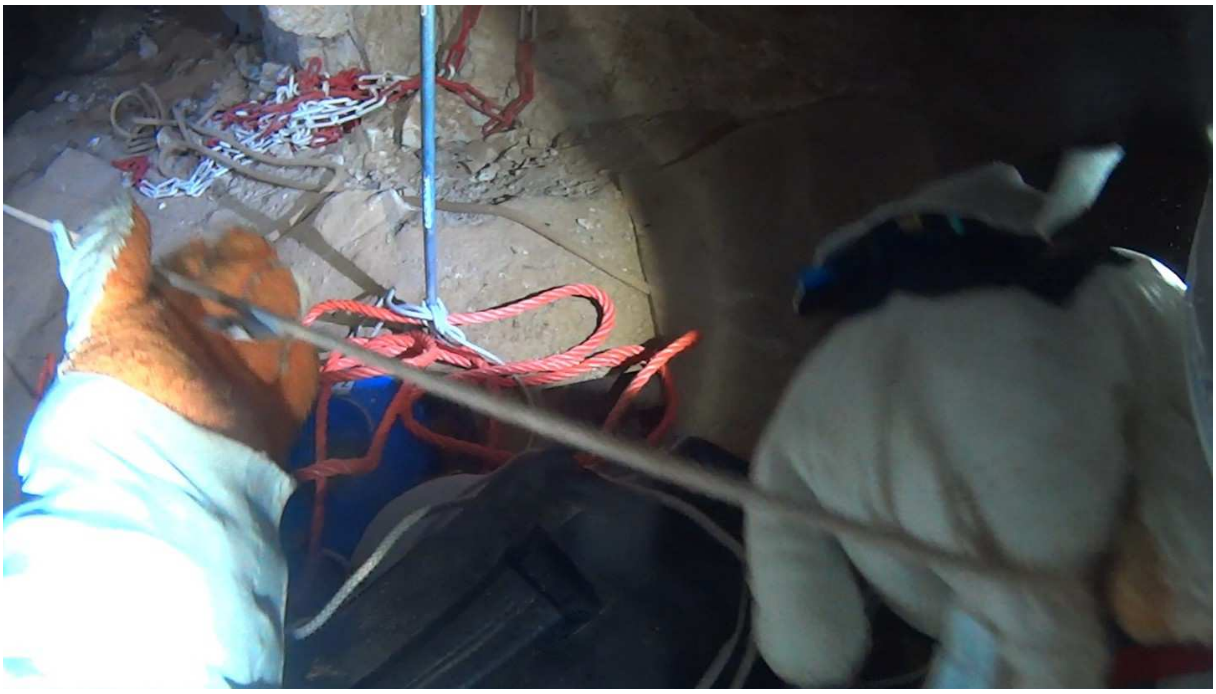
At 18mn 10s crossing of the 11 m mark and the rope tension decreases (helmet camera)

From 18mn 23s to 18mn 40s a double knot is done to tie the rope on the safety pole. Comment at 18mn 48s: "Let us say, as the CRV has not fallen in a hole, that we can go". Then Alain opens his left lateral bag to extract the rope. (Helmet camera)

Tying the CRV rope to the safety pole (doc. J. Barbier/I. Ebran/Gargouille Productions)

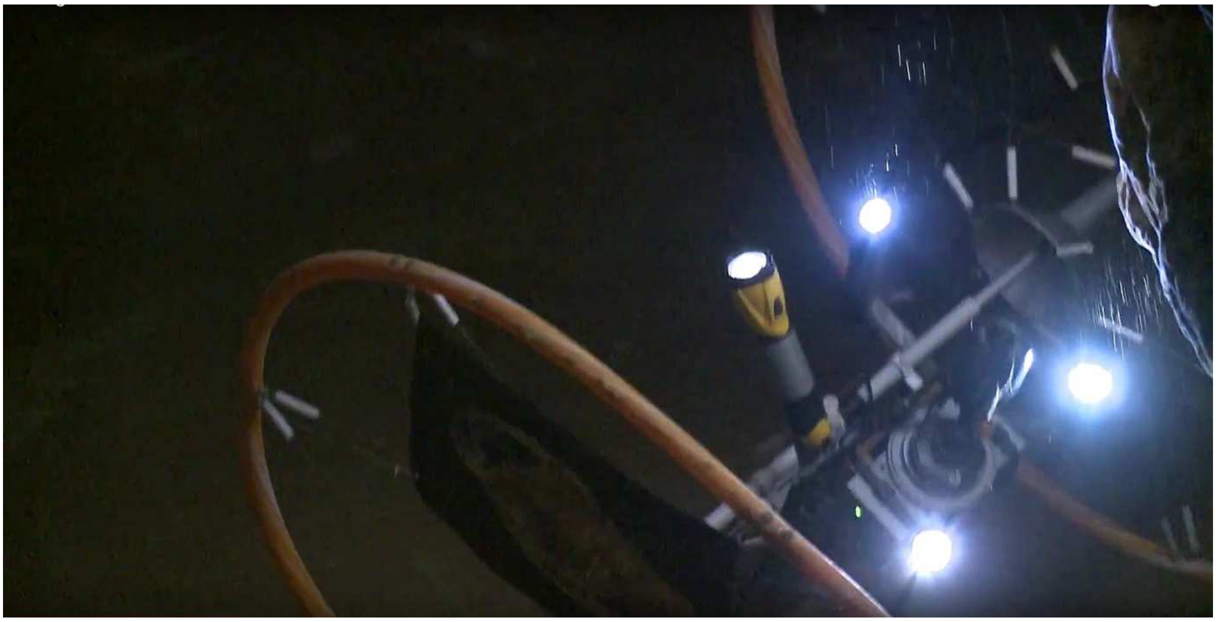


At 19mn 39s the rope is extracted. The descender was fixed on the rope prior to the simulation in order to avoid this operation in sim. At 19mn 38s one media team asks if it is possible to pull back the vehicle to shoot views from down slope. The vehicle is pulled back at 19mn 48s. Alain indicates that it can be part of the simulation because a verification that the vehicle could be brought back up slope was planned. At 20mn 02s and 9 m distance, a difficulty is mentioned but the ascent can be pursued. 8 m is reached at 20mn 48s. The Youki Vattier video team goes down at this time. At 21mn 44s, a spectator comment: "It is the anti roll stabilizer which deviates the vehicle". (Helmet camera)



At 22mn 00s the rope is pulled back till 5m. Alain's comment 3s before : "It is going to go through, but, there, it is thanks to the anti roll rod that it did not tip over". At 22mn 04s, at 4,5 m distance : "Do I send the vehicle back ?". (Helmet camera)

At 22mn 13s, rope manipulation (out of the field of view on the left) from a location left from the safety pole to try to orient the vehicle to the right in the slope. At 22mn 15s, around 6 m: « There, it is blocking». A pull up of 30 cm is conducted and, after releasing the rope, the descent is started again. (Helmet camera)



On this view taken from the slope lower part, the CRV has a wheel stuck on the left side of the siphon passage (as seen from above) but it is practically at the slope end. (Doc. J. Barbier/I. Ebran/Gargouille Productions)

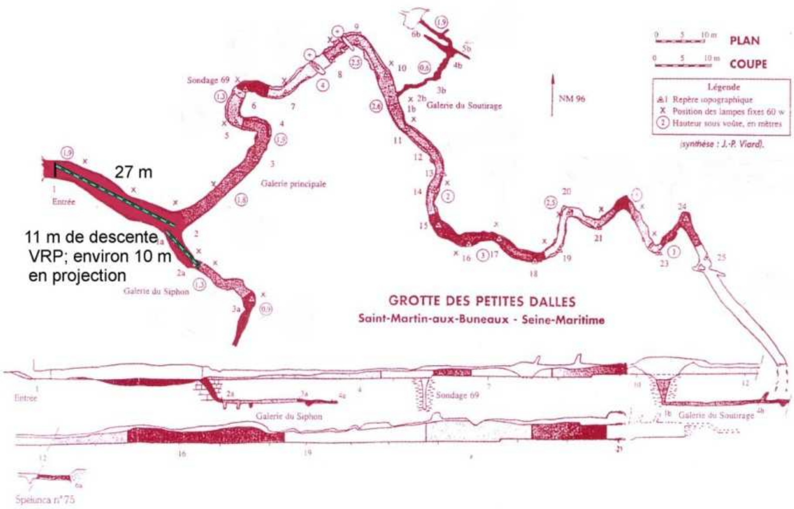
At 22mn 29s, at around 10 m, two pull ups of 65 cm are conducted followed by a comment: "Ah, here it is, it is upside down". The rope is then released till its knot on the safety pole at 11 m. (Helmet camera)

The vehicle presents a strong yaw angle following the anti roll rod and wheel contact with the passage left side on this picture taken from down slope. After some tractions and releases on the rope, the vehicle rotates by 180° in yaw, camera and lights oriented up slope. (Doc. J. Barbier/I. Ebran/Gargouille Productions)

At 22mn 33s the rope is released. End of the CRV utilization phase. (Helmet camera)

The CRV reconnaissance phase in the siphon passage slope has lasted 7 mn.

As foreseen the slope configuration in a left turn and canted on the left was not easy to manage, even with the anti roll length reduction from one meter to 50 cm. As suggested before, the vehicle could be equipped with two ropes which would allow some steering during the descent. This configuration was not tested till now because it is useless in normal use on vertical or steep slopes. The normal operations would even be complicated and the storable rope length in the container would be divided by two. But it would be useful when coming up from an overhang by keeping the vehicle in the right position. It is an interesting configuration to be tested in coming operations.

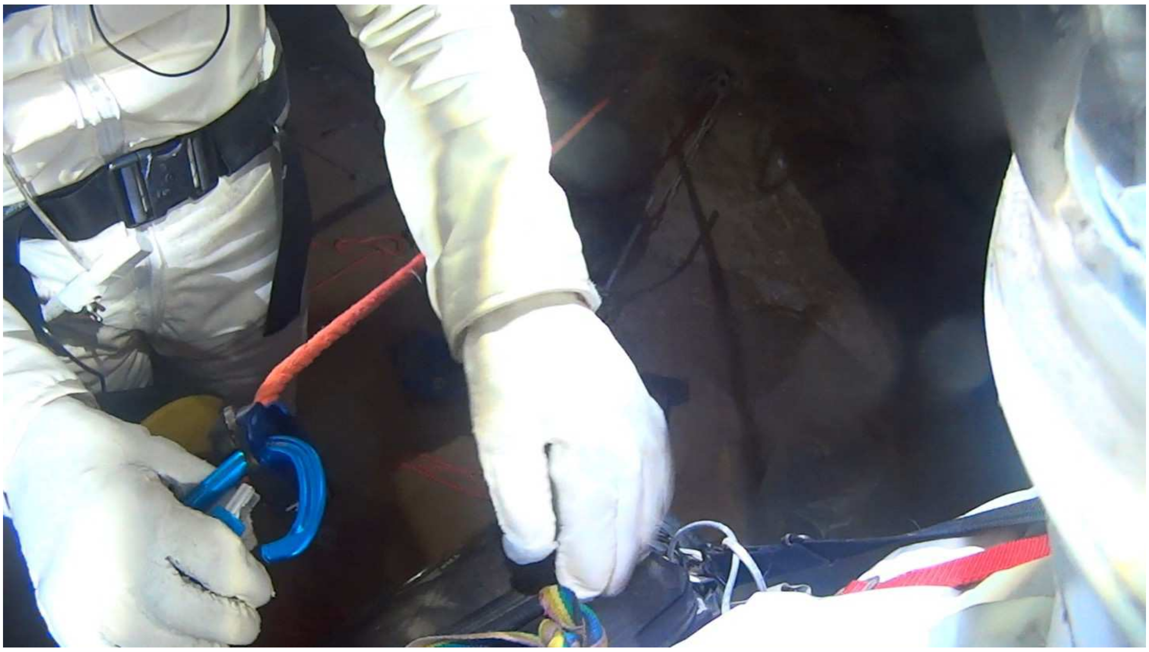


Reporting the position reached by the CRV in the slope on the cave map (doc. J. P. Viard, additions by APM)

<u>4-5 Going down the Siphon passage</u>

Tying the rope for the descent using an existing ring at 23mn 34s, after sliding the rope in the descender to get enough length to make a knot. At 24 mn 12s Alain indicates an internal temperature of 33°C and replaces the temperature dial on the left Velcro because it was loose. (Doc. J. Barbier/I. Ebran/Gargouille Productions)

After freeing more rope length Alain gives the rope to Lucie at 24mn 26s. Lucie ties the descender to Alain's harness. (Doc. J. Barbier/I. Ebran/Gargouille Productions)



The harness snap hook was previously equipped with a small tether loop to facilitate the descender hooking. If the descender is to be attached by the harness wearer himself, the harness snap hook is not visible through the spacesuit helmet (too close to the body). In the same way to unhook the descender it is fairly wishable to be able to see it. This configuration was tested during the « Black Cows » simulation in 2014. When the descender is hooked by another person the direct tying to the harness snap hook is possible but as Alain says at 24mn 57s : « It will be easier for me to unhook when I will be down slope". (Helmet camera)

The descender snap hook tied to the tether loop, itself tied to the harness snap hook (this last junction being prepared before the simulation). (Doc. J. Barbier/I. Ebran/Gargouille Productions)

Beginning of descent at 25mn 16s, still standing up (doc. J. Barbier/I. Ebran/Gargouille Productions)

At 25mn 21s, three attempts to catch and open the descender lever which commands the rope release (helmet camera)

Always in the leaning position taken by normally suited visitors descending the passage, but soon it will be necessary to kneel down (doc. J. Barbier/I. Ebran/Gargouille Productions)

With the spacesuit and its voluminous back pack and to manipulate the descender, it is necessary to conduct most of the descent kneeling down (helmet camera).

(Doc. J. Barbier/I. Ebran/Gargouille Productions)

Lucie is guiding from up slope, indicating that Alain should go on his right to beneficiate of the passage maximum height (doc. J. Barbier/I. Ebran/Gargouille Productions)

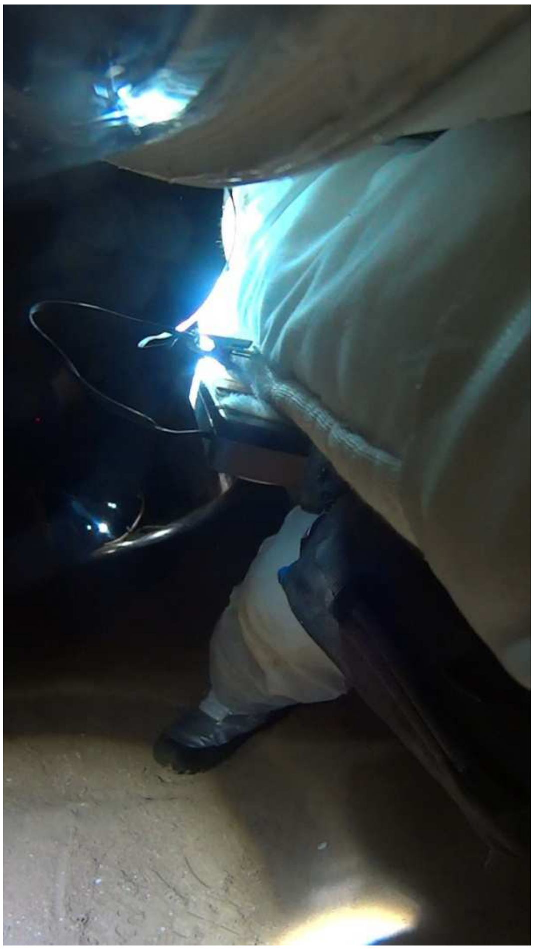
The mammoth drawing on the cave wall is not prehistoric! (Doc. J. Barbier/I. Ebran/Gargouille Productions)

Going down kneeling down at 25mn 42s (helmet camera)

The way visitors are going down the Siphon passage without need to kneel down (here during the 2014 reconnaissance). The slight turn on the left which precludes seeing the end of the slope from the upper part is clearly visible on this picture. (Doc. A. Souchier)

In some phases standing up or only one knee on the ground is possible. Alain is getting close to the CRV. (Doc. J. Barbier/I. Ebran/Gargouille Productions)

Short body rotation to have a look down slope (doc. J. Barbier/I. Ebran/Gargouille Productions)



The CRV down slope as seen from the helmet camera at 26mn 19s (helmet camera)

Alain's comment at 26mn 58s : « There I see down slope. It is flat after the slope ». (Doc. J. Barbier/I. Ebran/Gargouille Productions)

The descent has lasted only one minute and thirty seconds. From 27mn 50s to 28mn 27 the descender is detached starting by releasing some rope length. Unscrewing the safety device on the snap hook is easy. On this picture may be seen the advantage of the intermediate tether loop which allows to see the descender snap hook for the disconnection operations. (Helmet camera)

At 28mn 52s the CRV is set on the side to free the passage, after retrieving the two anti roll rods. Alain tells to Lucie that she can go down. (Helmet camera)

Lucie is going down with the Ariadne thread container tied to her belt. Being without harness, she uses the rope installed for the visitors, the slope being not too steep. (Doc. J. Barbier/I. Ebran/Gargouille Productions)

Without being obliged to manipulate a descender, Lucie is able to descend without kneeling down (doc. J. Barbier/I. Ebran/Gargouille Productions)

(Doc. J. Barbier/I. Ebran/Gargouille Productions)

In order to take a picture of Lucie's arrival, the Canon EOS 7D camera is extracted from the bag without difficulties by Alain at 29mn 13s. Here at 30mn 30s the camera is set on the flash mode by turning the left knob. The photo is taken at 29mn 36s at guesswork but with the camera at eyes level. (Helmet camera)

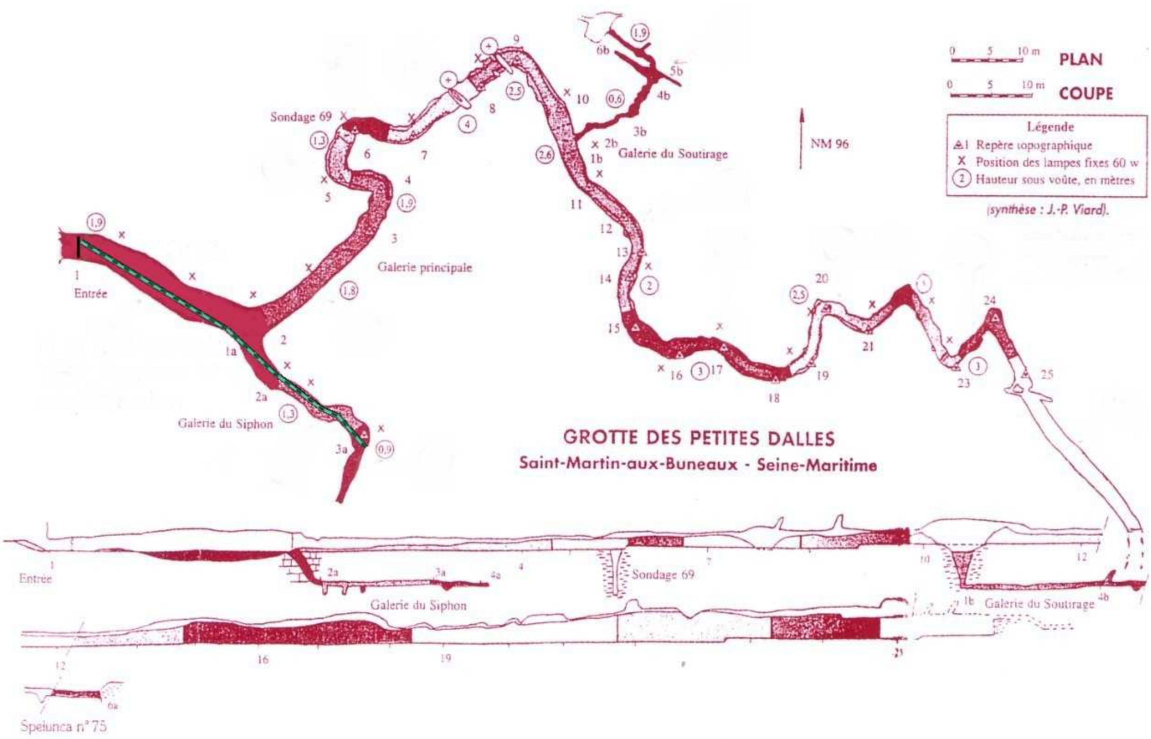
Photo « in simulation » of Lucie's arrival seen from down slope at 15h 34mn. This first picture « in sim » enables to define the absolute time of the helmet camera (15h 02mn) and of the cave entrance gate crossing (15h 04mn). (Canon EOS 7D, Alain in sim)

Alone on Mars in a cave?... (Canon EOS 7D, Alain in sim)

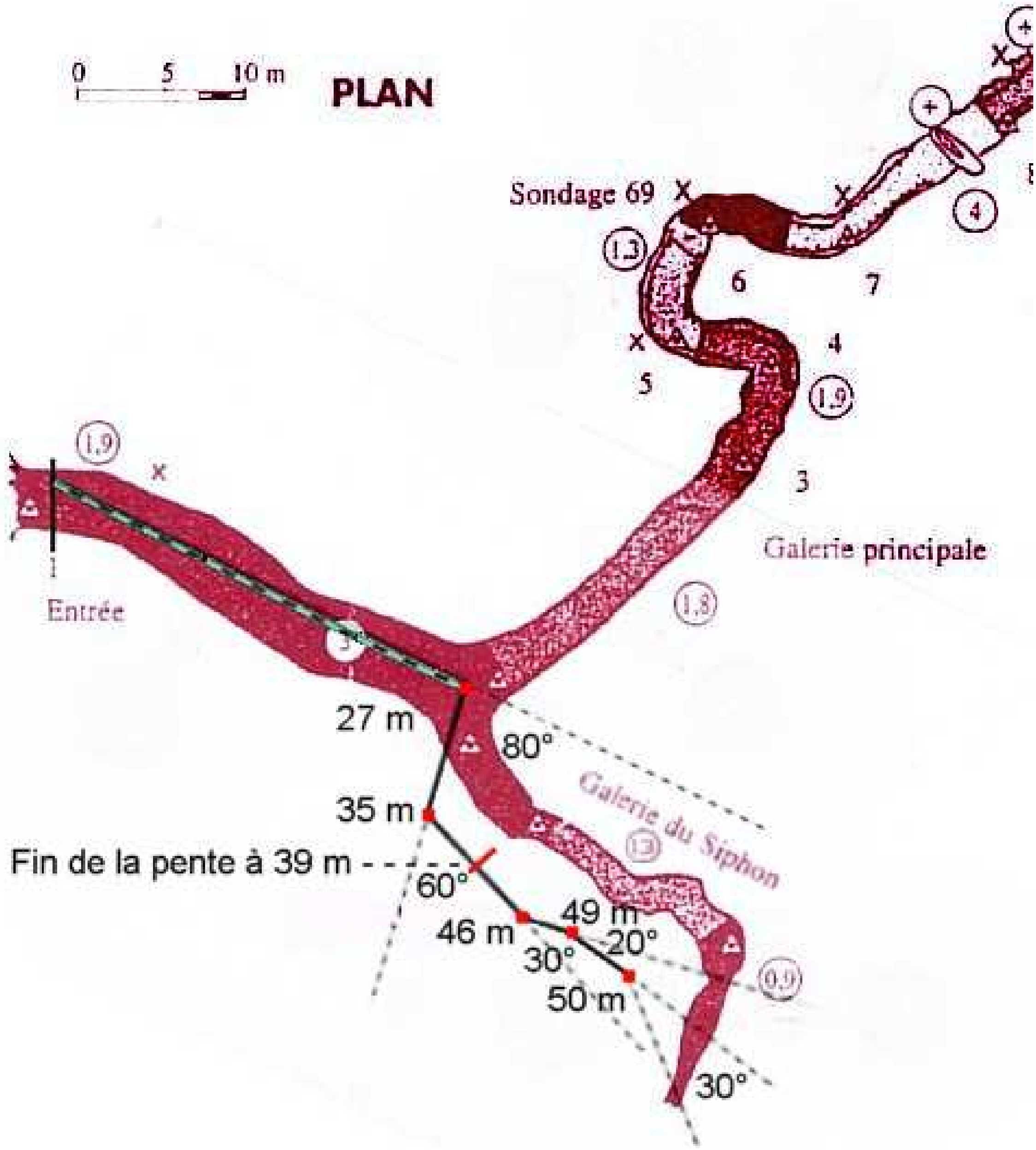
...Not really because observed by the two cameras of Youki Vattier and Jonathan Barbier (association member) teams. This picture was taken at 30mn 01s. (Canon EOS 7D, Alain in sim)

The photo at 30mn 01s was taken at guesswork. Soon after Alain announce: « The mysterious tunnel continues. We are progressing where man's hand has never set a foot" At 31mn 06s the Canon camera is set off with two attempts of the left thumb (small lever under the left knob) and the camera is stored back in the bag. At 31mn 34s the edge of the so called piezo pit is reached. (Helmet camera)

At 32mn 44s Lucie climbs down in the small piezo pit (upper left). Alain is waiting seated on the grid which closes the piezo well. At 33mn 08s the distance indicated for the well from the entrance gate is 51 m. At 33mn 21s, Lucie adjusts Alain's helmet U shaped fixations on the two horizontal rods linked to the back pack, operation which takes32s. (Helmet camera)

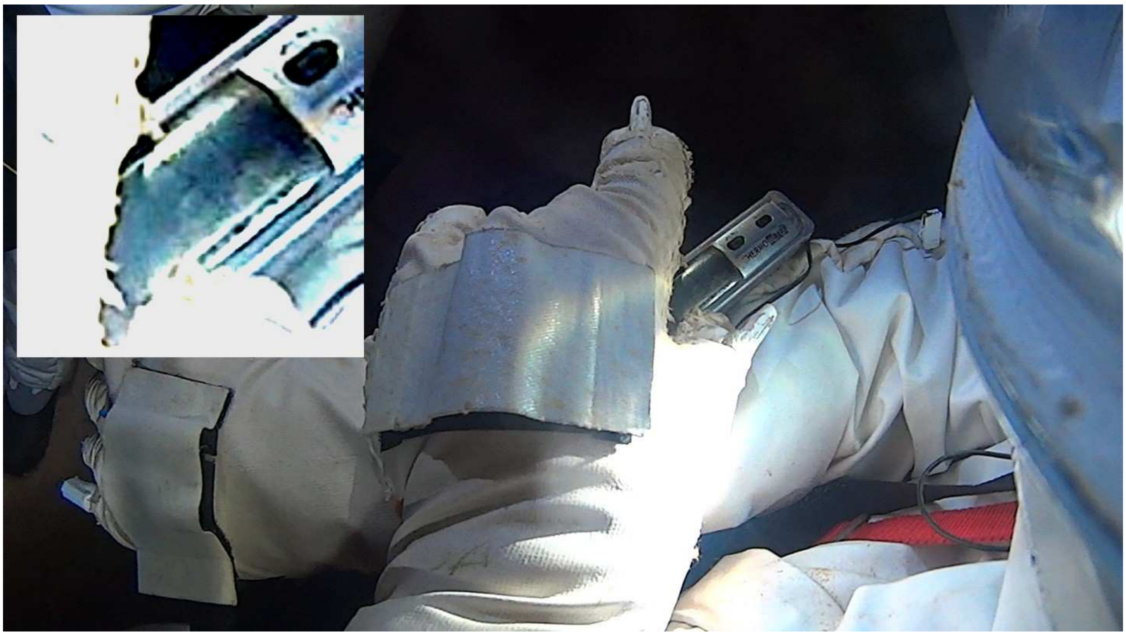


51 m from the cave entrance reported on the cave map. In fact 50 m were taken horizontally to take into account the siphon passage slope.(Doc. J. P. Viard, APM modifications)



The measures taken by Lucie till the piezo pit are reported on this map. The localization error reaches 6 m or 10%. The error comes mainly from the angles measurements as was foreseen. In a first step the Siphon passage angle with the main tunnel was indicated at 70° instead of 80°. If we take this value the piezo pit localization is given with a 2.5 m error or 5%. (Doc. J. P. Viard/APM modifications)

The piezo pit is the limit allowed to visitors in the Siphon passage (picture taken during the 2014 reconnaissance). The three visitors are here at the bottom of the slope which goes down from the main tunnel and is hidden by the passage turn. The bags are useful to avoid the pit wall tumbling when the water level rise in the pit. (Doc. A . Souchier)



At 33mn 51s the internal Alain's spacesuit temperature is at 33,1°C, stable since the last measurement. The indications having shifted in Farenheit, the left index spike is used to push on the small switch which controls the screen indications. At 33mn 59s Lucie remarks fog on Alain's helmet inner upper part. Answer : « It is OK at eyes level, I put less soap on the upper part. It is interesting. There is no fog in front and some fog in the upper part". (Helmet camera)

The Siphon passage descent and access to the piezo pit, including the distance measurement ends towards 34mn 20s and has lasted 11mn 57s.

4-6 Passage to cavity 46

The EVA continues by the passage in a low ceiling (around 90 cm) tunnel going to the cavity 46 (lighted in the far distance). The cavity 46 is a diaclase enlargement by water flowing a long time ago. The distance is 17 m. This picture was taken during the 2014 reconnaissance. (Doc. A. Souchier)

The objective: a cavity 13 m long, 2,2 m wide and 4,5 m high (doc. A. Souchier)

At 34mn 21s Alain unhooks the Ariadne thread spool from Lucie's belt to facilitate the crawling progression to the cavity 46. Alain indicates that he intends to make a distance measurement to the cavity 46 with the laser range finder. At 35mn 35 s Lucie proposes to detach Alain's belly bag to also facilitate the crawling. But the bag tethers are under the back pack and the operation may be difficult. The range finder is extracted from its bag at 35mn 47s. (Helmet camera)

Alain's comment at 35mn 44s : « If I understand well, there is 17 m; 17 m on all fours". In fact it will be more difficult than initially foreseen. At 36mn 04s, Lucie proposes again to unhook Alain's bag by unleashing the two lateral hooks; Alain fears that if only one hook can be released, the situation would be problematic. At 37mn 45s: « If they are there (the video team in cavity 46), I will not be able to do the laser measurement. I am not going to shoot at them with the laser ». (Helmet camera)

At 38mn 17s Lucie puts back in the right position the right Alain's helmet flashlight which was interacting with the helmet supporting rod. (Helmet camera)

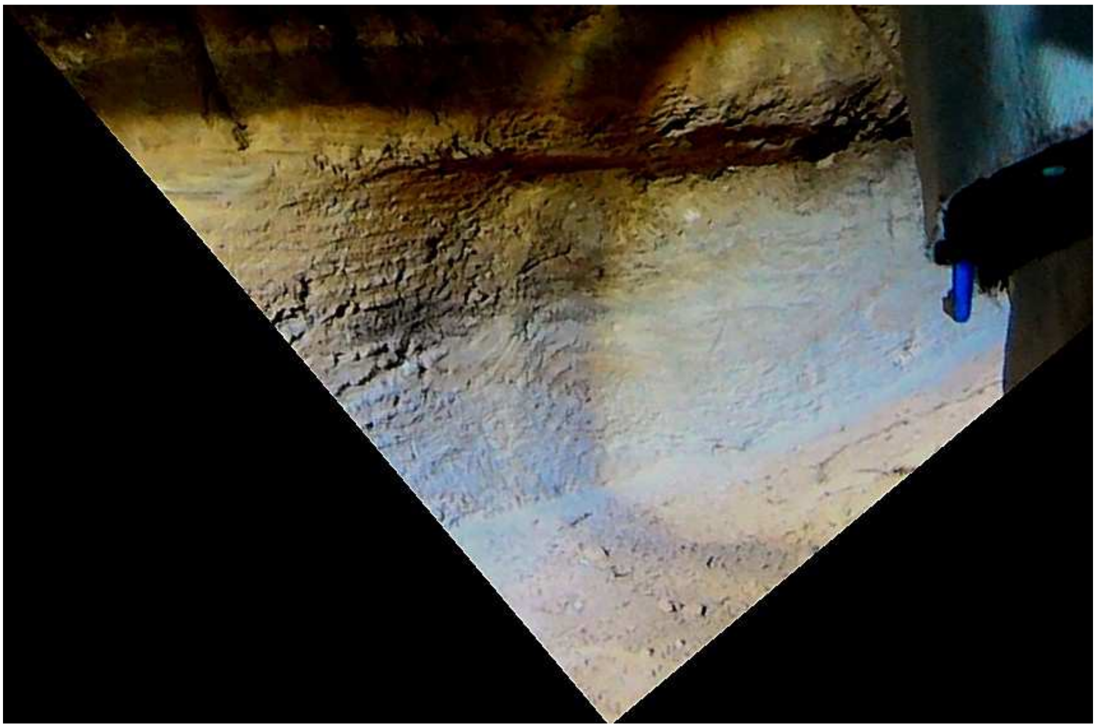
Alain is still holding the laser range finder, here at 39mn 57s seen from the laser beam side as indicated from the indication "warning". At 40mn 09s : « I am going to store back the range finder because I will not send laser beams to the cavity 46". At 40mn 46 the range finder is stored back in its bag and the bag is closed. At 40mn 52s: « Lucie you go in front. I am… more bulky; I may be stuck before you". There was around 4 mn waiting in the piezo pit to let the video teams (Youki Vattier and her cameraman and Jonathan barbier for APM and Gargouille Productions) reach the cavity 46. (Helmet camera)

Lucie enters the narrow passage at 41mn and chooses to crawl on belly side. The passage height measures 90 cm. The back pack being 45 cm wide, this allows, on this picture, a good verification of the passage height. The back pack thickness amounts to 34 cm which let 56 cm for the body crawling. (Doc. J. Barbier/I. Ebran/Gargouille Productions)

At 41mn 49s Alain follows but is crawling on his left side, probably because of the belly bag. (Doc. J. Barbier/I. Ebran/Gargouille Productions)

On the left at 41mn 58s still close to the piezo pit (white bags), then on the right at 42mn 21s (helmet camera)

Thin alluvia layers appear on the passage side (view at 43mn 34s).These thin layers indicate deposits in a very slow flow. This passage was totally underwater thus the name Siphon passage. (Helmet camera)



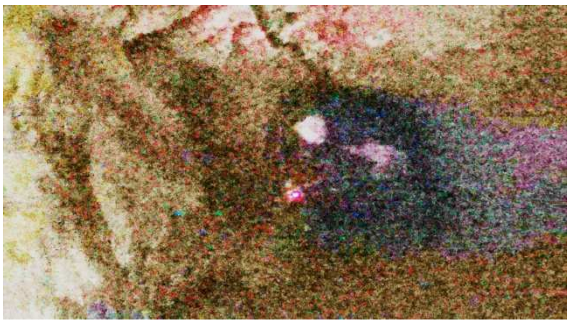
The thin alluvia layers at 44mn 14s (helmet camera)

The thin alluvia layers at 44mn 41s (helmet camera)

At 45mn 22s (helmet camera)

Zoom on the previous picture layers. One of the rulers could have been extracted to give a scale on this picture but the priority was to reach the cavity 46. (Helmet camera)

At 46mn 20s (helmet camera)



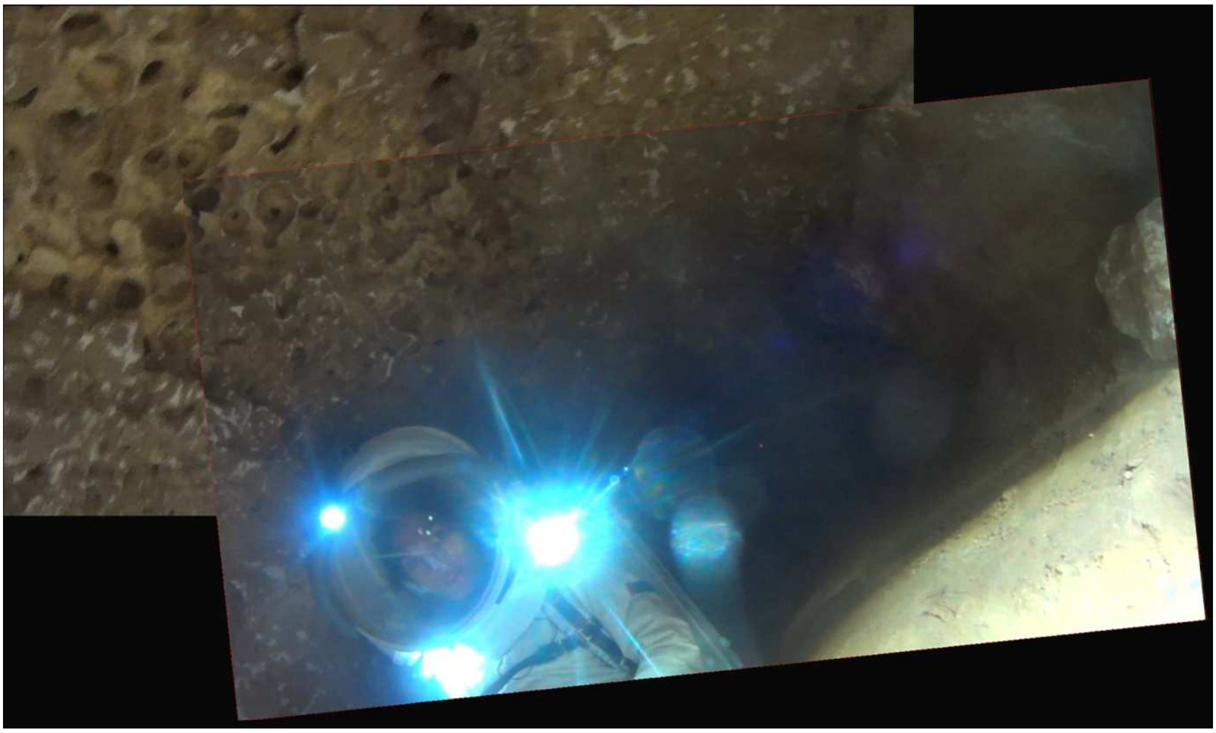
We are followed by Isabelle Ebran filming for Gargouille Productions (45mn 45s) (helmet camera)

Crawling is very harsh for the simulation spacesuits as well as for the operators. At 46mn 51 s Alain announces «I am loosing the camera», then at 46mn 54s «I have lost my glasses», then at 47mn 02s «I have no more ventilation», then at 47mn 37s «I have lost my helmet". All this at less than 2 m from a small zone where the ground is lower which allows to be seated and where Lucie is waiting. Picture taken at 48mn 08s. During « nominal » simulation operations, it happens that the glasses are slipping from the nose. They are then brought up by pushing on the left and right ventilation inlets. During the Utah simulations the drinking tube was used for this utilization. In the crawling configuration the method is useless. The glasses should be attached behind the head with an elastic band. (Helmet camera)

Lucie is seated in the area where the ground is slightly lower and is located 5 m from the cavity 46 which means 12 m from the passage inlet. Picture taken at 48mn 54s. (Helmet camera)

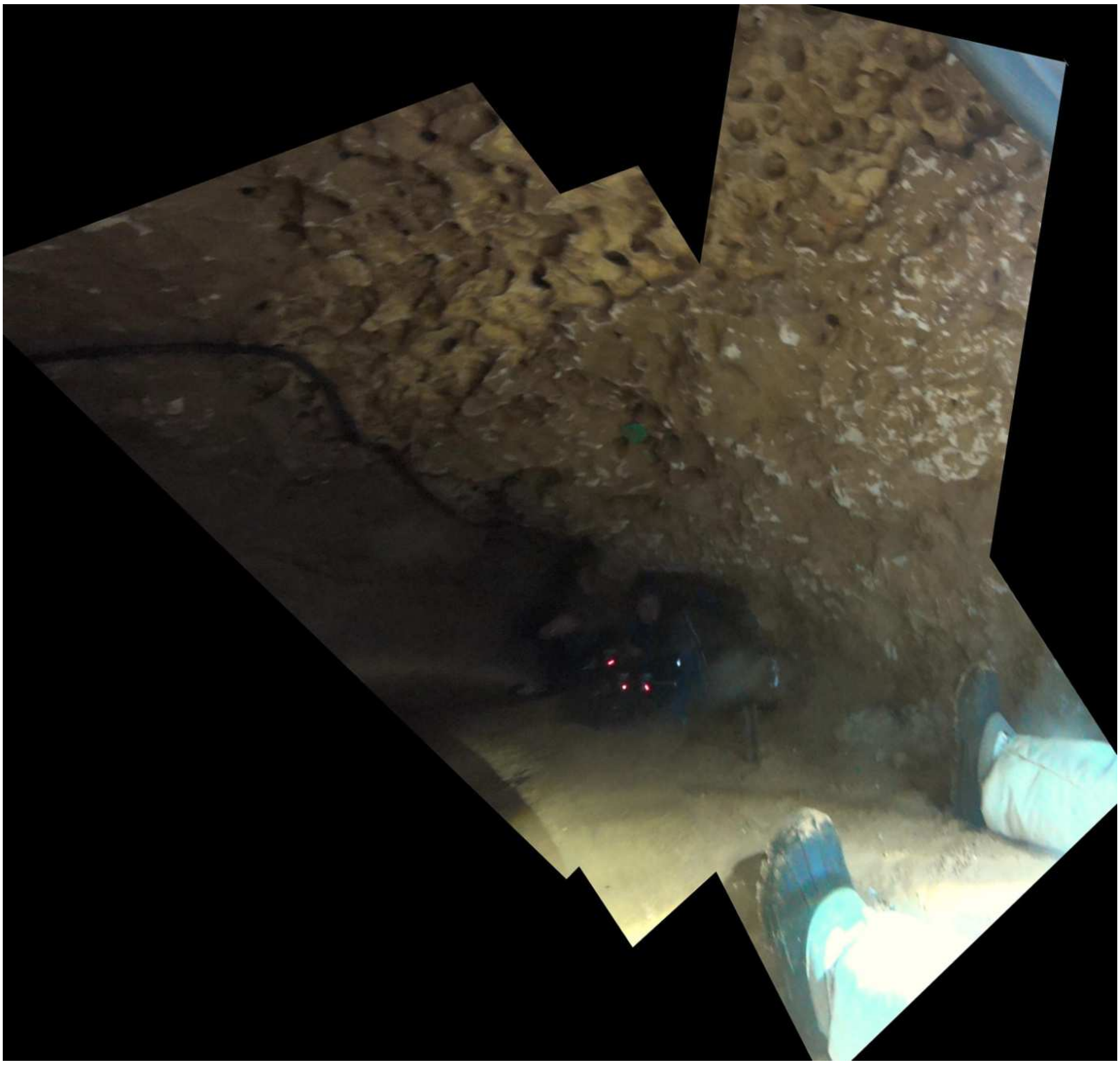
At 49mn 04s Alain is nearing the zone where Lucie is waiting (helmet camera)

49mn 10s: it is not full comfort but close to it (helmet camera)



49mn 24s (helmet camera)

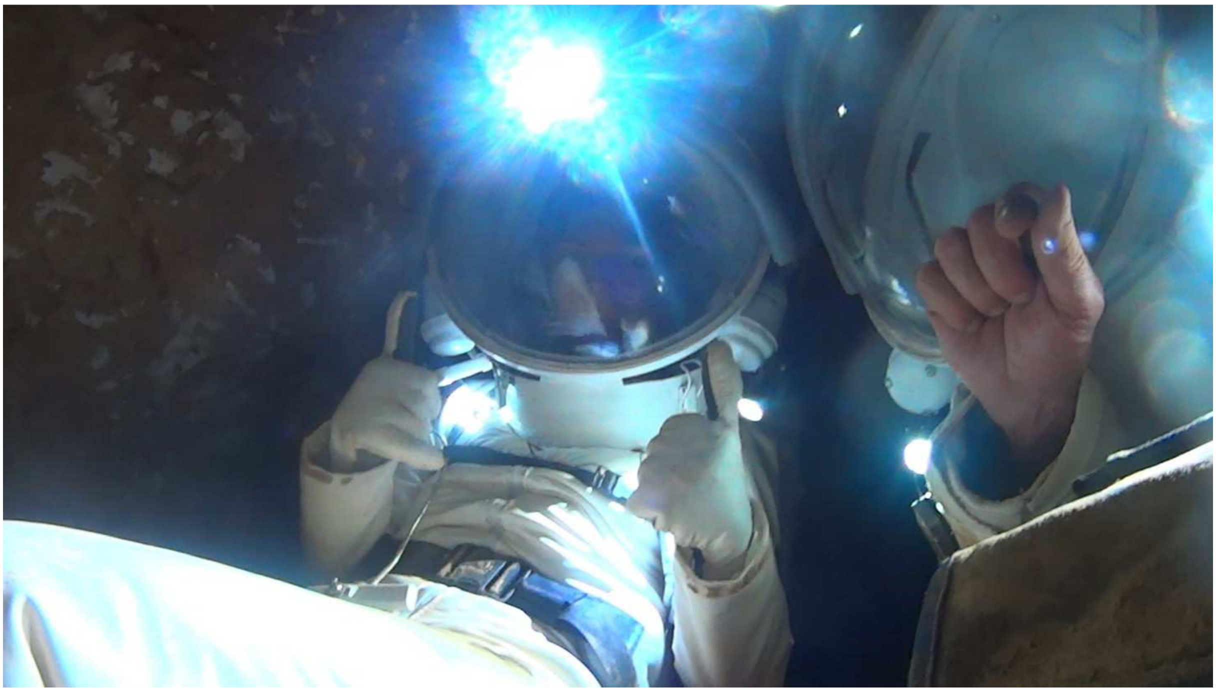
49mn 30s (helmet camera)



At 49mn 47s, Alain has reached the small larger and higher area. Behind Isabelle Ebran from Gargouille Productions is filming. (Helmet camera)

Back in simulation configuration for Alain. Picture at 50 mn 01s. The gloves are removed shortly after. (Helmet camera)

50mn 41s: Alain out of sim (helmet camera)



Picture at 50mn 49s. The camera is screwed again on its support. The ventilation is switched on. The glasses and the helmet are put back in place with Lucie's help. (Helmet camera)

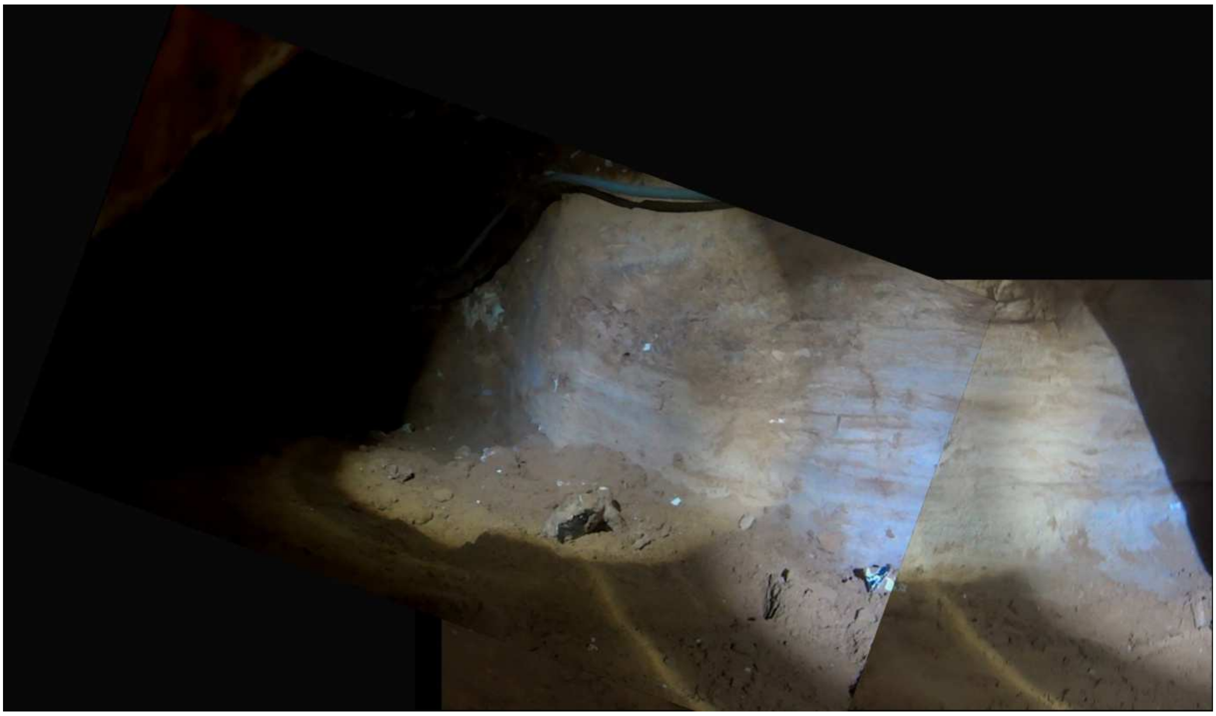
A look behind at 51mn 53s. A comfortable working position may be found in this small pit. The gloves are put back on with some difficulties because they are made of two gloves, one in the other which necessitates that the inner glove be well in place in the outer glove. Isabelle Ebran helps putting back on the right glove. At 58 mn the reequipment is completed. (Helmet camera)

Lucie starts again at 58mn 28s for the last 5 meters always using the belly crawling method (helmet camera)

Lucie far away at 59mn 47s. At 60mn 07s Alain follows using again the left side crawling method. (Helmet camera)

The last 5 m towards cavity 46 (doc. J. Barbier/I. Ebran/Gargouille Productions)

Alain in lateral crawling follows behind Lucie (doc. J. Barbier/I. Ebran/Gargouille Productions)

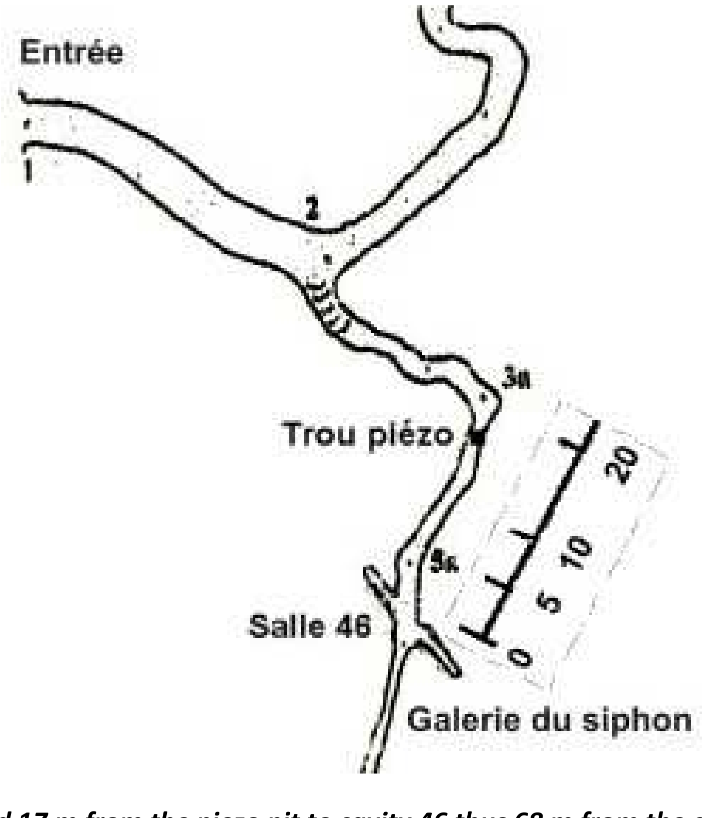


The thin alluvia layers are still present on both side of the passage (helmet camera)

Lucie about to reach cavity 46 (doc. J. Barbier/I. Ebran/Gargouille Productions)

Lucie entering cavity 46.. There is some fog on her helmet upper part where less liquid soap was deposited. (Doc. J. Barbier/I. Ebran/Gargouille Productions)

Alain arrives also crawling in cavity 46 at 61mn 32s and has changed his crawling side only upon arrival (doc. J. Barbier/I. Ebran/Gargouille Productions)



Around 17 m from the piezo pit to cavity 46 thus 68 m from the cave gate

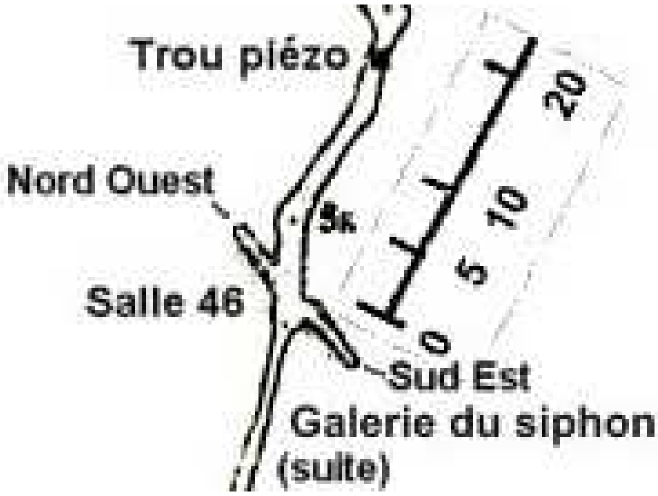
The preparation phase and access to cavity 46 has lasted 27mn 12s. For Alain the crawling duration for the first 12 m (to 5a above) has taken 7mn 40s (and for Lucie a little less) which gives a mean progression at 1,56m/mn.

The last 5m were crossed by Alain in 1mn 25s which gives a mean speed of 3,5 m/mn.

4-7 In cavity 46

From 61mn 32 s to 63mn 21s Alain remains on the ground waiting for the media teams to be ready. Most of the time in cavity 46 will be devoted to the media teams (visible here in the cavity South East corner) with Lucie and Alain interviews. However, at the end of the stay, there will be macro videos of the thin alluvia layers visible here as a clear zone in the upper left corner. (Helmet camera)

Mosaic of pictures from 63mn 47s to 64mn 05s showing cavity 46 on more than 180° with the arrival passage on the right. The passage continues beyond the cavity 46 and may be seen in the middle left. Although the operation was not initially planned, it is possible to recreate panoramic views of the cavity by stitching different views from the helmet camera. The stitching software have difficulties to stitch the pictures owing to the halo type of lightening and also wide angle distortions. A software creating panoramas from videos would be interesting to test. It would be useful that the head motions to swap the landscape be voluntarily executed and be conducted slowly to avoid blurring. Small rulers were prepared for macro views, but a larger scale reference (around one meter) would have been interesting to give better information on the cavity dimensions. Concerning orientations the question is not easy on Mars owing to the absence of magnetic field. Apparently there are residual magnetic fields which would allow the use of a compass, defining an arbitrary "North" which could give a local reference. Or an inertial measurement unit would have to be used. (Helmet camera)



Cavity 46 main axis orientation

Pictures mosaic from 64mn 39s to 64mn 42s showing the South West side and particularly the passage which continues beyond the cavity. At 65mn 36s the helmet camera which had rotated 90° is set upright again. The last picture on the right is taken when Alain shoots a photo with the Canon camera and a flash (see next picture). (Helmet camera)

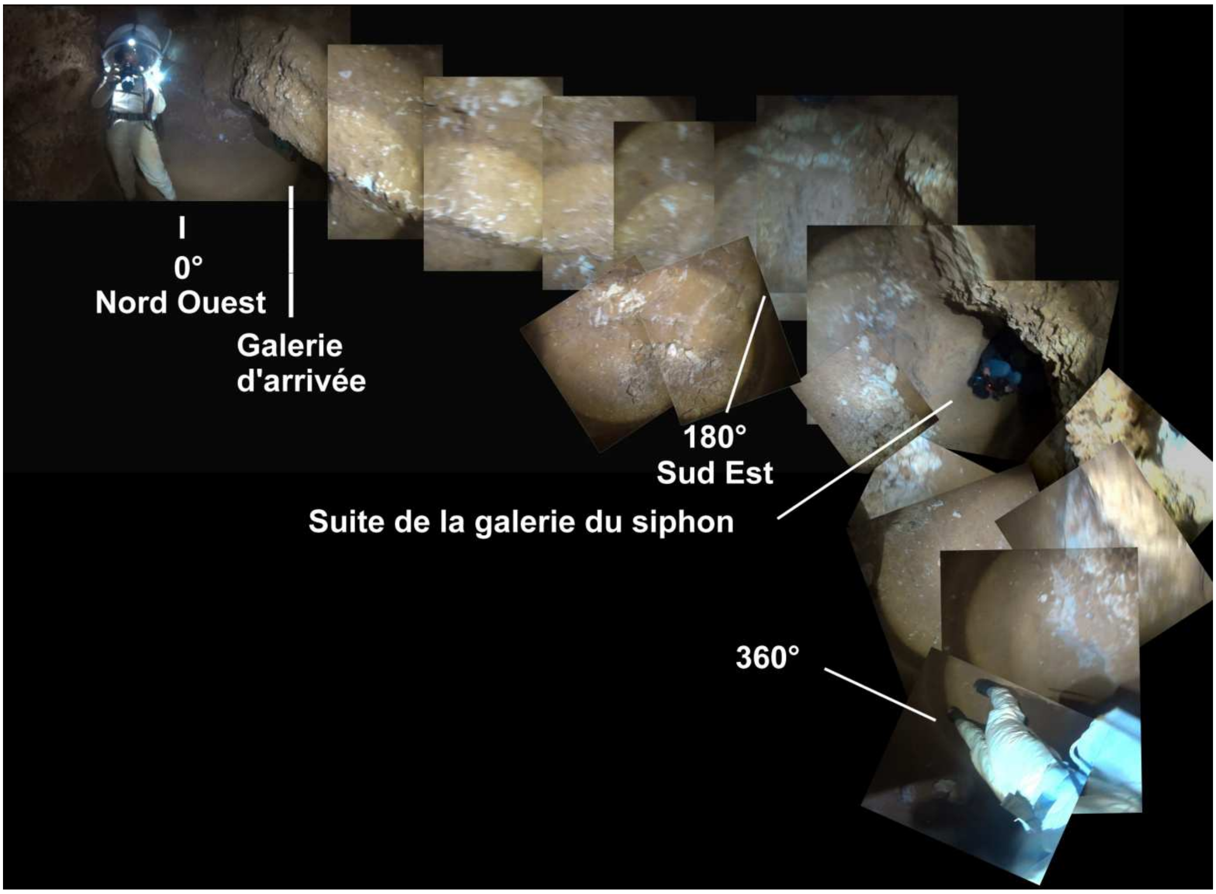
Lucie on the North West side of cavity 46 at 16h09, 64mn 42s after the simulation beginning (Canon EOS 7D, Alain in sim)

View by the helmet camera at 65mn 17s. Lucie has taken the Canon photo camera at 65mn 06s and takes four photos in 26 s starting at 65mn 18s. (Helmet camera)

The Siphon passage continues on the right on this picture oriented South East and taken at 65mn 18s. Since the crawling in the access passage the camera has rotated 90° (see insert) although the fixation screw was secured by glue, which does not preclude pictures use, the field of view being, by the way, extended vertically. (Canon EOS 7D, Lucie in sim)

Photo taken by Lucie in simulation at 65mn 44s as Alain has just set the camera upright again at 65mn 36s (Canon EOS 7D, Lucie in sim)

65mn 46 ; Lucie has taken four photos in 26 s using the camera visor which provides a narrow field of view through the helmet. The arrival passage is on the right on this picture oriented North West. (Helmet camera)



Pictures mosaic from 65mn 46s to 66mn 31s providing a 360° panorama of cavity 46 (helmet camera)

From 66mn 18s to 66mn 44s, Lucie takes different photos of the walls. Combining three views (taken at 65mn 44s, 66mn 44s and 65mn 26s), a large view of the cavity South East side may be obtained. The South East side ends on a slope from which Jonathan Barbier has taken the views seen from above which are shown in the following pages. (Canon EOS 7D, Lucie in sim)

Stitch with an additional view (Canon EOS 7D, Lucie in sim)

In cavity 46. View oriented North West taken from the upper part of the slope on the South East side. (Doc. J. Barbier/I. Ebran/Gargouille Productions)

(Doc. J. Barbier/I. Ebran/Gargouille Productions)

View taken by Isabelle Ebran from the inlet of the passage which goes beyond cavity 46 (doc. J. Barbier/I. Ebran/Gargouille Productions)

(Doc. J. Barbier/I. Ebran/Gargouille Productions)

The North West side and ceiling at 66mn 18s and 66mn 24s. The arrival passage is out of the field on the lower right. (Canon EOS 7D, Lucie in sim)

The wall above and on the left of the passage going beyond cavity 46. Photo at 66mn 44s. (Canon EOS 7D, Lucie in sim)

Previous picture localization relative to the passage which goes beyond the cavity 46; photo taken at 65mn 26s. (Canon EOS 7D Lucie in sim)

Lucie is taking a view of the South East side at 66mn 46s and Alain is leaning towards the area close to the arrival passage where thin alluvia layers are visible. The search for alluvia layers has started at 66mn 27s. Macro views of such layers were planned but mainly in the cave main tunnel. However the crawling progression in the narrow passage had shown these interesting structures on the sides and one could imagine that they would be present in cavity 46. Apparently they are only present close to the entrance. (Doc. J. Barbier/I. Ebran/Gargouille Productions)

Preparations for macro video of the thin alluvia layers (doc. J. Barbier/I. Ebran/Gargouille Productions)

A cardboard ruler (light and very small volume) was prepared to provide a scale for the macro views. It is deposited against the wall at 67mn 26s. The full area of alluvia layers at the outlet of the access passage is presented here on this stitch of two pictures taken by Lucie at 67mn 39s and 68mn 06s. (Canon EOS 7D, Lucie in sim)

Two pictures taken at 67mn 53s and 67mn 56s stitched together (Canon EOS 7D, Lucie in sim)

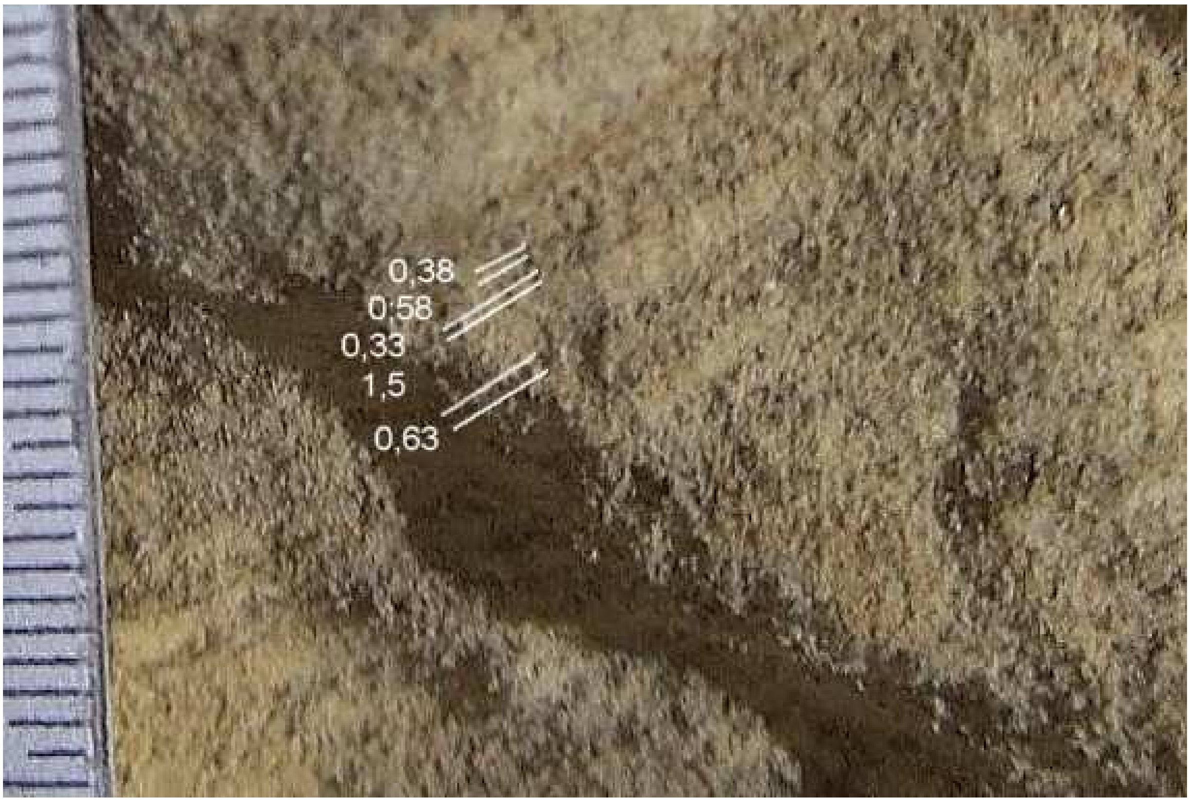
Zoom on the main zone of layers on the 67mn 53s picture (Canon EOS 7D, Lucie in sim)

A second zone of thin layers on the right side of the 67mn 39s picture (Canon EOS 7D, Lucie in sim)

Mosaic of picture taken at 66mn 57s, 67mn 01s and 68mn 30s. On the left the outlet of the access passage. On the right at 68mn 30s Alain extracts the Sony HDR GW 55 video camera which will allows macro views, after kneeling at 67mn 18s. At 67mn 45s Alain restarts the ventilation which accidently stopped. Three successive videos sequences will be taken. (Helmet camera)

View extracted from the first video sequence. This sequence lasts 23 s and starts at 68mn 41s. View taken at 68mn 51s. The time is calculated from the flashes of the Canon activated by Lucie. (Caméra Sony GW 55, Alain in sim)

View at 68mn 54s (caméra Sony GW 55, Alain in sim)



Example of layers thicknesses measurements (in mm) which may be obtained from the previous picture (camera Sony GW 55, Alain in sim)

View taken at 69mn 00s focused on the upper part compared to the previous picture (camera Sony GW 55, Alain in sim)

Previous picture detail which seems to show a curious cross bedding phenomenon. Normally the layer cut by another one more recent is located under. There it is located above as if the oldest layer was deposited on the ceiling side. In what direction one has to read the chronology here ? From bottom (old) to up (recent) or the opposite. One must not forget that the cavity was full of water and that deposits on the ceiling side is a possibility (Sony GW 55 camera, Alain in sim)

A stitch of two pictures taken at 68mn 44s and 46s during the first macro video sequence. The low layers level implies a lying working position. (Canon EOS 7D, Lucie in sim)

Alain during the first macro video sequence, at 68mn 53s, with the access passage to cavity 46 on the left (Canon EOS 7D, Lucie in sim)

At 69mn 01s (Canon EOS 7D, Lucie in sim)

For the second video sequence which starts at 69mn 26s and lasts 27s, the ruler has been repositioned on the left of the white stone but it is always the same layers zone which is shown here in this stitching of pictures taken at 69mn 27s and 69mn 30s (Sony HDR GW 55 camera, Alain in sim)

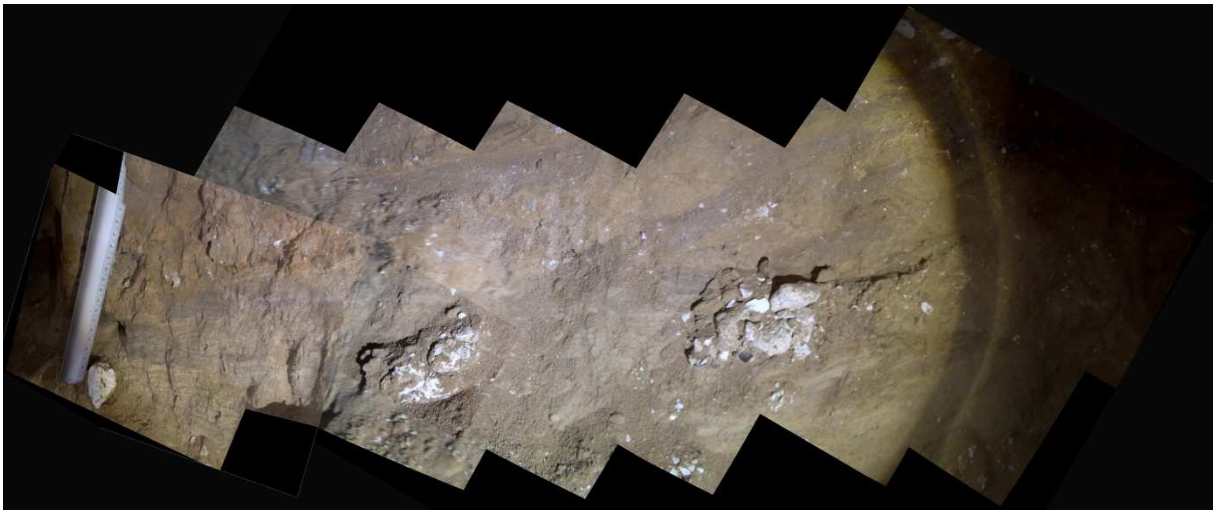
(Doc. J. Barbier/I. Ebran/Gargouille Productions)

View at 69mn 36s (helmet camera)

View at 69mn 38s (Sony HDR GW 55 camera, Alain in sim)

View at 69mn 39s, beneficiating of a Canon flash (Sony HDR GW 55 camera, Alain in sim)


Alain during the second macro video sequence at 69mn 39s at the same time as the previous picture (Canon EOS 7D, Lucie in sim)



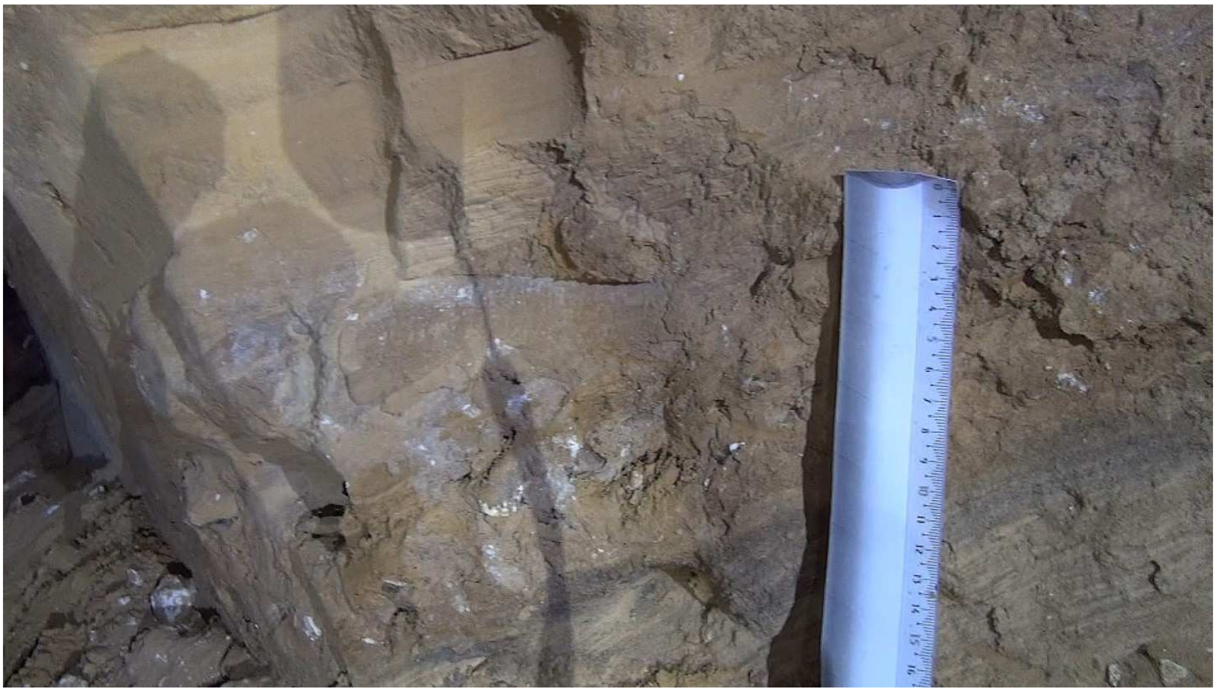
Mosaic of video pictures from the Sony HDR GW 55 camera taken between 69mn 42s and 52s (Sony HDR GW 55 camera, Alain in sim)

View at 70mn 42s during the second macro video sequence. It is clearly visible that the alluvia layers are more important in the access passage on the left than in the cavity 46. (Canon EOS 7D, Lucie in sim)

A third video sequence is shot at media request. It starts at 70mn 54s on views of the access passage (here at 70mn 53s) showing Jean-Pierre Viard and a young observer. On the left the Youki Vattier team cameraman. (Sony HDR GW 55 camera, Alain in sim)

The access passage at 70mn 58s (helmet camera)



The ruler has been repositionned on the right of the white stone. On the left, at the access passage outlet very thin alluvia layers may be seen (upper left in clear brown). View taken at 71mn 05s. (Sony HDR GW 55 camera, Alain in sim)

Detail at 71mn 13s (Sony HDR GW 55 camera, Alain in sim)

Previous view detail showing one of the smallest layers which can be measured (Sony HDR GW 55 camera, Alain in sim)

Under cameras eyes at 71mn 17s (Canon EOS 7D, Lucie in sim)

71mn 41s: under cameras eyes (Sony HDR GW 55, Alain in sim)

Camera against camera at 71mn 50s (helmet camera)

72mn 15s. The third macro video sequence ends at 72mn 33s. The right camera belongs to Youki Vattier's team and the left one to Gargouille Productions (Isabelle Ebran) shooting for APM. There was in fact two Gargouille productions cameras, the second one being operated by Jonathan Barbier. (Helmet camera)

Panorama showing the examined alluvia zone situation in regard to the access passage outlet (Sony HDR GW 55 camera, Alain in sim)

The third macro video sequence (doc. J. Barbier/I. Ebran/Gargouille Productions)

From 72mn 39s Alain has stored back the ruler in the belly bag. In this operation one of the two samples box falls from the bag. It is stored again. Alain then says that he is losing his glasses (consequence of the horizontal working station probably). At 73mn 29s the glasses are put back in place using the usual method of pushing against the helmet air inlets. Youki Vattier indicates she wishes to film a sample collect. These two media teams pictures are taken at 73mn 38s and 40s. (Helmet camera)

Sample collect. A first stone too big for the sample box is taken then a second one, the video sequence running from the box opening to the box closing. The sample box is closed at 76mn 21s. Just after, an interview deals about the difficulties brought by the simulation spacesuits on the different operations (volume, general clumsiness, increase in the operations durations, reduced visibility, manipulation clumsiness with the gloves). (Doc. J. Barbier/I. Ebran/Gargouille Productions)

Picture at 77mn 56s. Then (78mn 43s) the interview deals with the difficulties linked to cave operations then (79mn 03s) on the need to publish the simulations results in order that other teams may beneficiate from these results. At 79mn 19s a commentary: "We do not imagine Martian caves exploration as being conducted during the first expeditions but in the long term, such explorations will be interesting because caves are sheltered locations (in particular from cosmic rays) in which organic molecules and eventually life forms may have subsisted". Around 79mn 30s, new answer on the need to publish simulation results and lessons learned. After 80mn, answer on the theme of Mars exploration interest: "In the long term the question is : does man can be a multiplanetary species ? For every time mankind has been exposed to new environments, progresses and knowledge have been resulting. When our ancestors left Ethiopia to be confronted with new landscapes and cold countries they invented technologies, clothes, fire. In the same way when mankind ventured on the seas, we invented boats and navigation techniques. Thus being exposed to new environments has always been a progress incentive. This is why mankind has to try to be a multiplanetary species. But this is the long term view. "At 81mn 21s the cameraman shuts off the Alain's central flashlight which sends too much glare in the camera. (Helmet camera)

The media teams in the cavity 46 South East corner at 82mn 22s. The red lights of the operating three cameras may be seen. Youki Vattier is at center left. For Gargouille productions, Jonathan Barbier is standing in the middle, partially out of the field of view and Isabelle Ebran is on the right close to the passage which continues to the South West. (Helmet camera)

Pictures at 82mn 46s and 47s stitched together. At 83mn 09 new interview on the question « Mankind a multiplanetary species ?» with new interview also on the purposes of planetary and Mars exploration. (Helmet camera)

From 84mn 43s to 85mn 01s, Alain transitions from semi kneeled position to seated position reclining on the back pack which is very comfortable (here at 85mn 18s) before answering questions on the utility of simulations on Earth till 86mn 44s, then on the need to publish results. The contacts with other organizations conducting simulations, like Comex, are then described till 87mn 53s. (Helmet camera)

Lucie et Alain seated and answering Youki Vattier questions in cavity 46 as seen from the access passage (doc. J. P. Viard)

From 88m 18s to 89mn 06s, Alain stands up again and goes to the South East corner to seat again. Youki Vattier shifts to interviewing Lucie. Mosaic of Canon EOS 7D pictures taken at 89mn 19s, 27s and 30s. The outlet of the access passage may be seen on the right. (Canon EOS 7D, Alain in sim)

Lucie during interview around 92mn 50s. This last video sequence from the Sony HDR GW 55 lasts 32s. (Sony HDR GW 55 camera, Alain in sim)

Lucie during interview at 94mn 18s. This interview ends at 98mn 31s. Alain: "Well, we go back to the main tunnel ? » (Helmet camera)

The cavity 46 activities phase, outside the return preparation phase, has lasted 36mn 59s.

4-8 Back to the main cave tunnel

At 98mn 53s Alain suggest to get rid of the belly bag to facilitate the return. The two bag tethers are under the back pack tethers but above the mountain harness. At 100mn 33s Alain stands up to facilitate the operation conducted by Isabelle Ebran, Youki Vattier and Lucie. The bag is detached at 102mn 14s. Mosaic of pictures taken between 101mn 45s and 102mn 03s. (Helmet camera)

At 102mn 34s, Isabelle catches a piece part of the ventilation control. It would be necessary to better attach (better than with Velcro) this control on the suit sleeve to avoid unwanted activations or shock with other people as happened some seconds before. (Helmet camera)

At 104mn 42s after discussion with Jonathan the departure order has been decided: Jonathan first who will be progressing backward to film Lucie's crawling then Isabelle who will film Alain. For the moment Alain seats close to the passage. At 104mn 57s (picture above), Jonathan starts to progress backward in the passages. (Helmet camera)

At 105mn 27s, Alain has repositionned the left side of Lucie's helmet, the U shaped collar fixing the helmet on the support rod being disengaged (arrow). This U covers in fact 270° but the force with which it holds the helmet is rather weak. For a crawling operation (which was not initially foreseen for these simulation spacesuits), it would be better to have the U shaped collar turned by 180° or to have a more definitive screwed fixation, because the helmet can be opened by rotating the two rods upwards. On the right side the fixation is similar but the collar is equipped with a closing tether and the fixation is stronger. This configuration is the helmet 1 configuration worn by Lucie. For helmet 2 the configuration is opposite, the collar with the small closing tether being on the left. Picture taken at 105mn 31s. (Helmet camera)

At 105mn 14s the U collar is again loose and Alain fix it again at 105mn 48s (helmet camera)

Lucie ready to go (doc. J. Barbier/I. Ebran/Gargouille Productions)

At 106mn 11s, Lucie starts her progression. She is crawling on belly side as for her arrival, holding her helmet most of the time. She made once the remark that the helmet is pushing too much on the back of her head. (Helmet camera)

106mn 26s (helmet camera)

Beginning of progression for Lucie. Alain is behind, still in cavity 46. (Doc. J. Barbier/I. Ebran/Gargouille Productions)

(Doc. J. Barbier/I. Ebran/Gargouille Productions)

106mn 34s (helmet camera)

Alain waiting that Lucie be far enough in the passage (doc. J. Barbier/I. Ebran/Gargouille Productions)

(Doc. J. Barbier/I. Ebran/Gargouille Productions)

106mn 53s : Lucie disappears in the passage (helmet camera)

Isabelle has started her backward squatting progression at 107mn 26s. Picture at 107mn 33s. (Helmet camera)

Alain starts moving at 106mn 37s and elects to crawl on his right side. Picture taken at 107mn 44s. (Helmet camera)

The passage left side with alluvia layers at 108mn 06s and 09s (helmet camera)

Previous picture details (helmet camera)

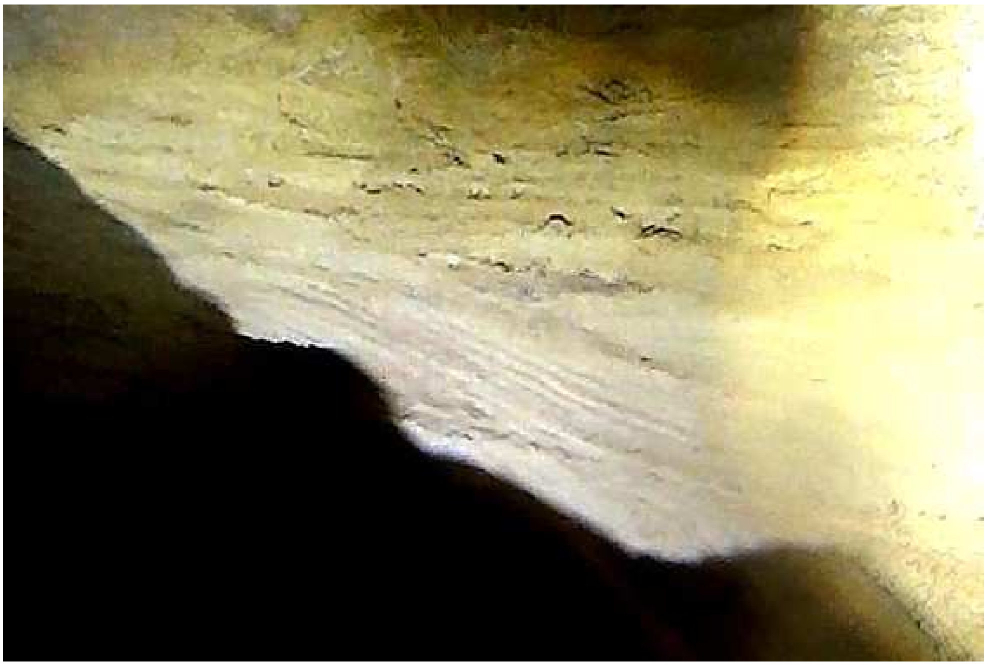
Nearing the small pit area, 5 m from cavity 46 (doc. J. Barbier/I. Ebran/Gargouille Productions)

During this time Lucie is progressing to the passage end (doc. J. Barbier/I. Ebran/Gargouille Productions)

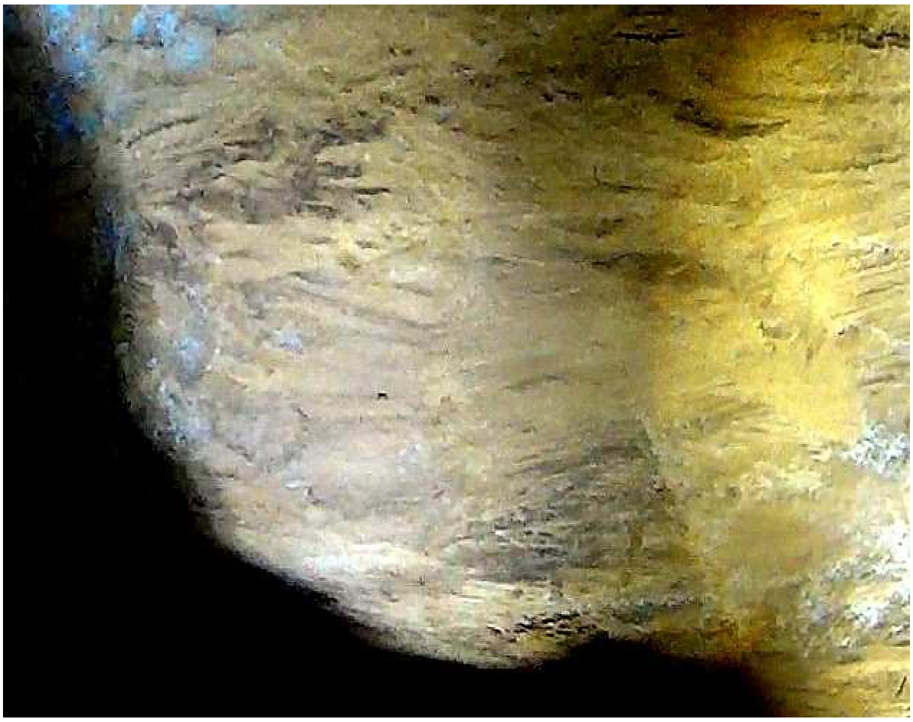
Alain arrives in the small pit area at 109mn 18s after a 1mn 41s progression (with however some stops on the way) on 5 m thus 3 m/mn (compared to 3,5 m/mn on the same path on the way to cavity 46). In this area one may kneel up. Picture taken at 109mn 45s. (Helmet camera)

On the left, departure from the small pit area at 110mn 01s, always by crawling on the right side. On the right, the passage left side and its layers at 110mn 40s. (Helmet camera)

Passage left side with its alluvia layers. Pictures at 112mn 06s and 112mn 45s. (Helmet camera)



Detail of the 112mn 06s picture showing again, seemingly, upside down cross bedding, the lower layers cutting the upper layers, whereas it should be the opposite. (Helmet camera)



112mn 45s picture details (helmet camera)

Passage left side at 113mn 44s and 115mn 30s (helmet camera)

Progression in right side crawling (doc. J. Barbier/I. Ebran/Gargouille Productions)

Alain arrives at the piezo pit at 115mn 37s. Jonathan gives indications to climb down the bags wall. Picture taken at115mn 59s. 5mn 36s were needed to cross the passage second part 12 m thus a progression at 2,1 m/mn. (Helmet camera)

In summary the progression speeds in the passage on the way to cavity 46 and back, were the following:

Section length	12 m		5 m
Speed to cavity 46	1,6 m/mn	-->	3,5 m/mn
Speed back from cavity 46	2,1 m/mn	<--	3,0 m/mn

At 116mn 52s tipping over the bags wall in the piezo pit (helmet camera)

During the time Lucie climbs up the Siphon passage slope. She is here close to the main tunnel. (Doc. J. Barbier/I. Ebran/Gargouille Productions)

Alain catches back the Ariadne thread spool which remained hooked to the ladder on the exit side. The distance from cave entrance at 51 m is confirmed. Picture taken at 118mn 45s. (Helmet camera)

Climbing the bags wall towards the exit. The ventilation control box is detached. It was secured in the right hand during the trip back from cavity 46. The control is taken back again in hand at 119mn 22s. Pictures taken at 119mn 18 and 20s. (Helmet camera)

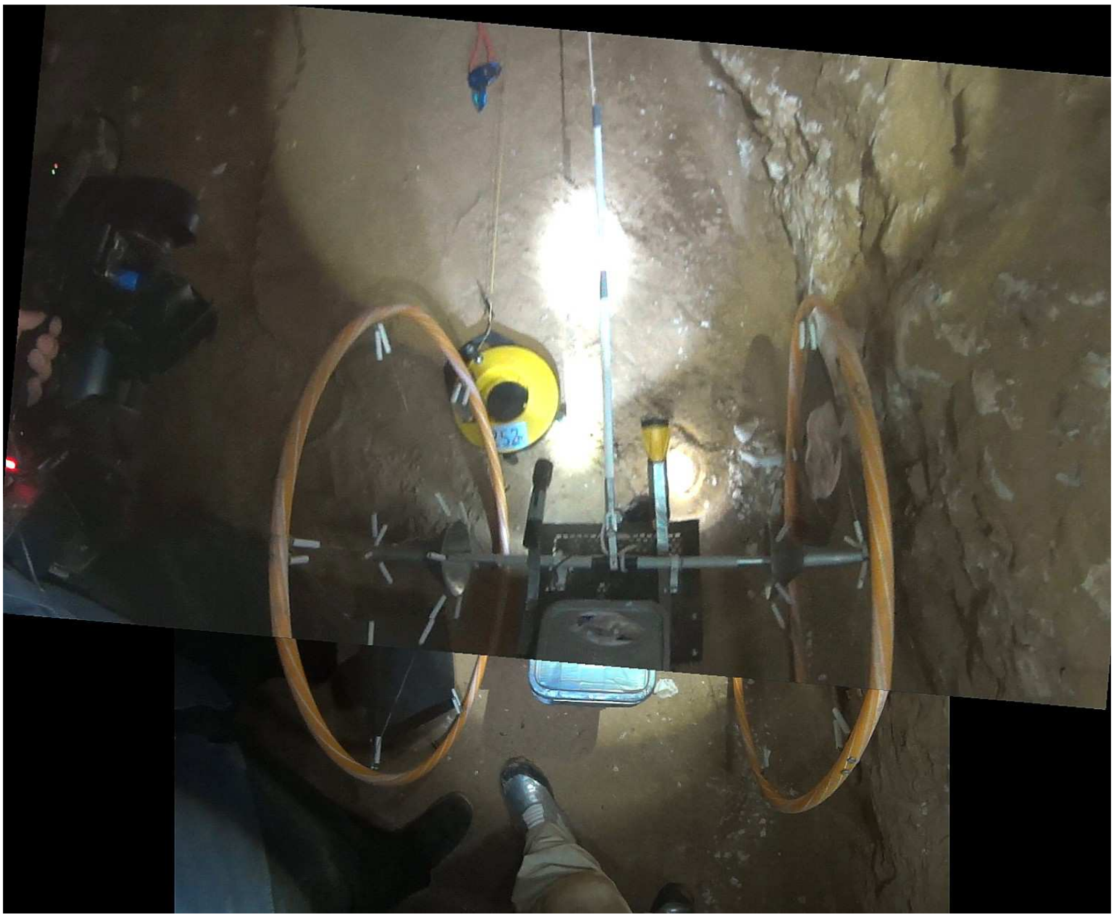
At 119mn 50s catching back the thread spool (helmet camera)

Then progressing to the slope lower part, rewinding the thread spool. Picture taken at 119mn 24s. (Helmet camera)

At 120mn 59s at CRV level down slope (helmet camera)

A 121mn 55s, spool blockage winding the thread around the knob and the hook in order for Lucie to pull it back up slope without unwinding the thread (helmet camera)

Anti roll rods retrieval at 122mn 10s (helmet camera)



The CRV equipments are still on (lights, video emission box and Bescor swiveling device). Pictures at 122mn 16s and 19s. (Helmet camera)

The two emission box switches are set off at 122mn 46s by Alain kneeling for this operation. Picture showing the two switches off at 122mn 55s. (Helmet camera)

At 123mn 15s Alain has placed the thread spool a little up slope in front of the CRV and has indicated to Lucie that she can pull up the spool. The message is repeated at 123mn 25s. Lucie starts the pull up at 123mn 42s. (Helmet camera)

Lucie pulls up the Ariadne thread spool from the main cave tunnel (doc. J. Barbier/I. Ebran/Gargouille Productions)

The spool catches accidently the orange rope (doc. J. Barbier/I. Ebran/Gargouille Productions)

Alain climbs the slope (doc. J. Barbier/I. Ebran/Gargouille Productions)

Alain uses the fixed rope; the progression needs sometimes kneeling. (Doc. J. Barbier/I. Ebran/Gargouille Productions)

The two anti roll rods are brought back at the same time. They could be obstacles to retrieve the CRV. (Doc. J. Barbier/I. Ebran/Gargouille Productions)

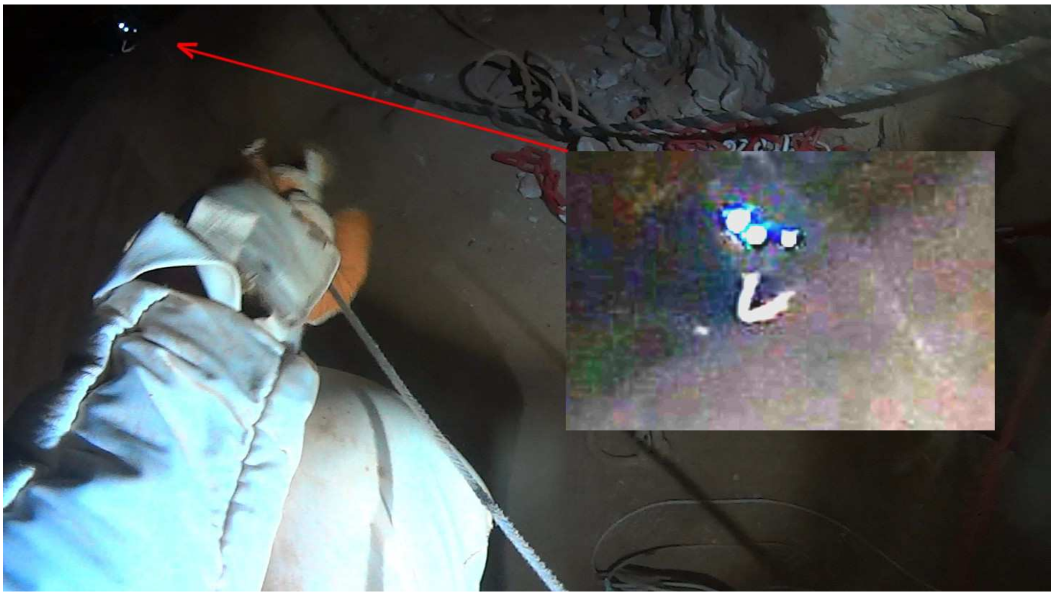
The back pack volume obliges again to climb kneeling (doc. J. Barbier/I. Ebran/Gargouille Productions)

Arrival at the slope upper part at 125mn 00s (doc. J. Barbier/I. Ebran/Gargouille Productions)

The return phase from cavity 46 to the main cave tunnel has lasted 26mn 29s.

4-9 Retrieving the CRV and main tunnel reconnaissance on a short distance

Picture taken at 127mn 20s. the CRV rope is at 11 m at the safety pole level. The 10 m is in the picture upper part in left center. Alain (who suffers from a sciatica!) is momentarily seated from 125mn 18s to 126mn 26s, and says at 125mn 52s: «I succeeded in pushing back up my glasses» (by pushing on the ventilation helmet inlets), and repeats twice: «we shall bring back the CRV» (adding the second time: "if it agrees"). At 126mn 47s somebody adjusts one of the flashlights on the helmet. At 126mn 54s Alain lays the anti roll rods on the ground. At 127mn 13s, Jonathan asks that we conduct a walk in the main tunnel. It is answered that this is in the planned activities for cave segments dimensions measurements.(Helmet camera)



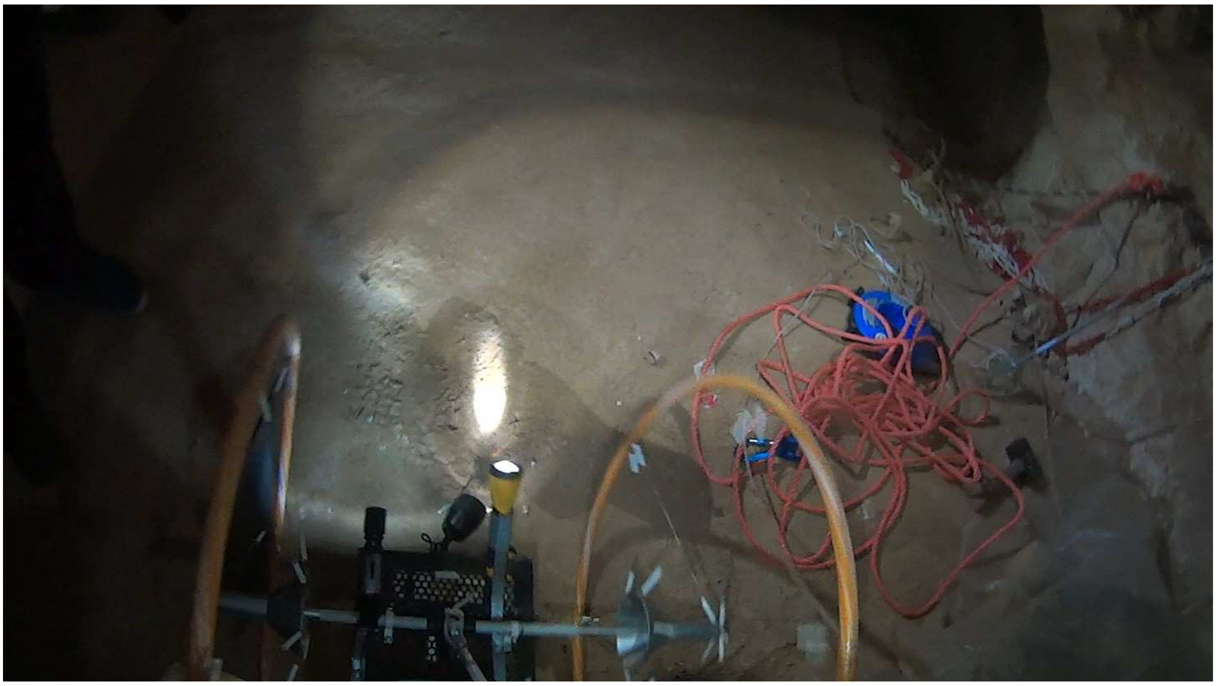
Picture at 128mn 35s. the CRV is on its side, the worst configuration. The retrieval has started at 127mn 26s. The configuration being different from the way down configuration, this operation is CRV test 125. Normally going down then up counts for only one test. At 127mn 36s Alain says: « It is going to tip over; here it is». The vehicle is not normally designed to operate without anti roll rod which are there to avoid a tip over. The anti roll rods were disassembled because they could prevent the retrieval. Without the possibility to steer the vehicle (for example with two ropes) the left CRV wheel (as seen from the operator) has climbed on the slope left side which resulted in the tip over. (Helmet camera)

The only previous case of CRV use without anti roll rods : a hole reconnaissance during the exploration simulation organized by ÖWF in Morocco in 2013. (Doc. ÖWF/K. Zanella-Kux)

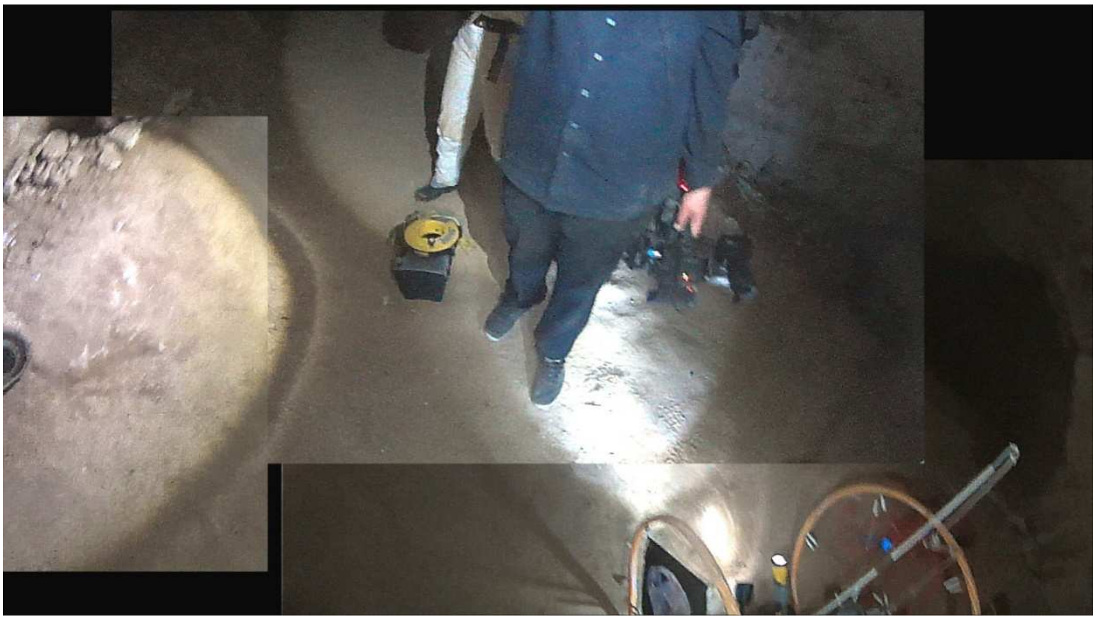
At 127m 36s the CRV still pulled up makes a quarter turn and is back again on its wheels with the lights oriented down whereas for the beginning of the climb they were oriented upwards. It was feared that the tip over on the side would be an irreversible situation. (Helmet camera)

At 127mn 58s the vehicle is back in the main tunnel. The retrieval, in spite of the tip over, lasted only 32s. (Helmet camera)

End of CRV retrieval (doc. J. Barbier/I. Ebran/Gargouille Productions)



Picture at 128mn 14s showing the CRV in storage position on the side with, in the upper right, the Siphon passage slope (helmet camera)



Mosaic of pictures at 128mn 25s, 26s and 128mn 27s. The Siphon passage slope is on the right. The main tunnel continues towards the upper left. (Helmet camera)

On the left at 128mn 37s, Alain is trying to replace the right hook level which links the neck collar to the helmet. But this lever is in general not used. It is a redundancy for the two others. The helmet camera has again rotated by 90° (which has the advantage of increasing the vertical field). At 128mn 57s the right picture shows the U collar fixing the helmet to the back pack rod which is loose. At 129mn 69s Alain: "The Us are gone". (Helmet camera)

On the left at 129mn 40s, the left U (opening downwards) is back in place but Alain does not succeed to replace the left hook lever fixing the helmet to the neck collar (arrow) and Jonathan comes to help at 129mn 41s. The left hook is put back in place by Jonathan at 129mn 50s and, after, he fixes the right side. At 130mn 12s the configuration is back to nominal. (Helmet camera)

Picture at 129mn 51s showing Alain's ventilation control loose then stored under one mountain harness tether (128mn 46s). But it will soon be loose again. At 130mn 19s Alain announces: "We will measure 2 or 3 cave segments but not more » and at 130mn 28s, after catching the Ariadne thread spool which was on the CRV reception box : « A little progression with distances and angles measurements ». (Helmet camera)

130mn 43s and 45s: Having pulled up the thread spool from down slope without rewinding 10 m of thread has been enough (as in some phases of manufacturing of this device) to create (false) knots. (Helmet camera)

130mn 54s and 131mn 09s: Lucie tries to undo the knots but with the gloves this attempt ends inevitably in a failure (helmet camera)

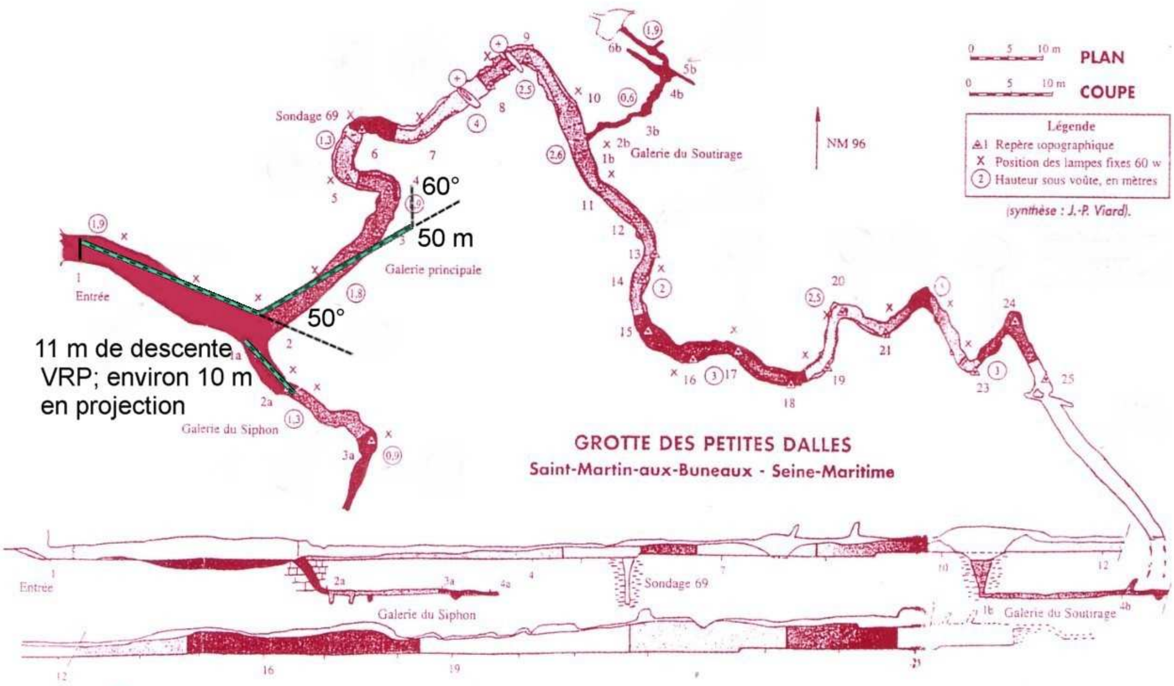
131mn 22s and 131mn 44s: Youki Vattier intervention to undo the knots (helmet camera)

131mn 53s and 132mn 00s: end of knots undoing on the thread and tension of the thread still linked to the cave entrance gate. The cave entrance may be seen in the upper right of the right picture. (Helmet camera)

On the left at 132mn 29s, the 30 m mark on the rope with, in the upper right, the flag pole and the inlet to the Siphon passage slope. At 132mn 13s Alain announces: "We are at 28 m at the corner". At 132mn 45s Lucie starts the angle measurement between the first and second cave segment by using the protractor as shown on the right picture at 132mn 51s. At 133mn 31s Alain announces: "50° on the left" and repeats the message 10 s later. The angle measurement has taken roughly 50s. (Helmet camera)

At 133mn 51s Alain has caught the thread spool and with Lucie starts walking in the tunnel. On the left at 134m 14s, a view on the tunnel towards the depths of the cave. On the right at 134mn 24s, a look backwards to see if the thread is in a straight line since the last turn in front of the Siphon passage. (Helmet camera)

At 135mn 51s : « We still see the CRV» (positioned in front of the siphon passage slope at around 25 m from the cave entrance). At 135mn 56s (left picture) the 50m mark from the entrance is reached. On the right at 136mn 09s, Lucie is measuring the angle between the section we have just walked in and the next one. The angle is 60° left. The measurement took 53 s. Alain is holding his ventilation control in left hand during this time. (Helmet camera)



Measurements comparison to the cave map. The 25 m distance from the Siphon passage are slightly in curve and not straight as indicated here. (Doc J.P. Viard/APM)

The protractor fell at the end of the measurement process (and it is not the first time). Lucie catches it back at 137mn 09s. How to avoid objects falling from hands equipped with gloves? Securing objects with wires could be worst in operations. (Helmet camera)

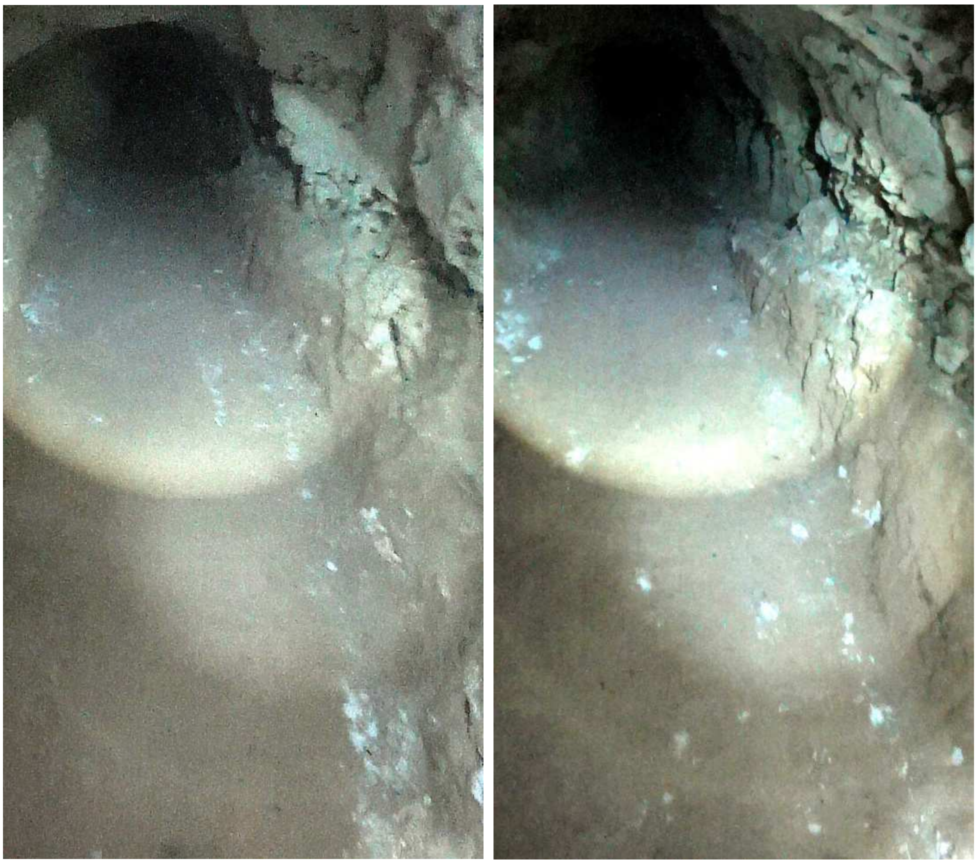
At 137mn 50s the Y. Vattier team cameraman asks if we can stop the measurements to film a normal progression in the cave. This mosaic of pictures taken at 137mn 56s shows the tunnel segment which follows the first sharp 90° left turn at around 5 m from the 50 m measurement thus at 55 m from the cave entrance. This short segment is followed by a right 90° turn. (Helmet camera)

Picture at 138mn 09s : the following part of the tunnel takes a right 90° turn (helmet camera)

Pictures at 138mn 15s. Then, some meters farther, a second 90° right turn follows. (Helmet camera)

Pictures at 138mn 21s and 138mn 33s showing that the tunnel then turns left in a longer turn than the previous ones (helmet camera)

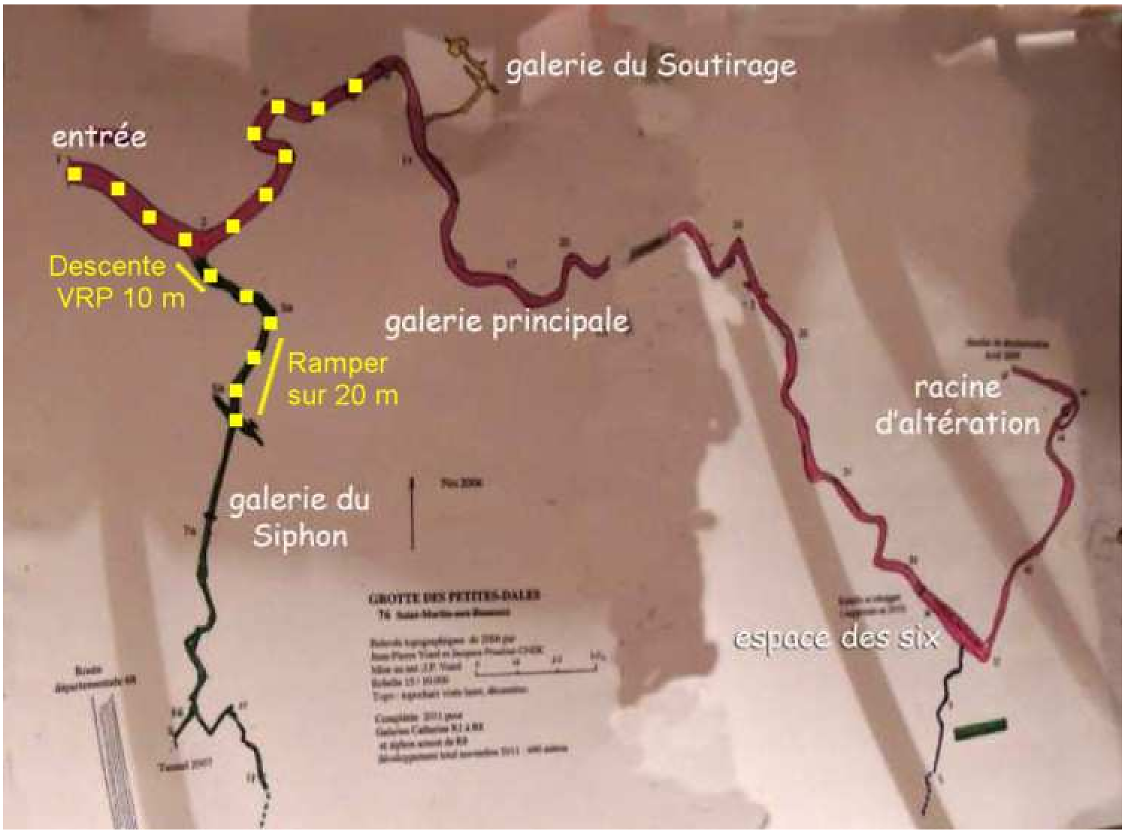
Nearing the left turn and in the left turn in these pictures taken at 138mn 35 and 36s (helmet camera)



The main tunnnel following part after the left turn at 138mn 41s and 44s (helmet camera)

The main tunnel following part at 138mn 48 and 56s (helmet camera)

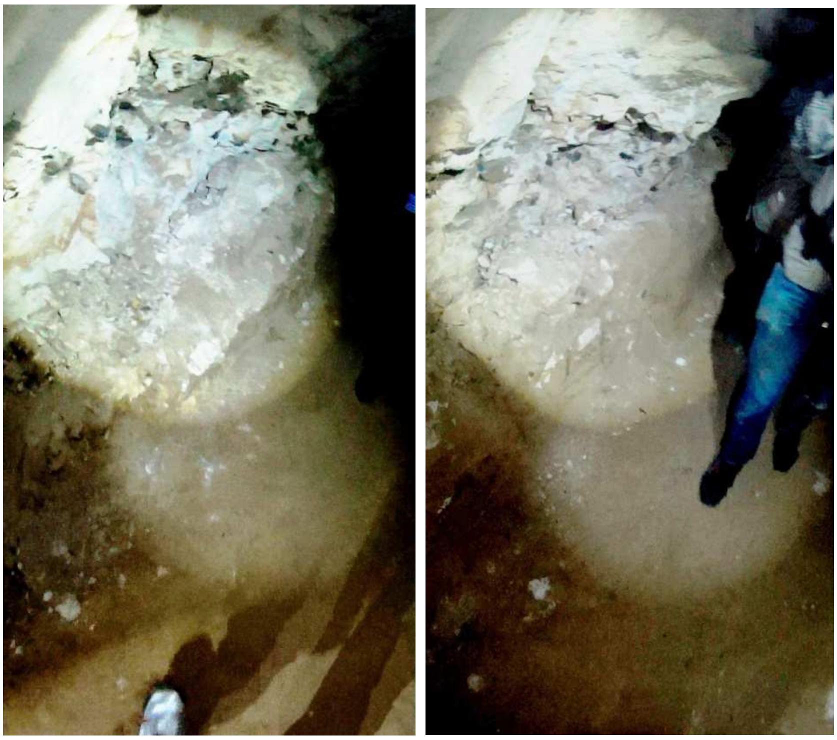
Farthest position reached in the main tunnel on the left at 138mn 58s before going back. In the picture upper part the beginning of the next right turn may be seen. On the right at 139mn the view is oriented towards the cave exit. (Helmet camera)



The paths followed in the cave (doc J. P. Viard/APM complements)

At 139mn 01s (two pictures stitch) Lucie going back (helmet camera)

139 mn 08 and 09s : going back under camera eye. (Helmet camera)

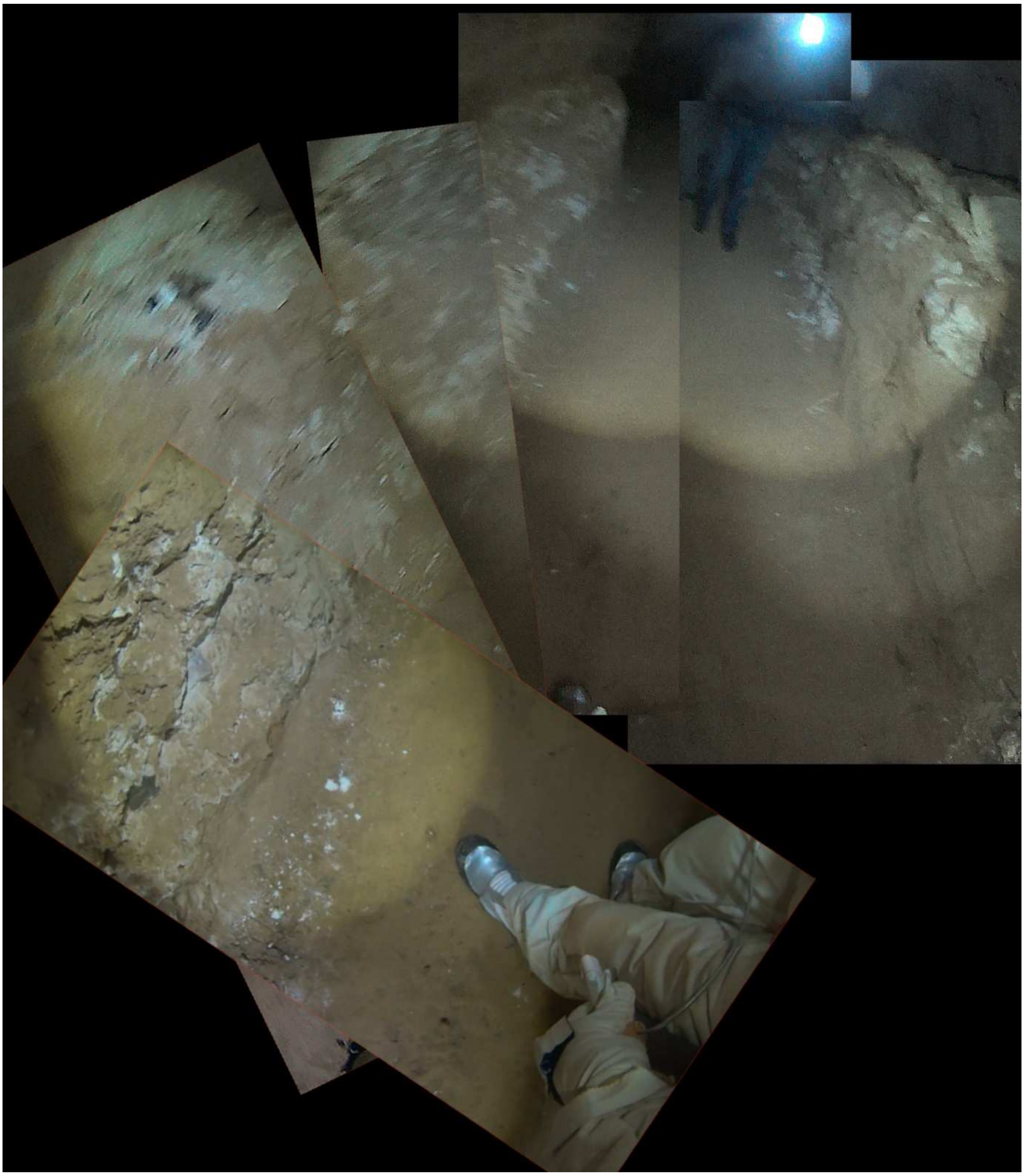


Flint layers in the wall at 139mn 14s (helmet camera)

Mosaic of pictures between 139mn 21 and 22s (helmet camera)

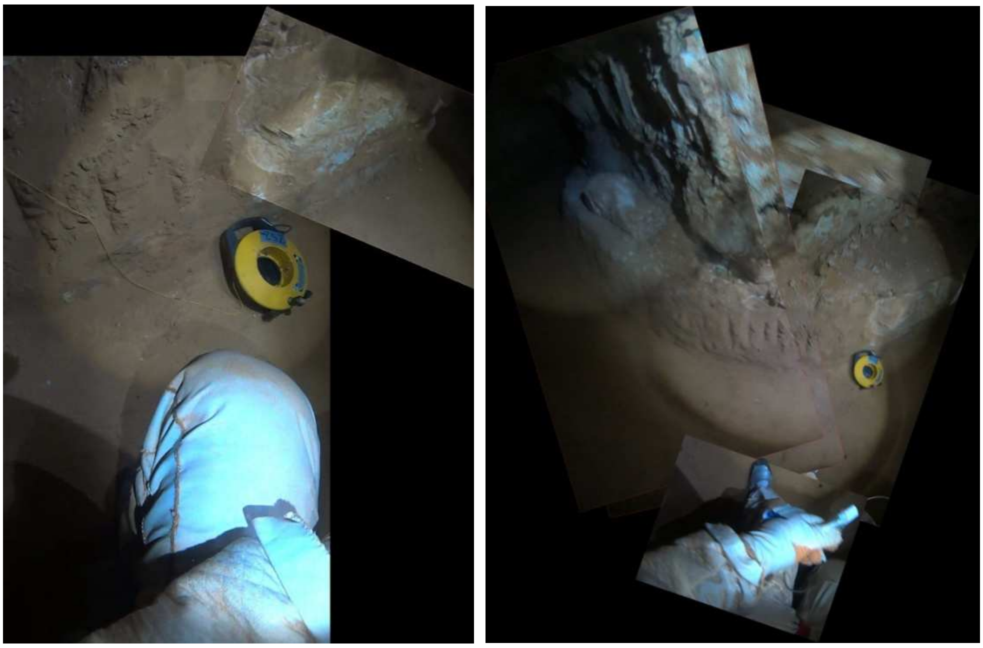
Mosaic of pictures between 139mn 30 and 32s (helmet camera)

At 139mn 38s and 44s walking in the return turn (helmet camera)



Mosaic of pictures at 139mn 46s showing the short straight segment before the second left turn. Alain is holding his ventilation control in hand. (Helmet camera)

On the left a wall view at 139mn 51s. Entry in the second turn (left turn) begins at 139mn 56s, and in the third turn (left turn also) at 140mn 08s. On the right after the turn, the Ariadne thread spool appears in the next turn corner on the stitching of two pictures taken at 140mn 10 and 13s. (Helmet camera)



Because of tiredness and mainly sciatica, Alain remains kneeling at the spool level from 140mn 23s to 140mn 46s. On the left picture at 140mn 44s (+ picture at 41s). On the right mosaic of pictures at 140mn 46s with the last turn on the right before the return to the first segment of cave tunnel in the upper left. (Helmet camera)

Mosaic of pictures from 140mn 52 to 56s showing the turn, the way out being on the left. Lucie is going to carry the thread spool for the following phase. (Helmet camera)

On the left picture at 141mn 12s. The CRV appears far away in front of the Siphon passage slope. The return to the CRV is filmed by Jonathan Barbier. On the right the CRV and the reception box at 141mn 31s. At 141mn 42s Alain seats in front of the CRV and straightens up the helmet camera at 142mn 24s then asks Jonathan at 142mn 37s to give him the CRV reception box to understand the 12 V failure which precluded the CRV on board video utilization during the initial Siphon passage slope reconnaissance.(Helmet camera)

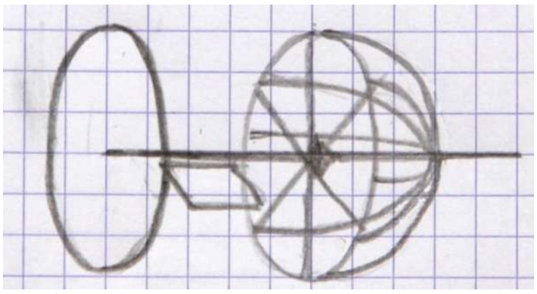
The CRV retrieval and main tunnel reconnaissance has lasted 17mn 37s.

4-10 CRV video repair and new utilization in the Siphon passage

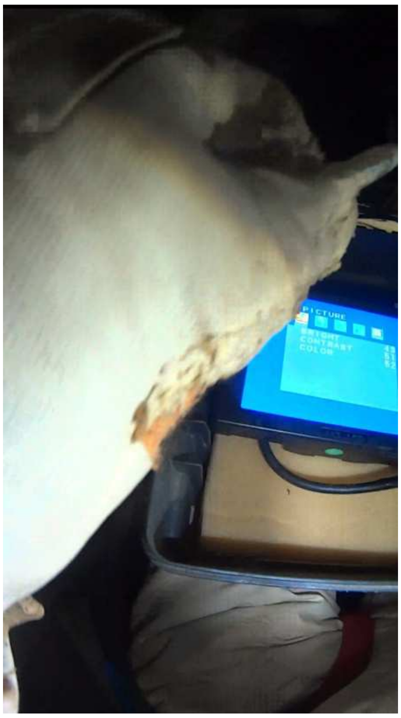
At 142mn 37s, Alain asks Jonathan to give him the CRV video reception box to "understand why we did not get a video. May be some battery connections were loose". It is the right scenario! The reception box is opened at 143mn 44s at the third attempt, here down right. (Helmet camera)

Here the box is shown open. The protective foam layer is removed at the second attempt. The blue receiver is on the right on this picture at 143mn 57s. (Helmet camera)

the helmet camera rotates again by 90° at 140mn 00s. From 144mn 08s to 145mn 12s Jonathan proposes improvements to the CRV configuration to avoid the anti roll rods. Alain reminds that the distance between wheels is defined by the necessity to be able to carry the disassembled vehicle in a suit case, particularly for the MDRS Mars Society simulations in Utah. As for the wheel diameter, the larger it is, the better the vehicle can deal with obstacles as long as it does not become too large for hand operations. The resulting configuration is a vehicle which can tip over without the anti roll rods. Alain and Jonathan discuss the idea of replacing the wheels by half sphere but which would could be stored in a suit case. Jonathan proposes hoops. Alain approves saying "a dome structure without the half sphere surface".



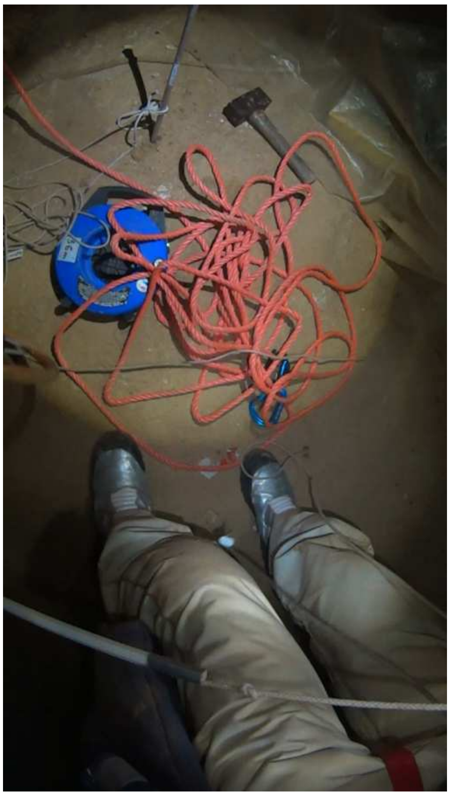
Concept sketch of a CRV wheel modification by replacement of the anti roll rods by hoops which may be disassembled



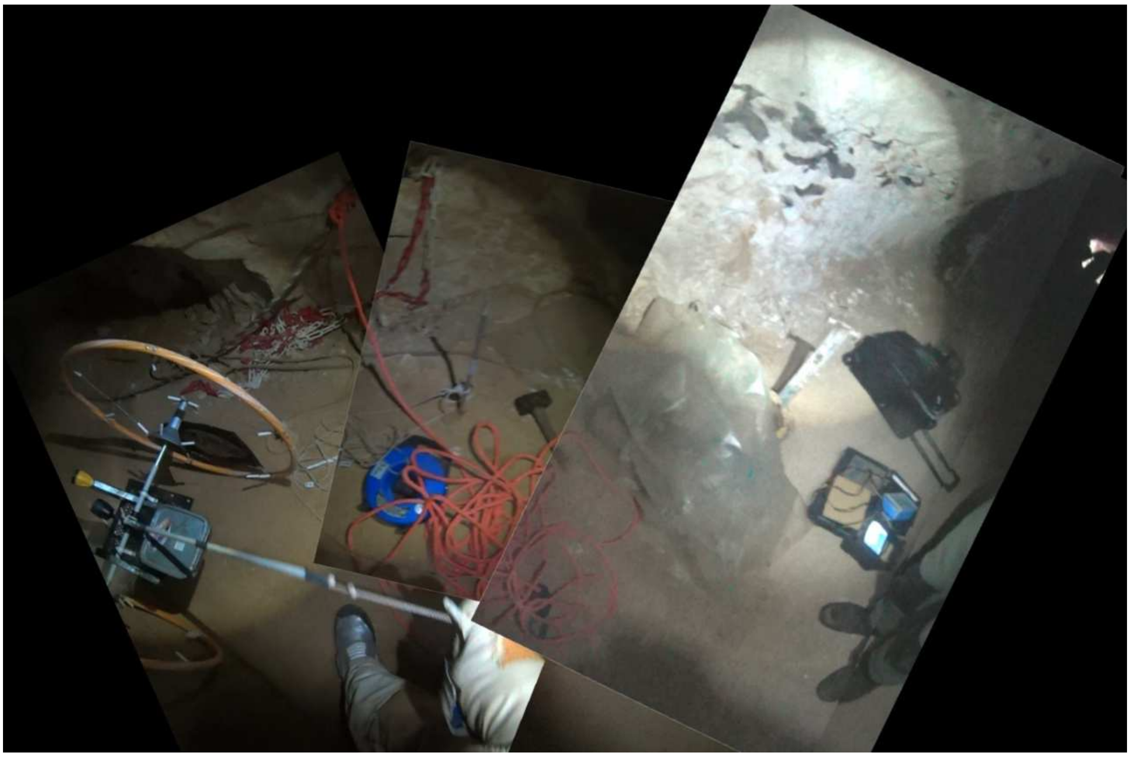
At 144mn 22s, Alain extracts wires from the reception box (out of the field of view) and at 144mn 27s finds that the + connection to the 12V battery is loose. At 144mn 50s Alain tells to Jonathan what has to be reconnected. At A 145mn 06s : «It works» (the receiver green light). At 145mn 08s Alain indicates: «We are going to conduct a new CRV descent». The video monitor is set « on » at 145mn 12s as shown on the picture above. There is not yet a picture because the vehicle emission box has been set « off » upon return from cavity 46. (Helmet camera)

Alain has left the reception box and has gone to the CRV to set on the two emission box switches, here at 145mn 29s. The picture sent by the vehicle appears on the video monitor hence exclamations at 145mn 31s ! (Helmet camera)

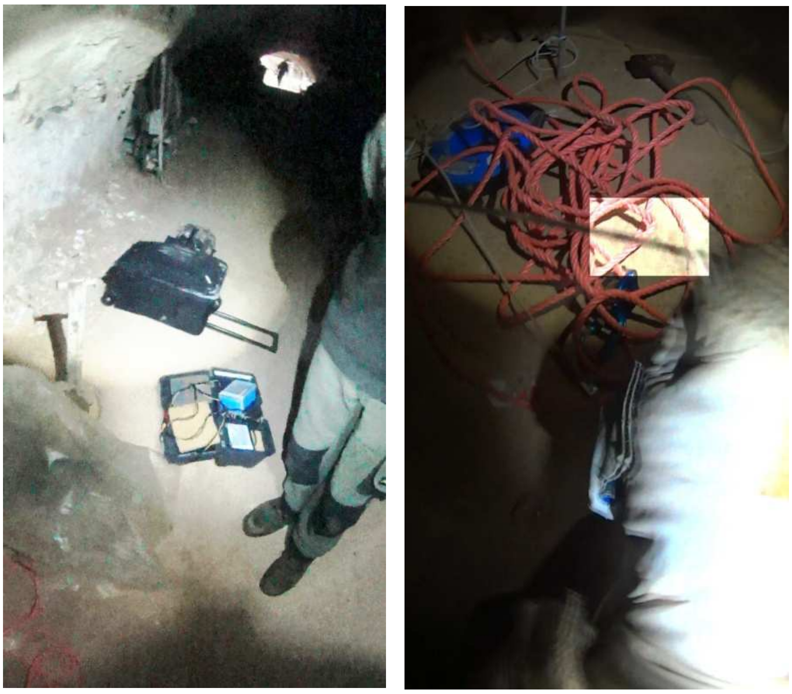
The CRV is ready for a new test at 145mn 39s. Nota: the flashlights and the Bescor swiveling mechanism were not stopped since the simulation beginning. (Helmet camera)



Picture at 146mn 12s. The CRV rope remained attached to the safety pole at distance 11 m. (Helmet camera)

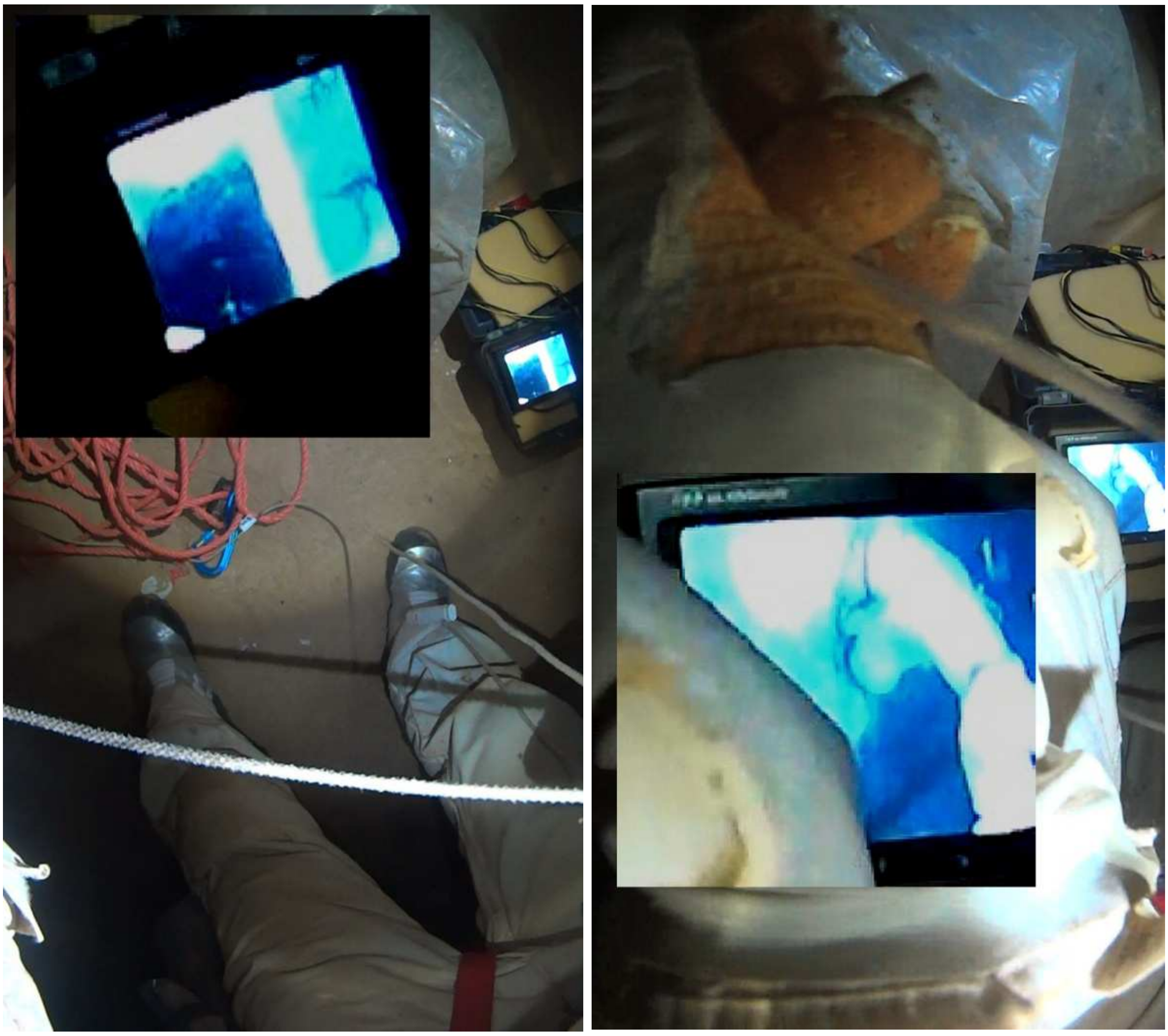


Mosaic of pictures between 146mn 13s and 19s showing the vehicle on the left, in front of the Siphon passage slope, and on the right the reception box. In the upper right corner, the cave entrance may be seen. The CRV test n° 126 begins at 146mn 13s. (Helmet camera)



At 146mn 28s, on the left, the reception box on the ground, with the blue receiver still in the box, and far away at 25 m in the upper right the cave entrance. A discussion started at 146mn 18s with the man on the right on the CRV characteristics and its possible improvements. At 146mn 33s on the right picture, the CRV is at 5 m (2 back lines on the rope in the enlightened insert). The descent is conducted with some stops and go. (Helmet camera)

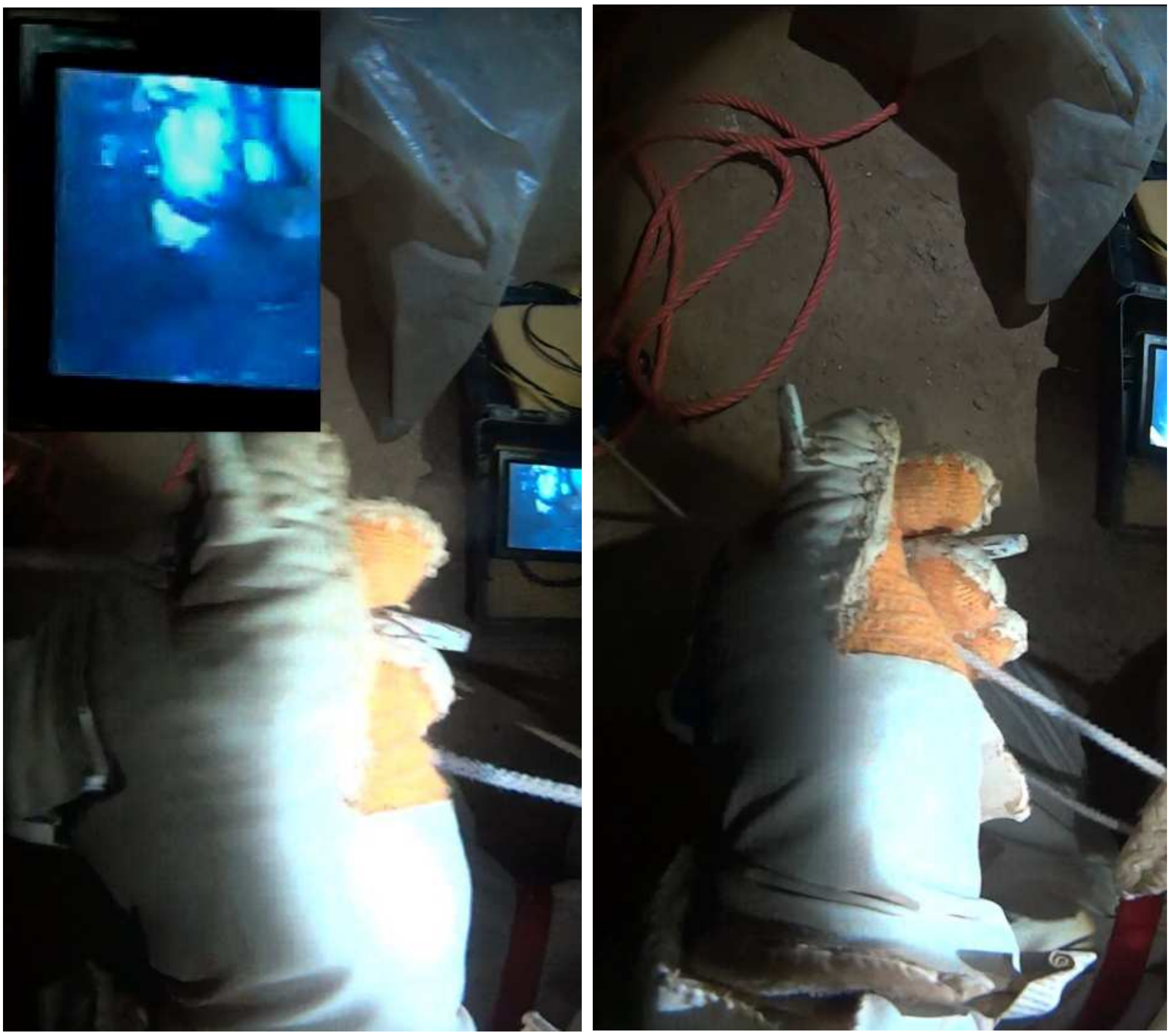
At 147mn 08s Alain hooks the CRV rope to the safety pole at distance 9 m. Jonathan has indicated his wish to shoot again videos of the vehicle evolution and Alain proposes to pull it a little at 147mn 40s, and more precisely by about 2m. At 148mn 16s Jonathan going down is visible on the monitor screen. At 148mn 27s (right picture), Alain undoes the rope knot at 9 m (which needs only 5 s) and pulls up the vehicle by 2 m and then releases slowly the rope. (Helmet camera)



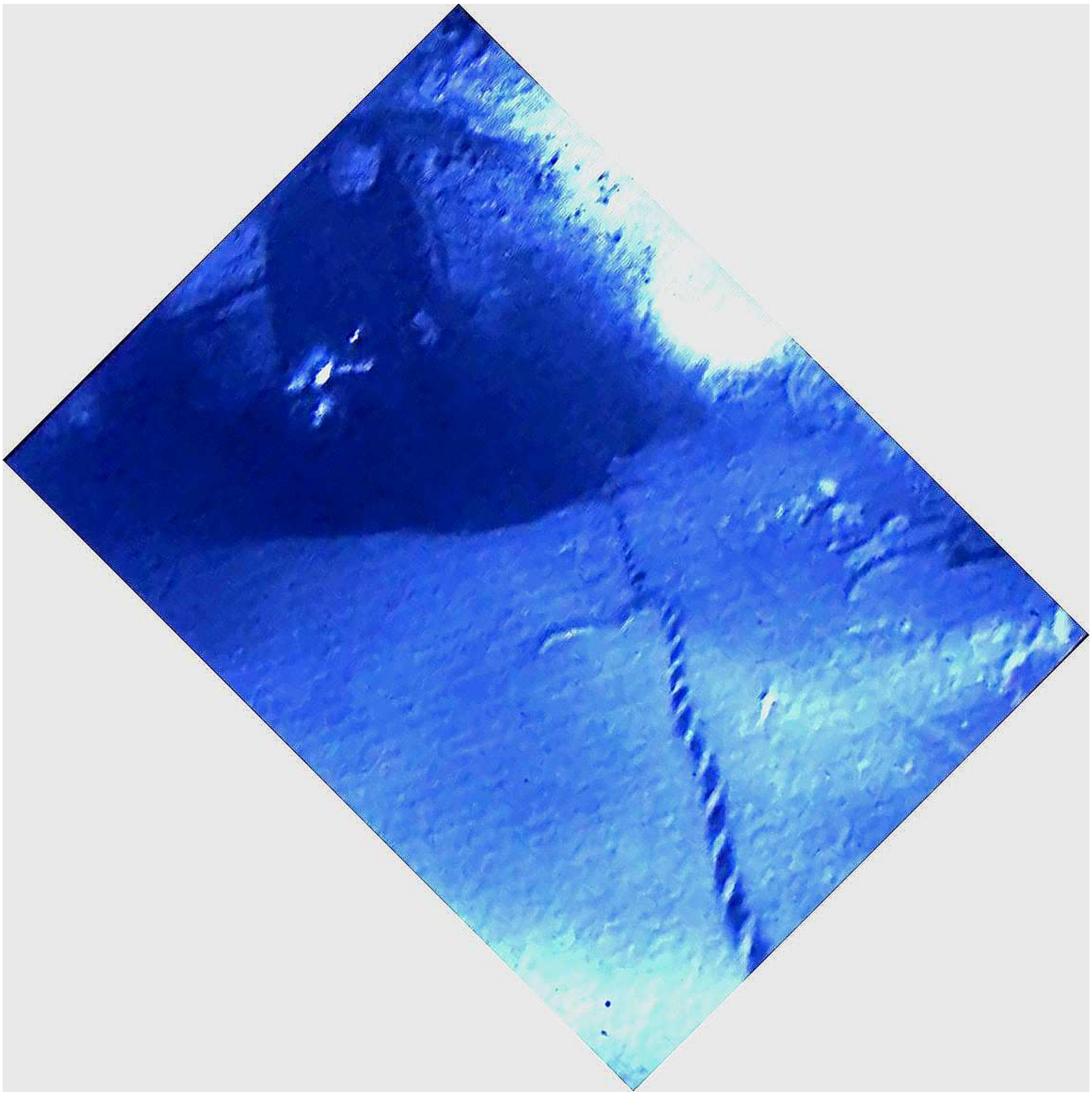
At 148mn 48s the monitor screen shows the plumb line (white band in the photo insert) which indicates the vertical, and, farther Jonathan. From 148mn 50s Alain comments : « A problem with the large swiveling angle is that we do not understand easily the orientation of what we see. So I added a plumb line in front of the optic to tell when the (*monitor*) vertical is the actual vertical". At 148mn 55s the rope is at 9m. At 148mn 57s (right picture) Jonathan arm is visible on the screen (see insert). At 149mn 03s Alain confirms that Jonathan is visible on the monitor and releases very slowly the rope. (Helmet camera)

The reception box and Alain (on the left) operating the CRV (doc. J. Barbier/I. Ebran/Gargouille Productions)

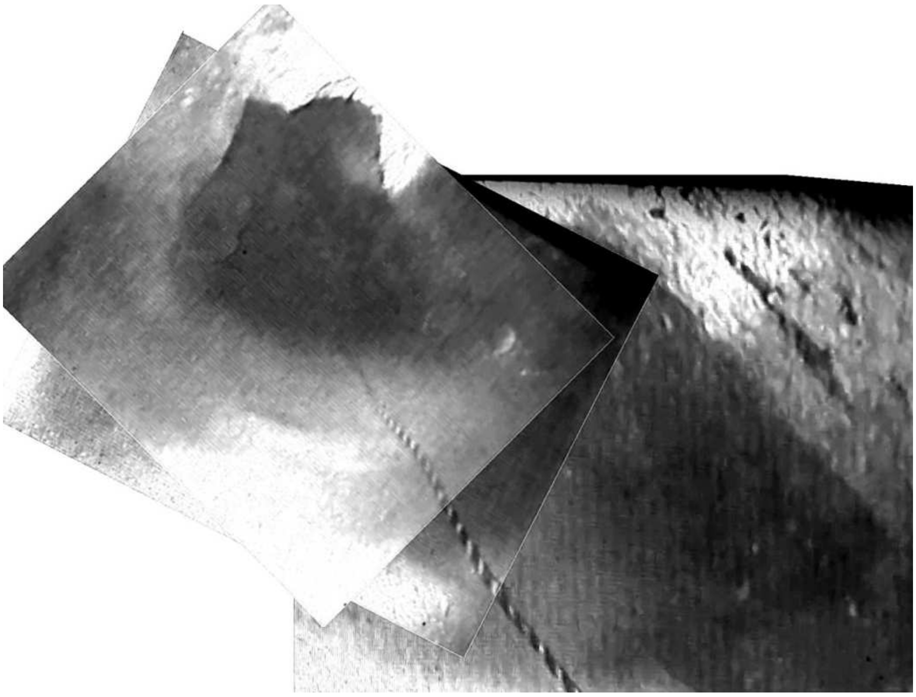
On the left at 149mn 05s the screen shows Jonathan's camera. Alain comments the picture as the Bescor system rotation shows different elements. At 149mn 28s : « Here we see the wheels, we are looking completely sideways". At 149mn 33s : « Here we see the ground ». At 149mn 34s: « Normally we will soon see the plumb line ». « Here it is » (149mn 36s). « It crosses the axis » (149mn 37s). And at 149mn 46s : « There we are on the side » indicating that the vehicle, without its anti roll rods has tipped over. The right picture is taken at 149mn 48s, the vehicle being still on its side. It is put upright shortly after, at 149mn 48s, by Jonathan. (Helmet camera)



On the left, at 149mn 48s, the vehicle has been put upright. At 149mn 51s, Alain pulls by small impulsions on the rope and comments : « This is because of the lack of anti roll rods". At 150mn 05s the descent is started again. At 150mn 12s comment while looking at the monitor: « When we are like that, we are wondering what is the orientation. Four cameras would be better looking up, down, left and right. For now I tried to get the same result by the camera rotation ». At 150mn 27s comment while looking at the monitor : « Here we are looking on the right side with the rope ", the fixed rope to help visitors. See picture farther. At 150mn 33s : « It is there that the picture should indicate that the slope is not ending in a hole ». At 150mn 39s, the vehicle is still descending and a knot on the rope is passed indicating 7,8 m. On the right at 150mn 42s crossing the 9 m mark (black dot on the lower right). For all this video sequence, it would have been better that the helmet camera would have been in its normal position and not in the 90° rotated position. (Helmet camera)



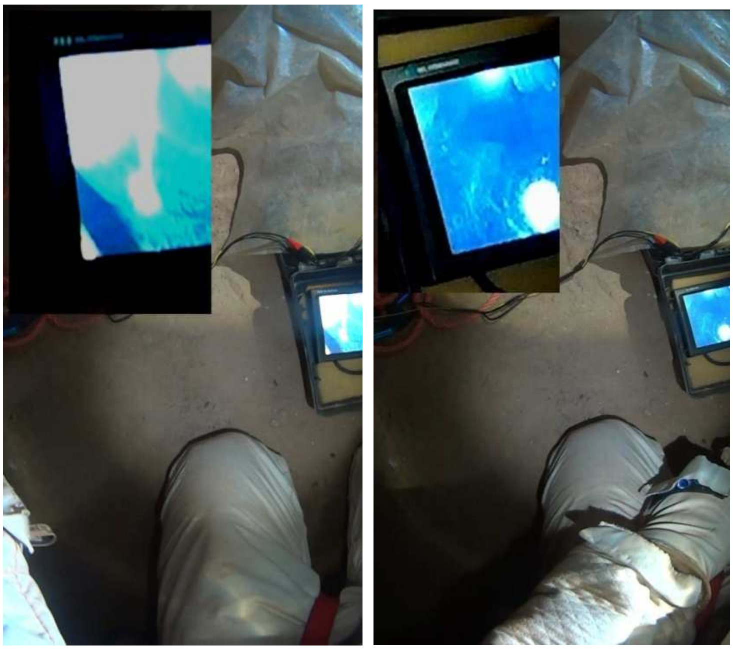
Jonathan Barbier down slope in the Siphon passage filming the CRV, as seen on the video monitor. In front the fixed rope installed to help access to the slope is visible. (Doc. J. Barbier/I. Ebran/Gargouille Productions)



Mosaic of pictures of the slope lower part after Jonathan departure and before that the CRV reaches its lowest position (doc. J. Barbier/I. Ebran/Gargouille Productions)

At 150mn 50s, a comment : « When there is too much soil in front of the emitter the signal may be lost. It is why the emitter may be separated, sorry, the receiver may be separated from the reception box and sent in the slope in order to be in direct view". On the left picture at 150mn 58s, the blue receiver is extracted from the reception box. On the right, picture at 151mn 01s showing the 10 m mark approaching and on the screen (upright picture in the insert) the ground and left wheel. (Helmet camera)

On the left at 151mn 04s, the receiver is pushed down slope. It is linked to the reception box by a rope and wires measuring 3,5 m which allow the positioning in the slope in direct view of the vehicle emitter. At 151mn 09s the CRV is at 10m. At 151mn 16s, while looking at the monitor screen: "Let us admit that I do not know the down slope configuration, what can be deduced ?" At 151mn 20s : « This is a wheel, but I do not know which one in fact ». (Helmet camera)



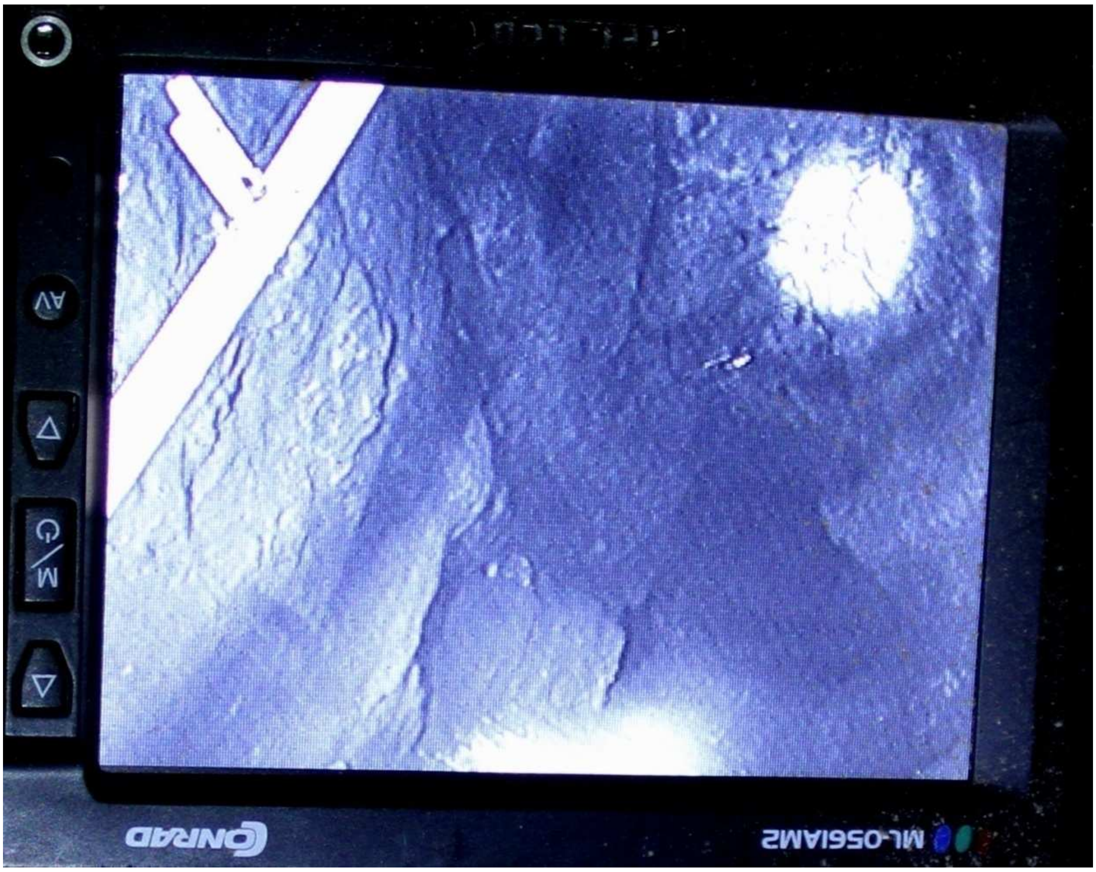
At 151mn 38s :"Here is the vertical". The rope is released from 10 to 11 m. At 151mn 47s : "We see well that there is no hole at the slope end ". At 152mn 06s : "Right side". At 152mn 09s : "Ceiling of the passage". At 152mn 14s : "We are coming back". At 152mn 22s : "Right side". At 152mn 23s : "The ground". At 152mn 33s : "The ground ; the vertical is coming". At 152mn 41s : "There we see that there is no hole down slope". At 152mn 51s : "The left wheel". Jonathan has climbed back the slope and this is why he does not appear any more on the pictures. At 153mn 13s (right image) : "Here it is the slope left side". (Helmet camera)

At 153mn 17s : "Ah, here there is a good hole"(when seeing a black zone on the picture). At 153mn 21s : "What is that ?". At 153mn 27s : "It is on the left side" thus not a hole in the ground. In fact it was the left turn of the passage down slope which demonstrates the necessity to have a knowledge of the picture orientation. The left picture is taken at the same time at 153mn 27s and shows the passage left side with a part of the vehicle left wheel. At 153mn 30s : "Left side; this is the ground on the left side". At 153mn 36s : "OK; we can go down, apparently there is no hole down slope". At 154mn 00s Alain stands up to seek the Canon camera which is in the bag carried back by Isabelle Ebran from the cavity 46, in order to take some pictures of the monitor screen, the monitor views being not recorded. The camera bag is naturally very dusty after the crawling to cavity 46 (picture at 154mn 04s on the right). The ventilation control is again not fixed. (Helmet camera)

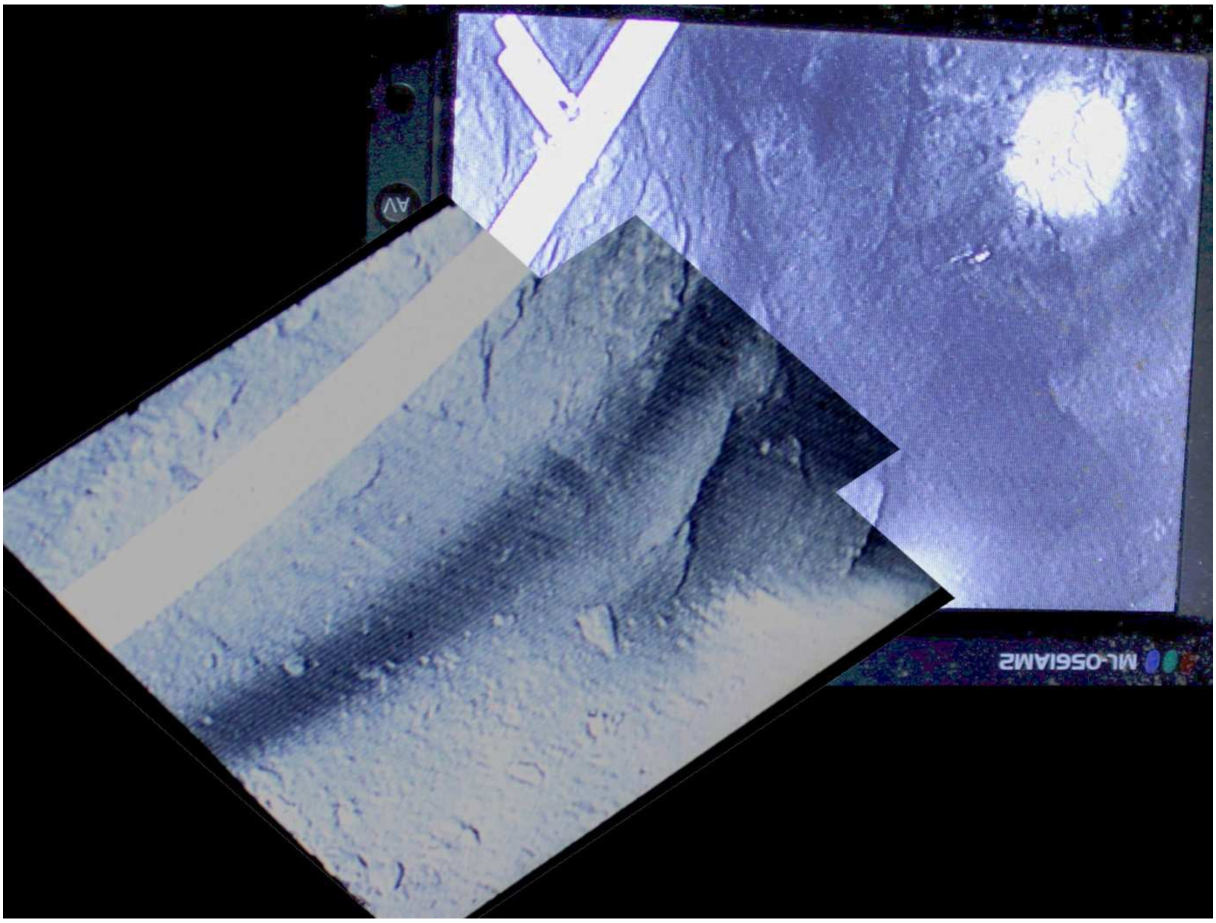
On the left, at 154mn 22s, the Canon camera very dusty after the cavity 46 expedition. On the right at 154mn 59s first monitor picture with the Canon (following picture) showing the left wheel, the picture being presented upright in the insert. (Helmet camera)

This screen picture rotated to present correctly the up and down sides, has been taken by the Canon EOS 7D at 154mn 59s (17h39mn). It shows a part of descent ground on the right, the passage left side on the left with a part of the CRV left wheel and the passage lower part in the up and right corner.(Canon EOS 7D)

At 155mn 08s is taken the 2nd screen picture with the Canon (see next picture). On this view the uprighted monitor picture is shown in an insert. The CRV left wheel and the descent left side may be seen. (Helmet camera)

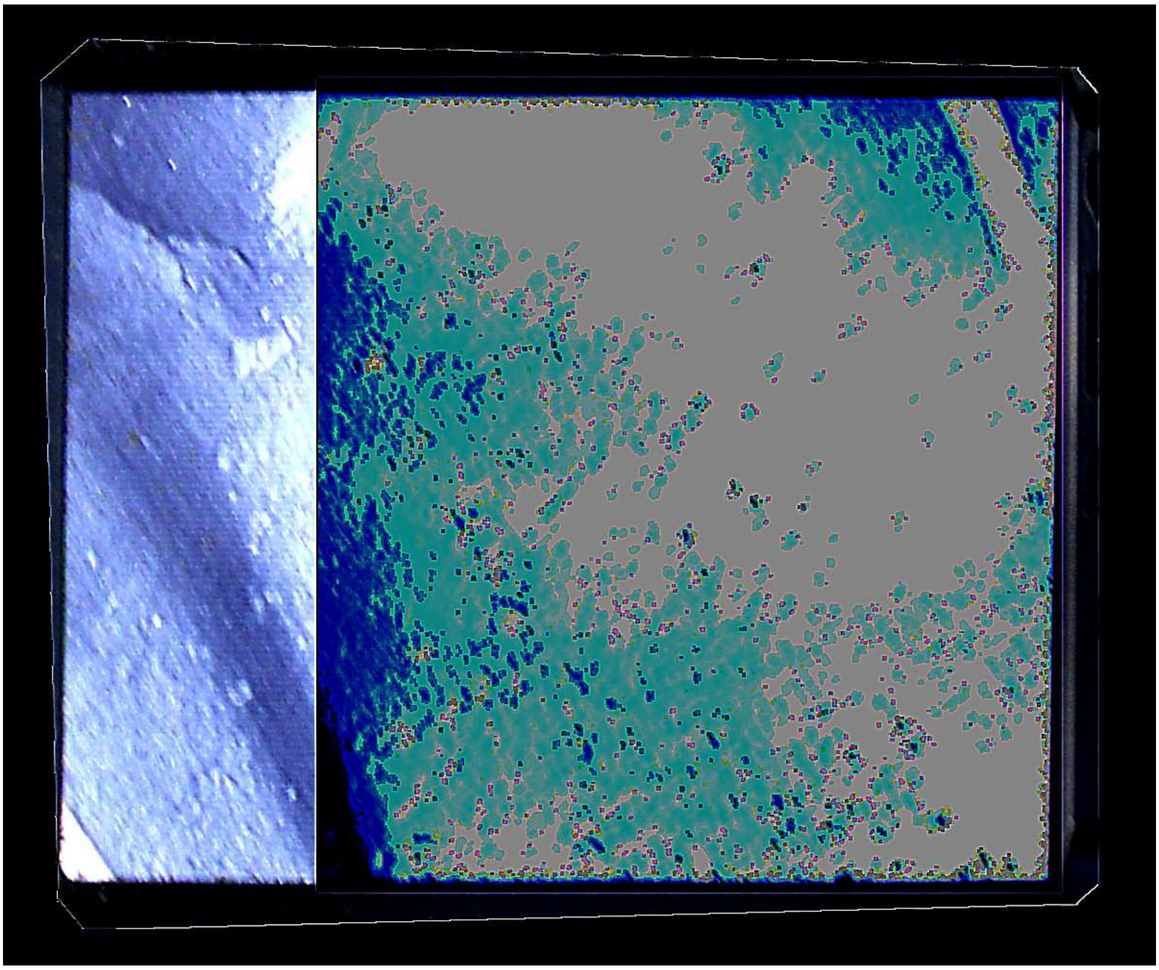


At 155mn 08s the screen picture taken by the Canon and rotated by 180°. On the left is the CRV left wheel and the descent left side on the upper right the passage ceiling and in the lower right the slope end transitioning to an horizontal ground. (Canon EOS 7D)



Combination of the two Canon first photos showing a part of the descent ground, the descent left side and the ceiling as well as the transition to the horizontal part on the right (Canon EOS 7D)

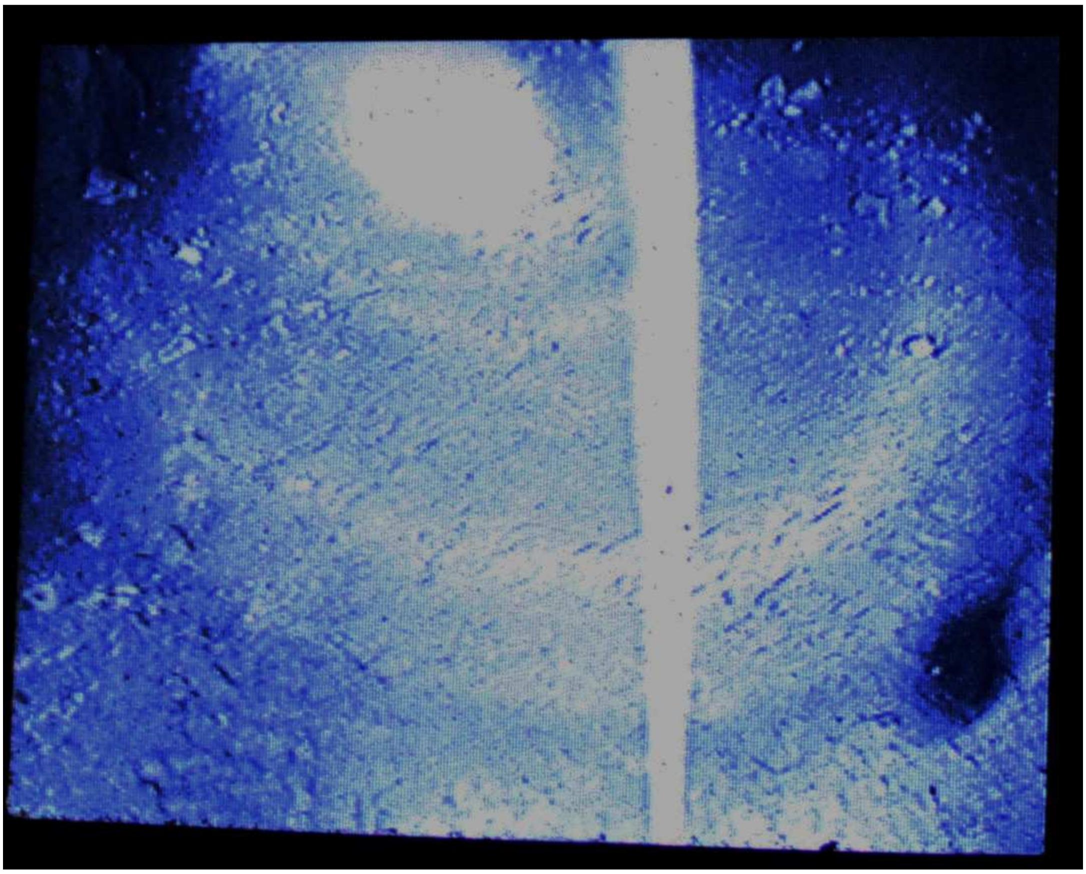
At 155mn 39s, third screen photo with the Canon when the vehicle camera looks to the ground. At 155mn 43s : "The plumb line vertical". (Helmet camera)



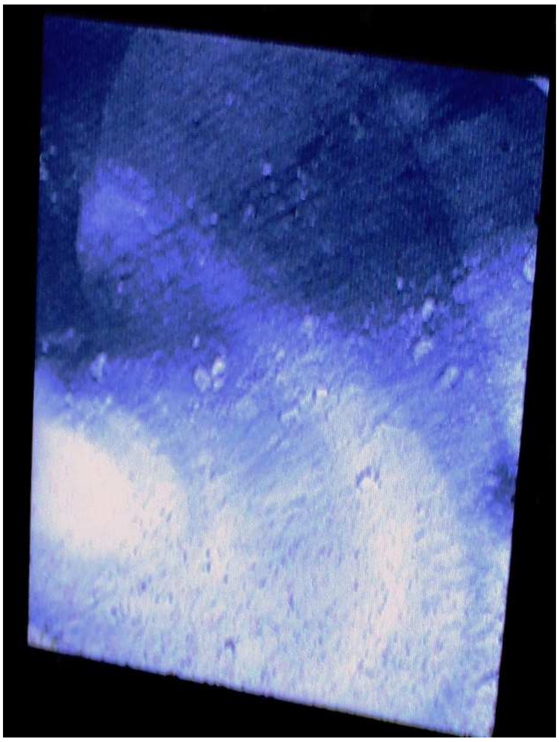
Screen picture by the Canon at 155mn 39s. As the Canon photos field of view is far larger than the screen (see the total picture next), The screen picture is often overexposed like here where the picture right three quarters have been specially treated. The picture shows the ground with, in the upper right, the plumb line indicating the vertical, and on the left the descent left side with a part of the vehicle left wheel. (Canon EOS 7D)

The screen at 155mn 39s. The camera should have been used in the screen visualization mode in order to better concentrate on the screen, the close framing being impossible through the camera eyepiece with the suit helmet. (Canon EOS 7D)

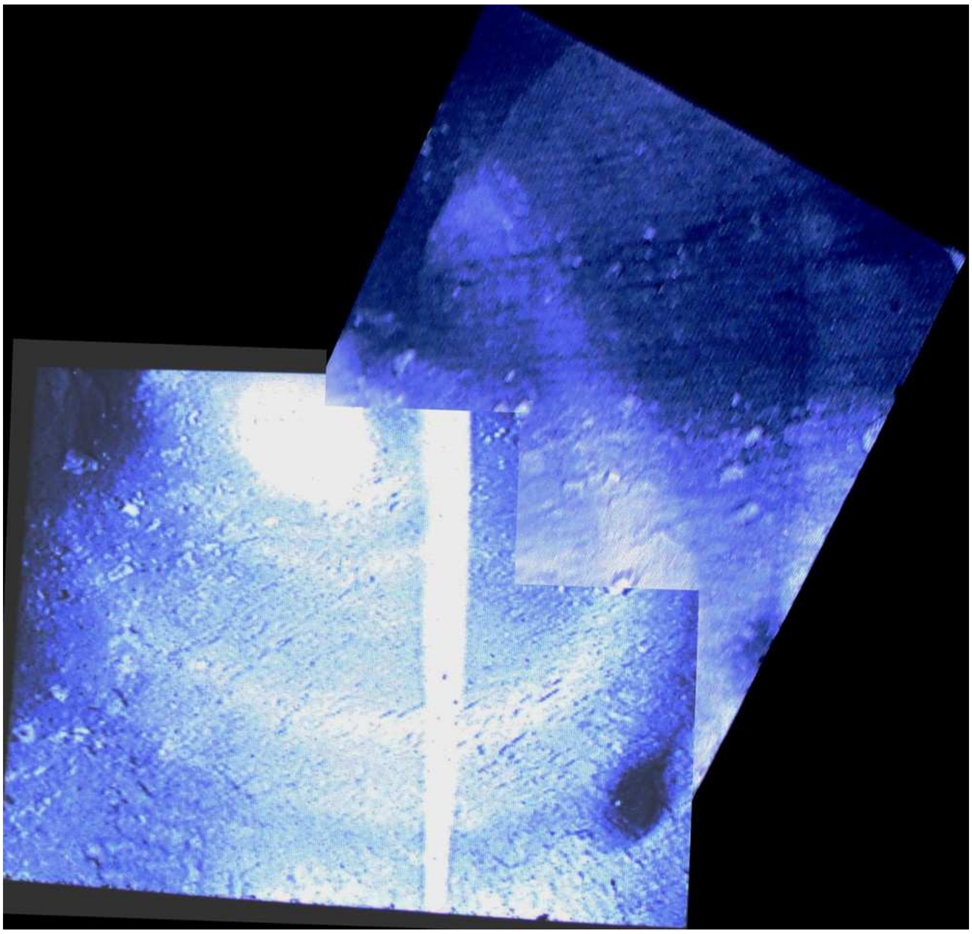
At 155mn 45s fourth screen photo by the Canon. The helmet camera stopped shortly after by battery depletion. The CRV camera is looking to the ground. (Helmet camera)



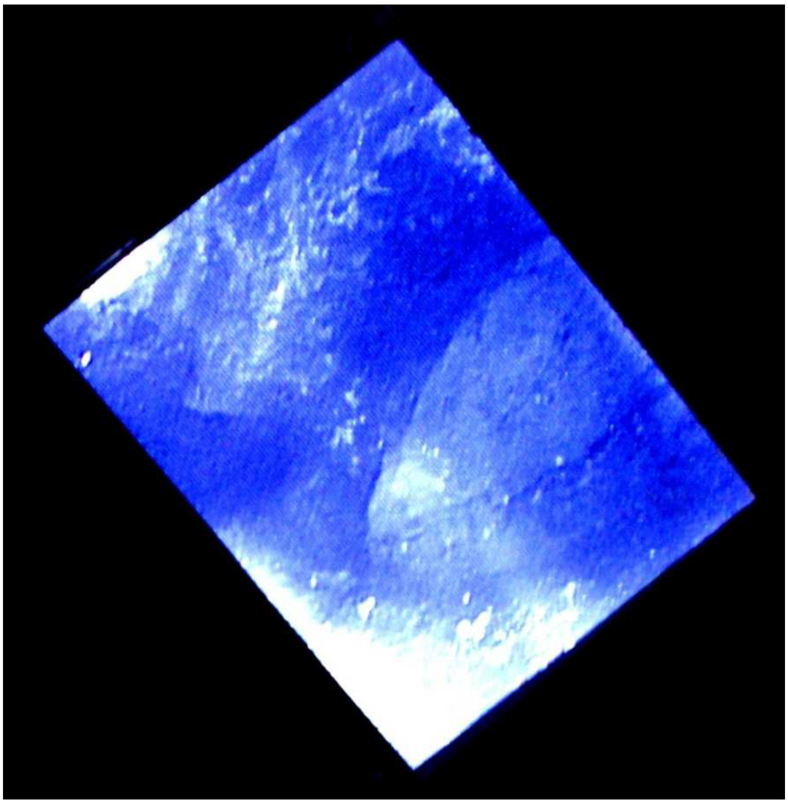
The screen at 155mn 45s showing the descent ground with the plumb line in front of the lens (Canon EOS 7D)



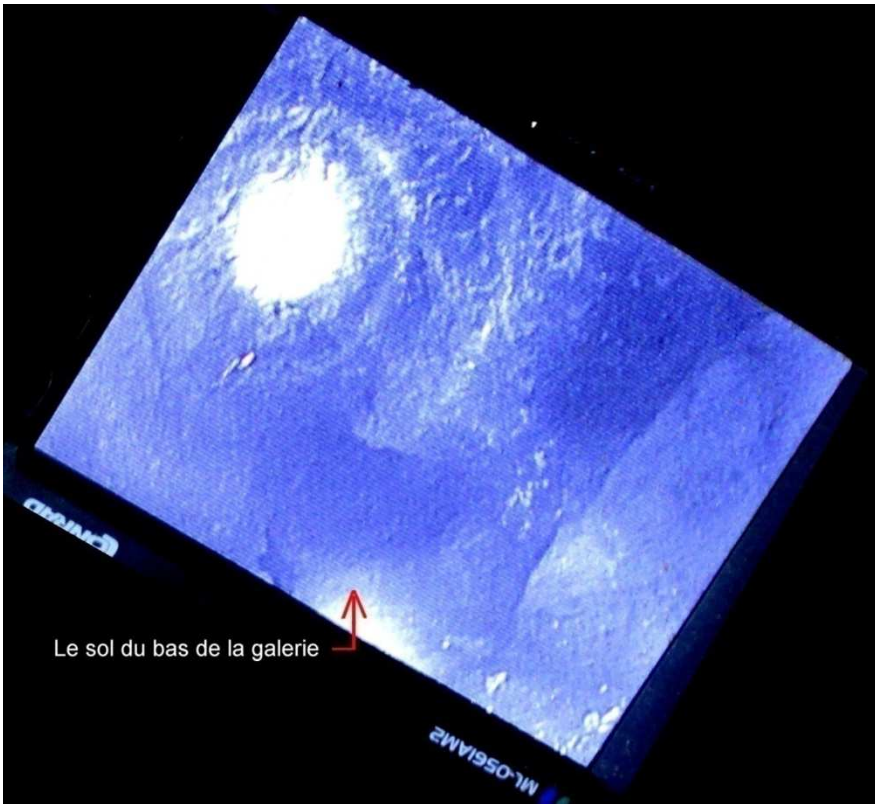
The screen at 155mn 54s on the Canon fifth photo showing the ground and the descent right side. (Canon EOS 7D)



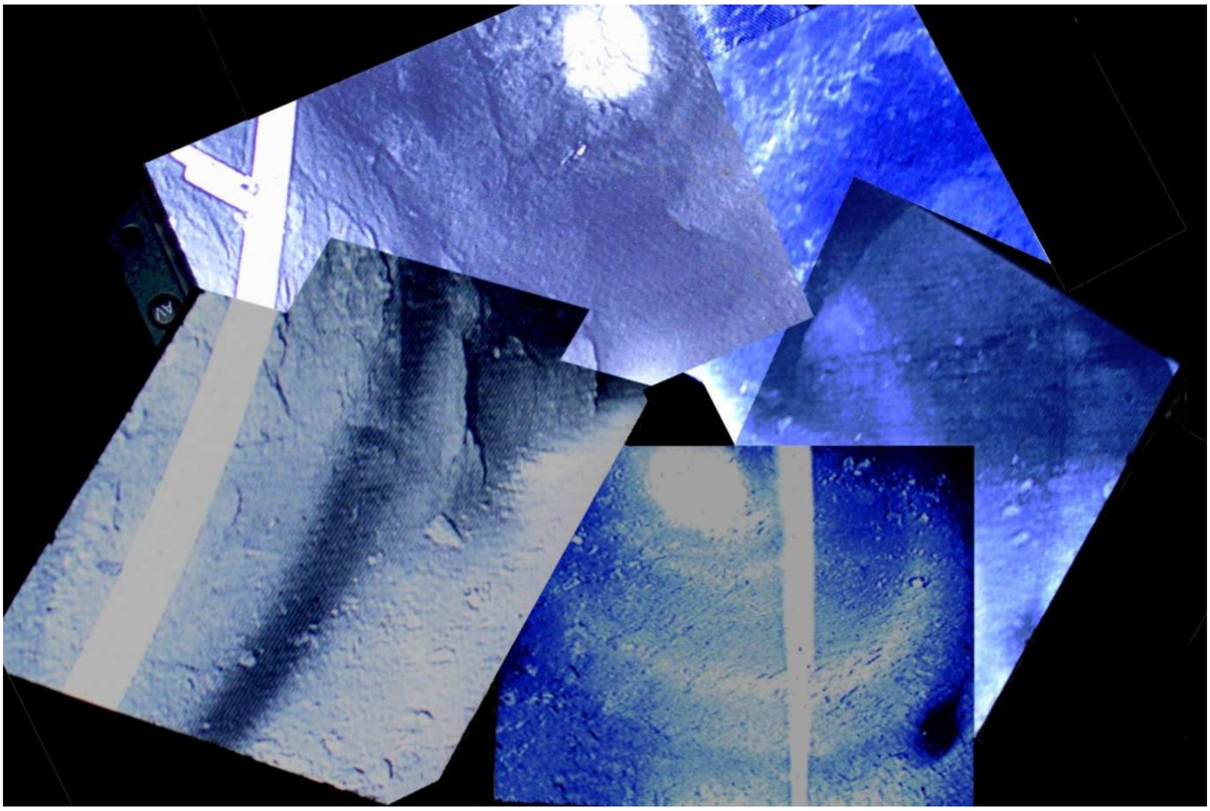
Combination of the Canon two last pictures (Canon EOS 7D)



The screen at 156mn 04s, on the sixth Canon photo, showing a part of the descent ground, the right side of the passage and its ceiling, with the slope end on the left (Canon EOS 7D)



The screen at 156mn 10s showing the right side, the ceiling and the left side as well as the ground (red arrow) at the slope end (Canon EOS 7D)



Combination of Canon photos 1, 2, 4, 5, 6, 7 to recreate a general view of the Siphon passage lower part (Canon EOS 7D)

The simulation ended around 10 mn after the last screen photo.

The operations conducted in these last 10 mn were:

-CRV retrieval

-A range laser measurement of the Siphon passage length as seen from above (not easy because the indications have to be read in the instrument eyepiece though the helmet). The value indicated was 9 m which is the minimum measurement.

This last phase of CRV video fixing and new CRV utilization in the Siphon passage descent has lasted 24 mn.

In total the simulated EVA has lasted 2 h 45 mn.

5 Durations of the EVA different phases

The simulation involved 10 phases (other phases decompositions could have been presented). The durations were the followings:

N°	Phase	Main activity	Beginning	End	Duration
1	Preparation and preliminary activities	Hardware transfert to the Siphon passage entrance - flag deployment - distance measurement from the entrance - 1st trip in the main tunnel	0 -Helmet camera time : 2mn 12 -15h04	7mn 13s	7mn 13s
2	Cliff Reconnaissance Vehicle preparation	Safety pole -anti roll rods fitting - angle measurement between main tunnel and Siphon passage - setting "on" all the CRV equipments	7mn 13s	13mn 34s	6mn 21s
3	Search on the CRV video failure		13mn 34s	15mn 23s	1mn 49s
4	CRV reconnaissance in the Siphon passage	124th CRV test - down 11m, back to 5 m, down to 11m	15mn 23s	22mn 23s	7mn
5	Going down the Siphon passage with the descender	Alain using the descender - Lucie using the fixed rope - reaching the piezo hole cavity - distances measurements	22mn 23s	34mn 20s	11mn 57s
6	Crossing to cavity 46	Waiting for the media teams to reach cavity 46 - crawling to cavity 46 with a stop in intermediate small cavity to reequip Alain	34mn 20s	61mn 32s	27mn 12s
7	In cavity 46	1st examinations - macro views of alluvia layers - interviews	61mn 32s	98mn 31s	36mn 59s
8	Back to the main tunnel	Preparations for the trip back - crawling - back to the piezo hole cavity - retrieval of the Ariadne thread spool - CRV anti roll rod disassembly - CRV emitter off	98mn 31s	125mn 00s	26mn 29s
9	CRV retrieval and main tunnel reconnaissance on a limited distance	CRV retrieval (125th test) - Tunnel measurement till the first turn - trip some tens of meters beyond - back to the Siphon passage entrance	125mn 00s	142mn 37s	17mn 37s
10	CRV video repair and new utilization of the CRV in the Siphon passage descent	12 V reconnection 12V - reception box "on" - CRV descent (126th test) - descent to 9 m, back to 7 m, descent to 11 m - video screen pictures - one laser range finder measure - last interviews by the media	142mn 37s	176mn (approx.) 17h50	34mn

6 Results and lessons learned

6-1 CRV

Configuration

The Cliff Reconnaissance Vehicle 3-6 configuration is described in reference 8. Compared to the configuration 3-5 used during August 2015 ÖWF Amadee-15 simulation and MDRS 164 in February 2016, the modifications were the following: installation of 4 flashlights, deletion of the Sciencecam (as it is used as helmet camera on spacesuit n°2 and as the Hazcam alone is to be used to evaluate the Siphon passage slope difficulties before descending), use of only two half anti roll rods to limit the vehicle width (the siphon passage being narrow), deletion of the two lasers which give a dimension reference in the Sciencecam field of view, deletion of the prelens enlarging the Hazcam field of view, addition of a plumb wire in front of the Hazcam lens giving the vertical when appearing in the field of view.
The main information on the vehicle previous configurations and tests are given in references 3 and 4.

The main geometrical characteristics are unchanged:

- wheels diameter 75 cm
- wheelbase 58 cm
- width 76 cm (main axis, without anti roll rods).

The 3-6 configuration mass is 4010g which on Mars would be the weight of a 10,58 kg vehicle.

Compared to previous use there is a main difference in the operating mode. Usually the cameras are looking rearwards during a descent, the objective being a slope or cliff observation and cartography. Here on the contrary the objective is to give to the operators information on the terrain in front of the vehicle. The Siphon passage slope being in a slight turn, the lowest part of the slope is not visible from above and the objective was to check that the slope was not ending in a hole or any other type of dangerous terrain as unstable debris slope.

Preparation

The vehicle preparation was quick as usual, less than 6 mn for:

Hammering the safety pole in the ground

Fitting the two half anti roll rods

Switching on the 4 flashlights

Switching on the Bescor swivelling mechanism

Switching on the 2 video emission box switches

Opening the video reception box

Switching on the receiver

Connecting the 12V

At this time two actions were remaining in the operating chronology: connecting the video cable and switching on the monitor. But it has appeared that there was no 12 V power. After some on/off actions on the receiver blue box switch, the (wrong) conclusion was that the 12 V battery was accidently depleted. The diagnostic would have been different if a voltage measurement could have been done with a multimeter. A depleted battery does not indicate zero whereas the measurement would have shown zero, rising questions on the connections. The failure cause was only detected at the simulation end: disconnection of the battery 12V + side. The helmet camera pictures show that this disconnection was clearly visible. But Alain chose not to spend too much time on the failure search in order not to delay the simulation following operations. The advantage of being in simulation made it possible to conduct a CRV test with the video on at the simulation end.

The disconnected red (+) connector was however clearly visible. The picture (from helmet camera) shows the reception box shortly after its opening and before any action. The connector is located above the other wires, which is a proof against an accidental disconnection during transport, because the battery is located down on the reception box floor. The last CRV video test occurred on the previous day morning. There are two possibilities: either the connector was disconnected voluntarily to prevent an accidental battery depletion, or it was accidently disconnected when the receiver blue box was stored in the reception box. (Helmet camera)

One may notice that the reception box opening which is easy with bare hands, requested five attempts with the gloves (succeeding in the fifth one), resulting accidently in separation of the RCA connector used to add pikes on the glove when needed for delicate operations. Three attempts were also needed to open the box in the final CRV reuse at the simulation end.

Test 124

The CRV use to scout the Siphon passage was test 124 of the vehicle, including all versions, since 2001. The previous tests were conducted by the MDRS 164 simulation team in Utah around the Mars Society simulation facilities in February and March 2016. An overview of all the tests in the different configurations is available in English on: http://planete-mars.com/planete-mars-association-cliffbot-experimentation-overview/ (reference 3)

Test description, time from the descent beginning:

0s: Descent beginning

27s: Crossing the 5 m mark.

40s: At 7,5 m two pull up of 40 cm are executed to free the vehicle. Comment: "askew, no, no more".

53s: «It is very askew » with, at 8,5 m distance, two new 40 cm pulls.

59s : « It is going to tip over" with one 80 cm pull at 9 m distance.

1mn 05s: "It is stuck" with a pull from 9,5 m to 8,2 m.

1mn 15s: Crossing the 10 m mark.

1mn 18s: "It looks stable" with a pull from 10 to 9,3 m.

1mn 23: Crossing again the 10m mark then pull from 10 m to 8,2 m: "let it go again".

1mn 50s: Crossing 11 m and the rope slackens.

From 2mn 13s to 2mn 20s making a double knot at 11 m on the safety pole.

2mn 28s: "Let us say that, as the vehicle has not fallen in a hole, we can go down".

3mn 18s: One media team asks to pull back the vehicle in order to film from down slope its descent.

3mn 28s: The pull up is started.

3mn 42s: At 9m indication of a problem but the ascent can continue.

4mn 28s: 8m is reached. The Youki Vattier video team descends at that time.

5mn 24s: Comment from an outside observer: « It is the anti roll rods which deviate the vehicle».

5mn 37s: « It is going to get through; but, there, it did not tip over thanks to the anti roll rod".

5mn 40s: Pull back till 5 m.

5mn 44s: at 4,5 m : « Do I send it back to you ?"

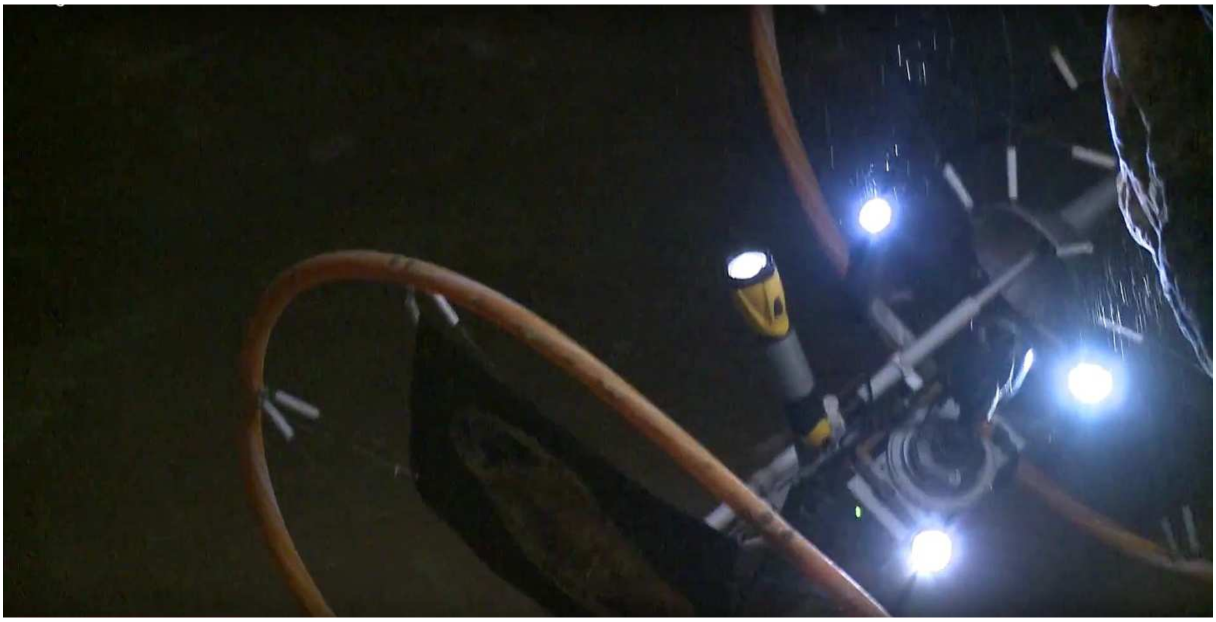
5mn 53s: Rope activations from a position left from the safety pole to try to orient the vehicle to the right in the slope.

5mn 55s: Towards 6 m: « There it is blocking ». A 30 cm pull up is executed then the descent is started again.

6mn 09s: At around 10 m, two 65 cm pull up are conducted, followed by the comment: "Here it is, now it is upside down" (hazcam looking up slope).

6mn 13s: The rope is released at 11m. End of CRV 124 test.

In this vehicle use, difficulties were encountered because the slope is canted on the left. This caused the left anti roll rod to rub against the left wall in the slope lower part which is narrower than the upper part. And we did not dare to use the CRV with no anti roll rods at all. Anti roll rods would not be necessary if the wheels were smaller or if the distance between wheels was larger. But the vehicle main axis length was determined by the necessity to fit inside a suitcase for transportation on far simulation terrains (Utah for example). And larger wheels have the capability to overcome bigger obstacles. The result is a tip over risk which is limited by the anti roll rods. The normal terrain for the vehicle is a steep slope or a vertical one. To orient the vehicle on a medium slope like the Siphon passage, the operator can move its operating position to left or right which has been done during this test. (Doc. J. Barbier/I. Ebran/Gargouille Productions)



Seen from down slope, the vehicle has its left anti roll rod and left wheel stuck against the passage left (as seen from above) wall (doc. J. Barbier/I. Ebran/Gargouille Productions)

The different operations have ended in a CRV rotation by 180° around a vertical axis (comment at 6mn 09s: "there, it is upside down"). The camera and flashlights are now looking up and not down. The final 60° rotation has been induced by a slight rope release. (Doc. J. Barbier/I. Ebran/Gargouille Productions)

To better pilot the vehicle in a medium slope, it could be equipped with two ropes which could be used to orient the descent. Till now this solution has not been used because it is practically useless on a vertical or quasi vertical slope. The operations would even become more complicated and the rope length storable in the spool would be divided by two. One may imagine two coupled spools or two uncoupled spools but then the operation by a single operator would become problematic. The two ropes configuration would be interesting in overhang allowing a vehicle retrieval in a controlled orientation. It is a configuration which could be interesting to experiment in next tests.

<u>Test 125</u>

The vehicle retrieval after expedition in cavity 46 was taken into account as test 125. Normally a return to a slope upper part is seen as the same test as the descent. But here the vehicle configuration was modified the two anti roll rods having been disassembled before the pull up. A new risk has been introduced: a tip over on the wheel side, which finally happened. For the retrieval the CRV was left camera and flashlights looking up.

The only previous case of operations without anti roll rods was the scouting of a hole in the ÖWF Morocco simulation in 2013 (Doc. ÖWF/K. Zanella-Kux)

Test description, time from the ascent beginning:

0s: Ascent beginning

1mn 09s: "It is going to tip over; here it is". The vehicle is on one wheel side, the other wheel having climbed on the passage left wall.

The CRV on its side (helmet camera)

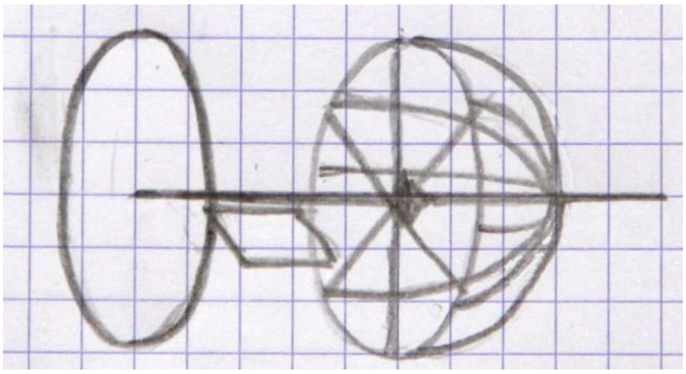
10s: After pulling on the rope, the vehicle is upright again. This is an interesting behavior which was not expected. The awaited scenario was that it would remain on its side.

At 10s from the ascent beginning, the vehicle is again on its wheels (helmet camera)

32s: the CRV is up slope

In the process of tipping over and getting upright again, the camera and flashlights are now oriented down slope again (helmet camera)

During discussions before the following test, Jonathan proposes to modify the wheels structure to give them a half sphere shape. This would be possible, still keeping the suitcase transport capability by using half circle hoops which could be connected to the wheels spokes as shown in the following drawing. This configuration is also compatible with anti roll rods.



Sketch of a wheel modification concept where the anti roll rods are totally or partially replaced by half circle hoops which may be disassembled.

Test 126

At the simulation end, with less constraints on chronology and while Lucie is being interviewed, Alain tries again to find the 12 V failure cause. The cause is found quickly (in 30 s after the reception box opening). Jonathan reconnects the + 12 V connector to the battery (but this could have been done also with the suit gloves) and the video becomes operational. A new CRV use to scout the Siphon passage descent is now undertaken.

Test description, time since the descent beginning:

0s: Beginning of descent.

20s: CRV at 5 m. The descent is conducted with some stops.

55s: Alain ties the CRV rope on the safety pole at 9 m. Jonathan wishing to film new sequences on the vehicle evolutions, Alain proposes to pull it back by 2 m. Jonathan descends.

2mn 14s: Alain unties the 9 m knot and pulls up the CRV by 2 m and let it go down slowly.

2mn 37s: Alain comments: " The problem with the left right swiveling is that it is difficult to understand where is up and down. This is why I introduced a plumb wire in front of the camera lens to clearly show when the monitor vertical is really the vertical."

2mn 42s: The rope is at 9m.

2mn 50s: Alain confirms that Jonathan is visible on the screen and let the vehicle go down very slowly.

3mn 15s : " Here we see the wheels. We are looking on the side. "

3mn 20s : " Here we see the ground. "

3mn 21s " Normally, we should soon see the plumb wire. "

3mn 23s: "Here it is ".

3mn 24s: " It is right in the middle ".

3mn 33s: "And there we are on the side" indicating that the vehicle not equipped with its anti roll rods has overturned on its side.

3mn 35s: The CRV is put upright by Jonathan

3mn 38s: Alain pulls on the rope and comments: "That's the lack of anti roll rods."

3mn 52s: The descent resumes.

3mn 59s: Comment while watching the monitor: "By example when we are like this, we wonder how we are *(in orientation).* It would be better if I put 4 cameras that look up, down, left, right. For now I had tried to replace with a field rotation. "

4mn 14s: Comment looking at the monitor: "So there we are looking on the right side with the rope " fixed to the ground.

4mn 20s: "This is where it should give us that there is no hole below."

4mn 26s: Passage of a rope connection indicating 7,8 m.

4mn 29s: Passage of 9m

4mn 37s: "When there is too much earth in front of the transmitter, you can lose the signal. It is for this reason that the transmitter can be separated, sorry the receiver, and sent in the slope in line of sight. "

4mn 45s: The receiver is out of the reception box.

4mn 48s: Approach of the10 m mark on the rope, the screen showing the ground and the left wheel.

4mn 51s: The receiver is pushed into the slope. It is connected to the box containing the monitor by a cord and wires (power supply and signal) of 3.75 m which allows to locate it in the slope as much as possible in direct view of the transmitter on board the vehicle.

4mn 56s: The CRV is at 10m.

5mn 03s: By examining the monitor to see what can be understood from the configuration of the bottom of the descent: "Suppose I do not know *(the slope lower part),* what do I deduce?"

5mn 07s: "It's a wheel but I do not know which one in fact."

5mn 25s: "Here is the vertical." The rope is released from 10 to 11 m.

5mn 34s: "It is clear that there is no hole down slope."

5mn 53s: «Right side».

5mn 56s: «Top of the passage».

5mn 58s: "And we go back."

6mn 09s: «Right side».

6mn 10s: "The ground".

6mn 20s: "The ground. The vertical is coming. "

6mn 28s: "There we see that there is no hole below."

6mn 38s: "The left wheel". Jonathan is back in the main tunnel which explains why he is no longer seen on the pictures.

7mn 00s: "Here, there is the passage left flank."

7mn 04s: "Ah, there is a good hole" (pointing to a black area on the picture).

7mn 08s: "What is it?"

7mn 14s: "It's on the left side" so not a hole in the ground. In fact it was the turn of the gallery at the bottom, which shows the importance of having a means of identifying the image orientation.

7mn 17s: «Left side; that's the floor on the left side."

7mn 20s: "That's it. We can engage. Apparently there is no hole at the bottom of this descent ".

7mn 43s: First picture of the monitor with the Canon recovered a few meters away, showing the left wheel.

7mn 55s: Taking the second photo with the Canon showing the CRV left wheel and the left side of the passage.

9mn 26s: Third picture of the screen with the Canon when the vehicle camera looks to the ground.

9mn 30s: «The vertical plumb line».

9mn 32s: Fourth picture of the monitor by the Canon. The CRV camera looks towards the ground.

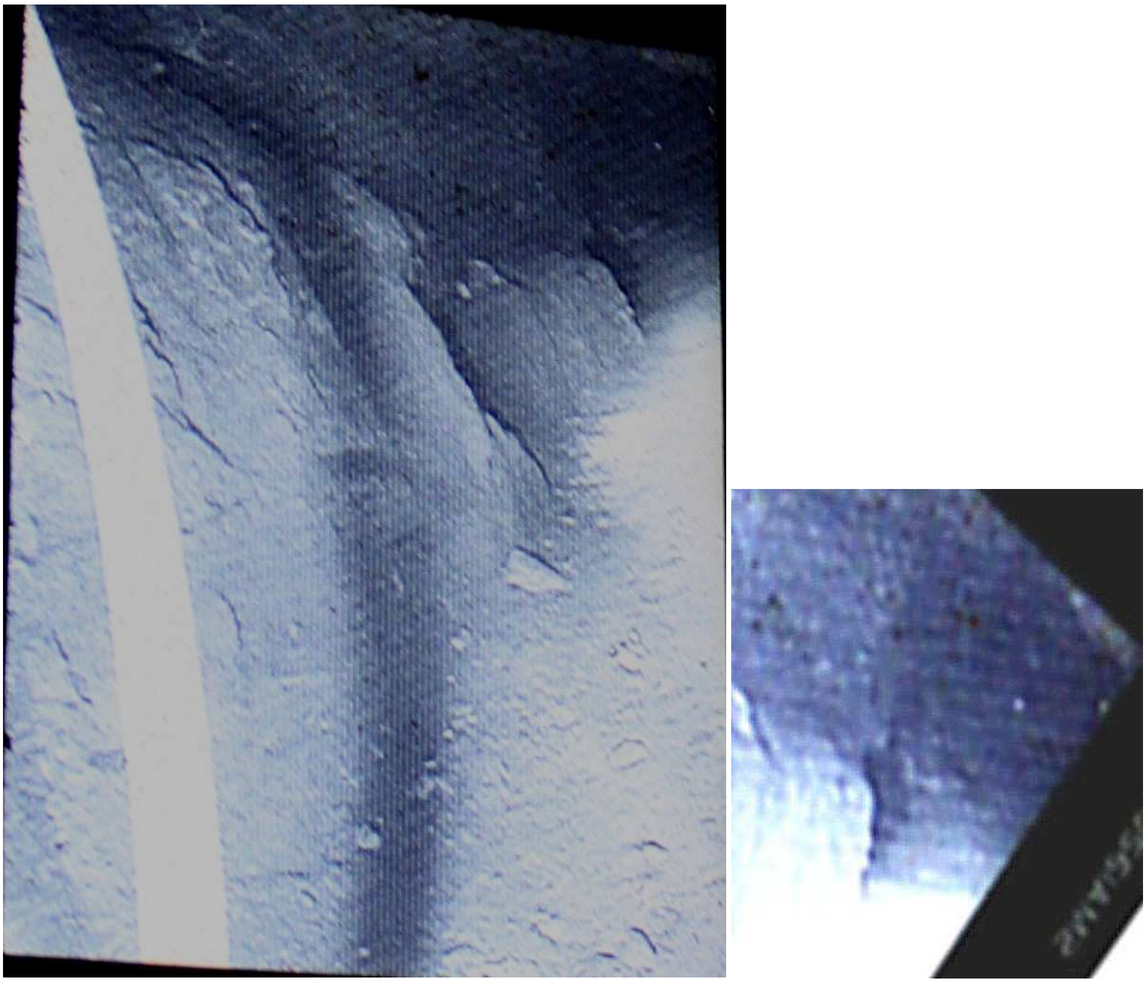
9mn 41s: Fifth picture of the monitor with the Canon showing the descent floor and the passage right flank.

9mn 51s: Sixth picture of the monitor with the Canon showing a portion of the descent floor, the right flank and the ceiling of the passage with the continuation of the passage on the left.

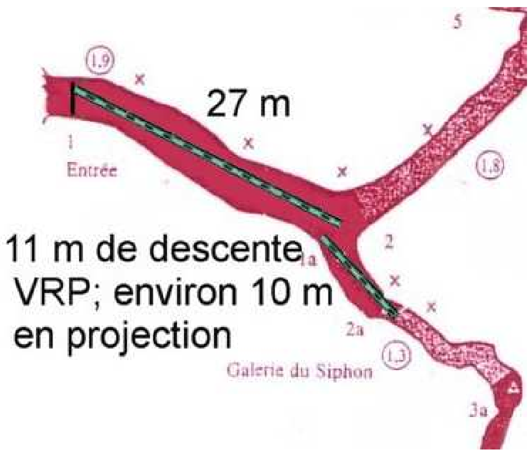
9mn 57s: Seventh and last picture of the monitor with the Canon showing the right side, the ceiling and the left side of the passage as well as its bottom floor.

The vehicle went up shortly afterwards but the helmet video camera having stopped operating by battery exhaustion a few seconds after the 4th photo, there are no indications of time.

This last CRV descent with the operational video showed that the recognition carried out made it possible to verify that the passage became horizontal at the bottom, at least on a few meters, which was the objective sought. The following photos show the bottom of the gallery, knowing that the direct observation of the monitor, from the landscape swept by the rotation of the camera, provided an even clearer perception.

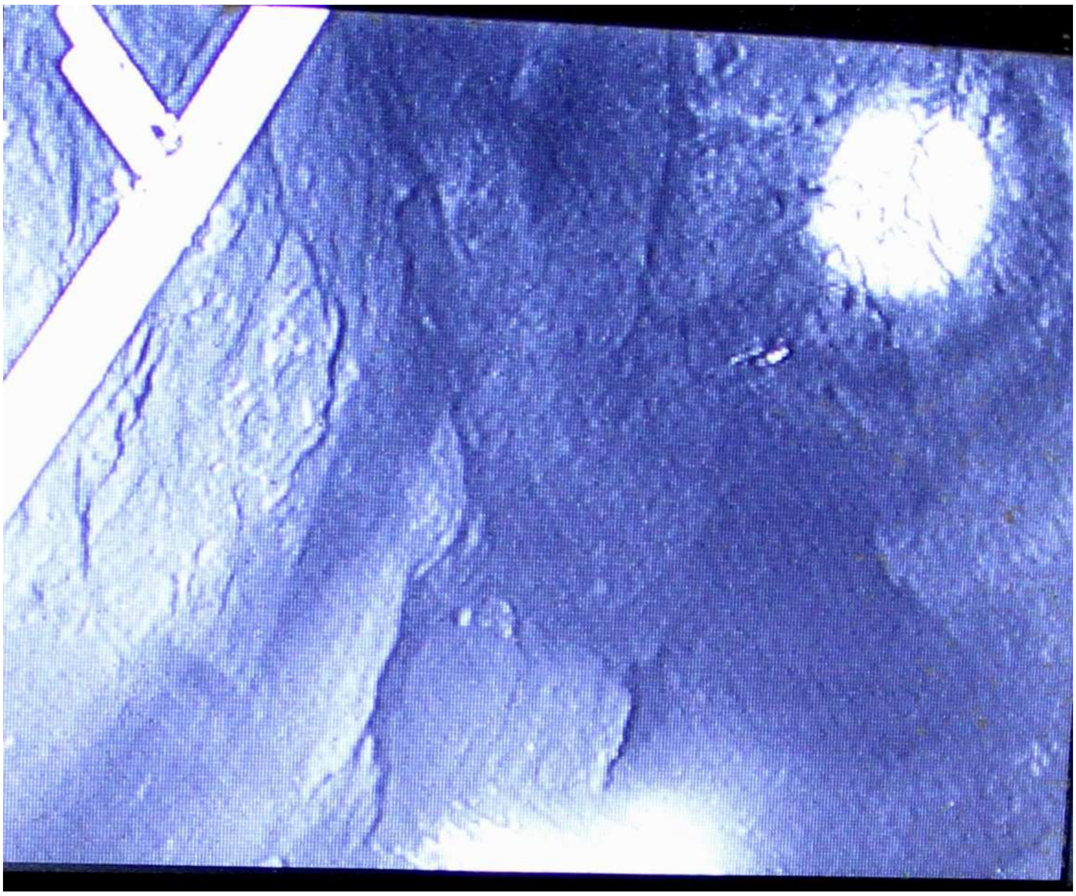


First Canon picture of the monitor showing the left wall of the descent (with a left wheel section in the foreground) and the left side of the descent with, in the upper right (see small photo on the right) the end of the descent where the ground is horizontal again. However, it is difficult to say where exactly the ground becomes again horizontal. With 11 m of rope released, the vehicle should be about 1 m from the bottom of the slope. (Canon EOS 7D)

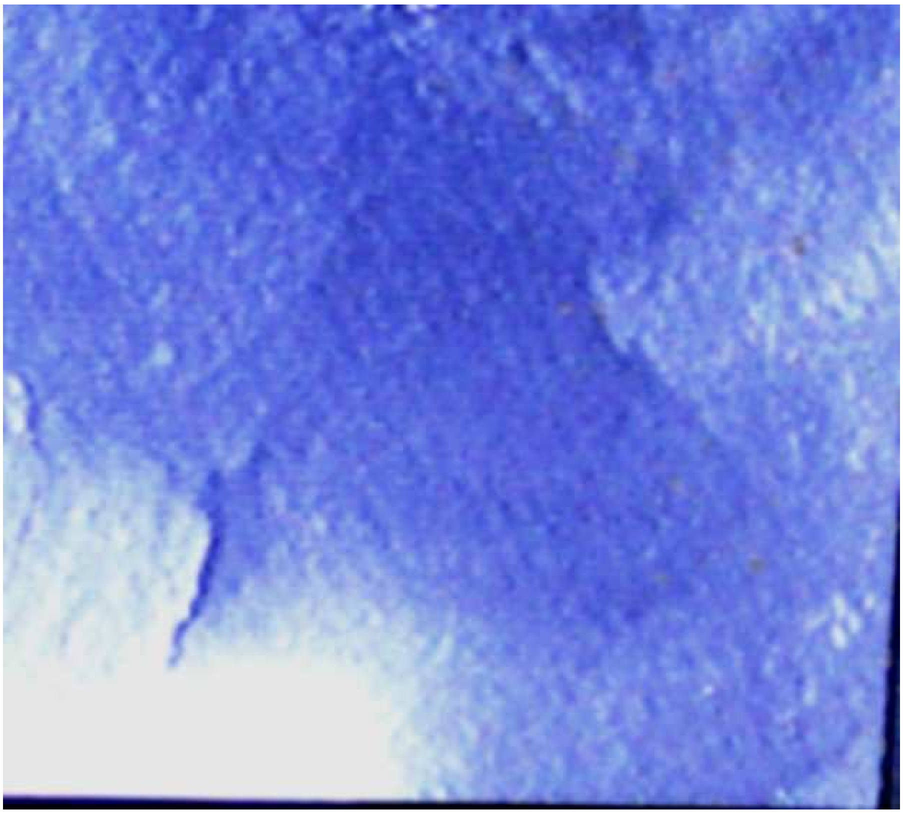


At 11m the vehicle is not far from the bottom of the slope in the Canon picture taken after the first descent. The measurements taken by Lucie indicated 12 m for the bottom of the slope. (Doc J. P. Viard / indications APM)

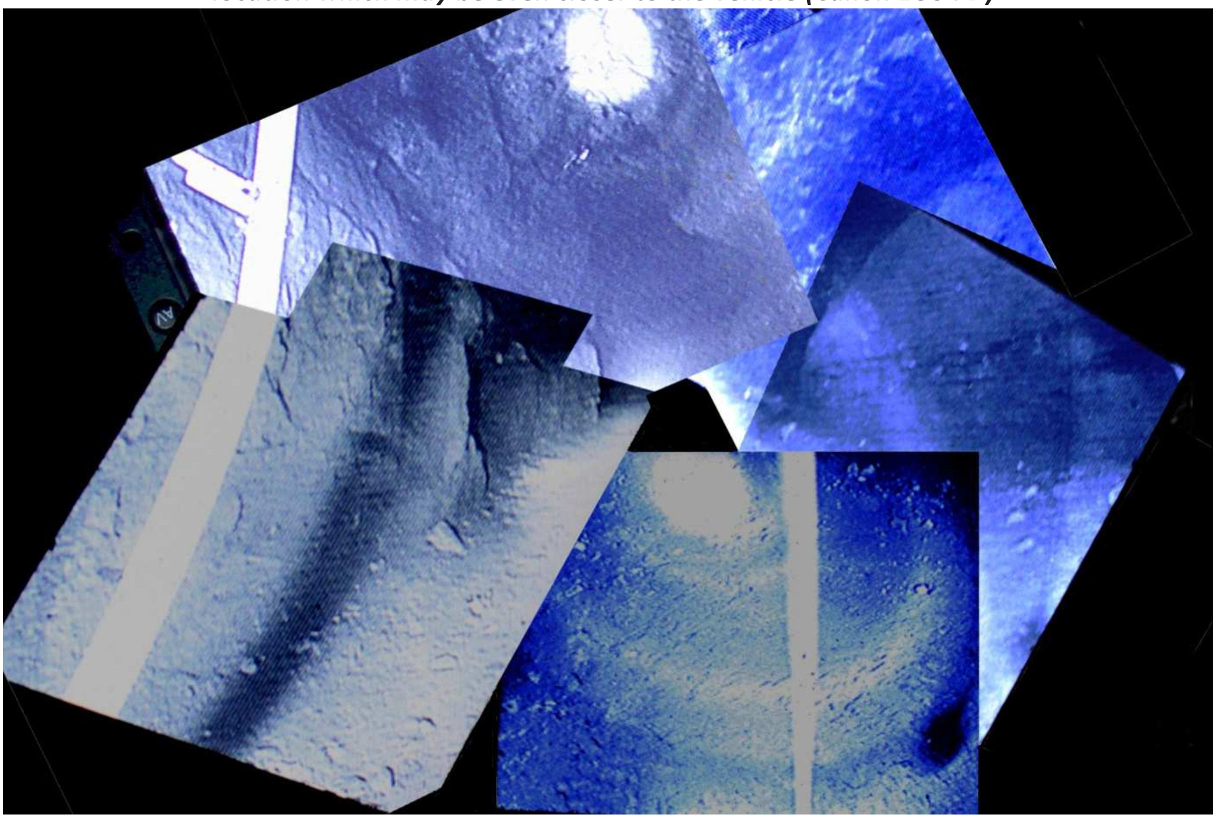
In this image taken after the first descent of the vehicle, while the length of unrolled rope is 11 m, it is clear that the CRV is in a zone of already lower slope. (Canon EOS 7D)



The second screen shot showing the bottom of the descent (Canon EOS 7D)



Enlargement of the bottom of the descent showing the ground that becomes horizontal in a location which may be even closer to the vehicle (Canon EOS 7D)



Overview by combining photos 1, 2, 4, 5, 6, 7. On the downward-facing image, the plumb-line indicates the vertical. (Canon EOS 7D)

Test	Beginning	Duration	Distance	Heigth	Remarks
124	16mn 20s	6mn 13s	11 m down	~3m	Video off (no 12V); a 180° yaw rotation
125	127mn26s	32s	11 m up	~3m	Video off; no anti roll rods; tipped over on one side but upright by traction on the rope
126	146mn 13s	12mn	11 m down and up	~3m	Video on; no anti roll rods; efficient descent scouting; tipped over in descent

Tests summary

Batteries autonomy

	Battery 1 emission	Battery 2 emission	Battery 12V reception
After charging the 27/5	7,37 V	7,37 V	14,34 V
After EVA the 1/6	6,60 V	6,68 V	13,27 V
Operations duration	110 + 20 mn	110 +20 mn	20 mn

The CRV 4 flashlights and the camera rotation mechanism (Bescor) were not stopped and thus operated for 165 mn.
A vehicle autonomy test during a subsequent exhibit showed a continuous operation of 7 hours before the video transmission stopping on battery 1 low voltage which is the one in the emission box which supplies the transmitter (6V) and video camera (12V) while the battery 2 only supplies the video camera.
The Bescor system batteries have not been changed during the 7 hours demonstration of autonomy after the cave simulation. A 9 hours and more autonomy has been demonstrated for this system.

Conclusions
The CRV first reconnaissance descent (CRV 124) had to be conducted without the video because of accidental disconnection of the 12V battery. A test had been made the day before. A verification test should be conducted as close as possible to the operations.
Although the length of the anti roll rods was divided by two (50 cm instead of 1 m), they proved (as might be feared) an obstacle to the descent by putting the vehicle across. The vehicle descended sufficiently however (11m) to show that the way was without pitfalls on these 11 m.
On the ascent (CRV 125), carried out without anti-roll rods, the vehicle tipped over on its side as might be feared, but unexpectedly straightened up when the traction on the rope continued. It is not said that this good behavior is systematic.
After repairing the video, the test (CRV 126) could be resumed under the initial conditions. The video worked well with the + or - 170° field scanning system which gave a good perception of the passage configuration at the bottom of the descent. This last test was carried out without anti-roll rods, taking into account the experience of the first descent, which resulted in a 180° yaw rotation.
Two ideas for improvements stem from these trials;
-Evaluate whether a two-ropes system would allow the vehicle to be steered on medium slopes such as the one encountered, allowing to manage a turn.
-Replace all or part of the anti-roll rods by means of arches or hoops giving the outside of the wheels a form of half-sphere while preserving the capacity of vehicle disassembly to be transported in a suitcase.

6-2 Cartography

The cave's mapping operations took place from the entrance to the Siphon passage and into the piezo well room. On the way back from cavity 46 the operation was conducted till the first bend in the main gallery.

The mapping was carried out from the distance information provided by the Ariadne wire unwinder (or spool) and by an angle measurement by means of a modified protractor for the changes of tunnel orientation. The unwinder contains 252 m of wire with a black marking every meter, a double black marking every 5 m, accompanied by a label with the distance indication every 10 m. Note that this unwind requires manual rewinding. Without rewind, knots are quickly appearing on the wire. This is what happened when the unwinder went up 11m from the slope of the Siphon passage. The detangling was carried out by a person out of simulation, the detangling being hardly possible with the simulation spacesuit gloves.

The angle change measurement method consisted of measuring the angle between the held wire stretched back and a view of the new tunnel or passage section in front, stretching the wire in the direction of this new section. In the picture above, the length of wire between the protractor and the snap hook represents the path already traveled and, between the protractor and the unwinder, the aiming in the direction of the next section. The angle measurement error can be evaluated at 10 °. The compass method was not adopted due to the absence of magnetic field on Mars, although it is sometimes reported that the presence of a residual fossil magnetic field could provide an orientation reference locally. (Doc. A. Souchier)

A laser rangefinder was also carried, capable of measuring up to more than 500 m but not falling below 9 m. This rangefinder has the advantage of also giving the inclination of the sight when it is used in LOS (Line Of Sigth) mode. In this case it gives the true distance (and not the horizontal distance) and the angle as the cosine of the angle in %.

The rangefinder to the left and what is seen in the field to the right with a measurement at 19 m distance and a quasi horizontal aim, cosine worth 0.997 (docs. A. Souchier)

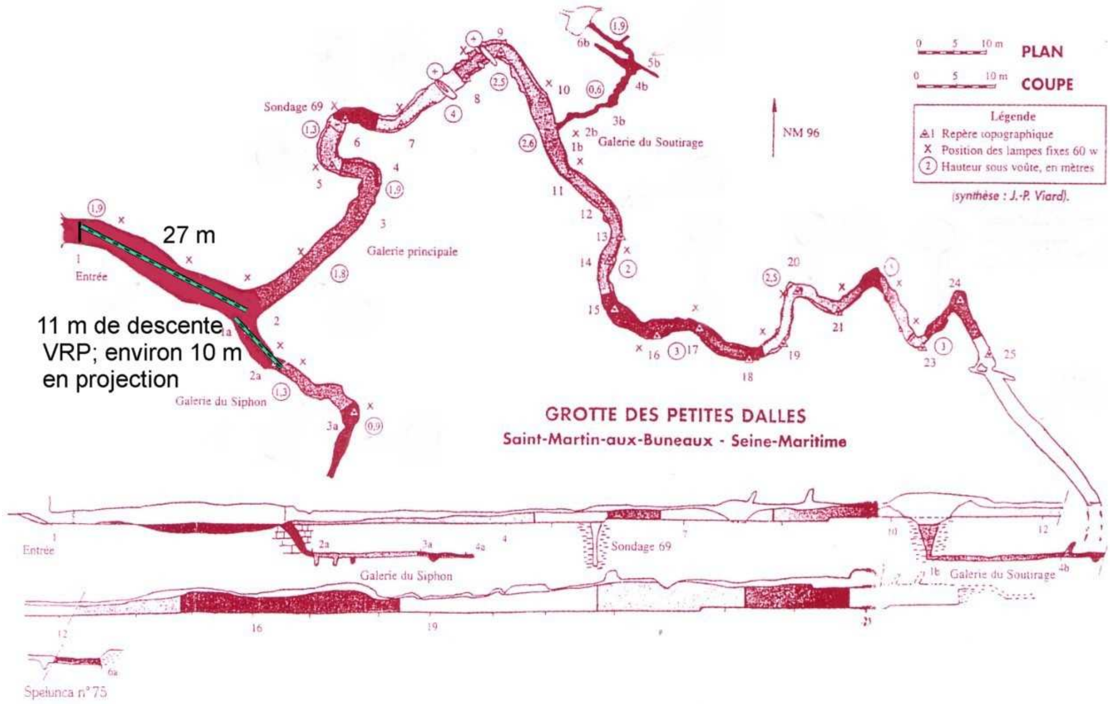
The rangefinder was used only once during the simulation, in the last few minutes of the EVA, to measure the distance from the top of the Siphon passage to the turn of the passage. The 9m value obtained corresponded to the minimum reading possible. The distance between the eyepiece of the range finder and the eye of the observer imposed by the helmet does not allow to see the two figures as in the picture above, but only one. The angle given in the downward inclination of the siphon gallery was not read. Alain planned to measure with the rangefinder the length of the passage leading from the piezo well room to cavity 46 but gave up given the presence of the media team in the tunnel or cavity 46. It would have been interesting to try a measure in the passage that continues beyond cavity 46, but that was not imagined while we were in cavity 46.

The cartographic data thus come from the distance measurements made with the Ariadne wire as well as measurements of angles, all made by Lucie Poulet.

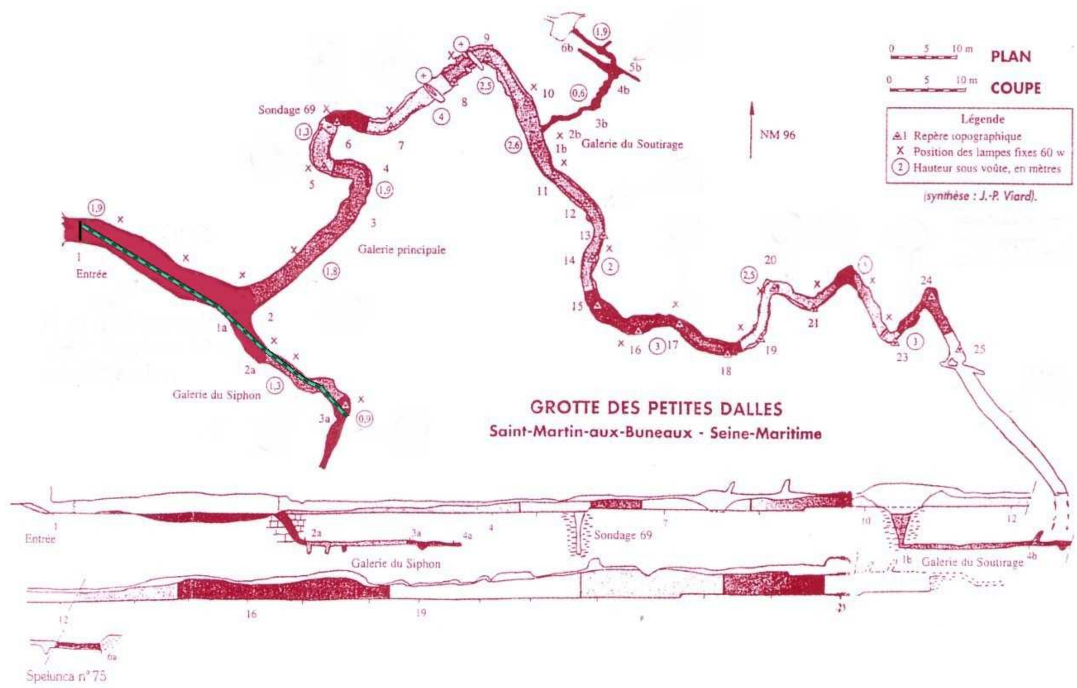
A remark on the distance measurement: it is necessary to unroll until reaching a label indicating n x 10m and to go back to give the distance. It would be useful to also put labels on distances n x 10m + 5m to facilitate measurement.

It had not been considered prudent to take the unwinder into the section between the piezo well room and cavity 46 for a first attempt to crawl with the simulated spacesuits.

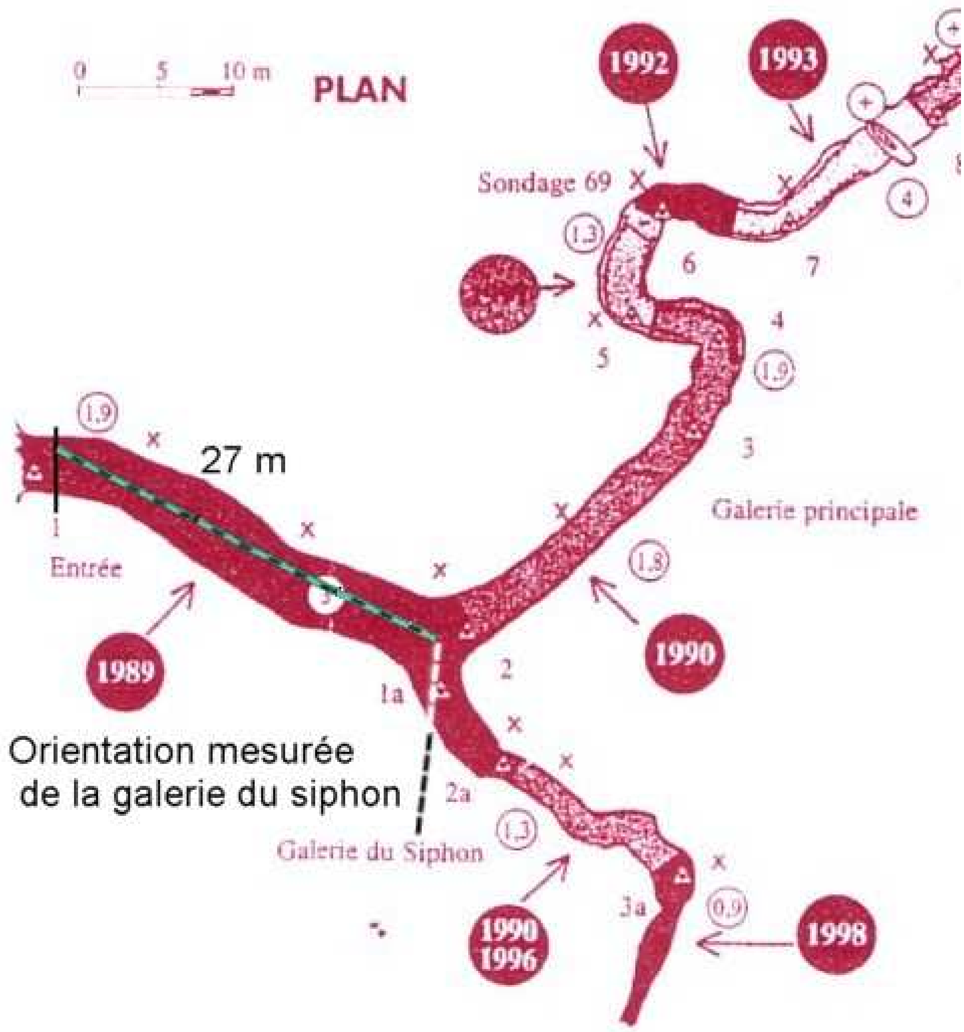
The cartographic results are given in the following images, comparing the measurements and a plan of the cave.



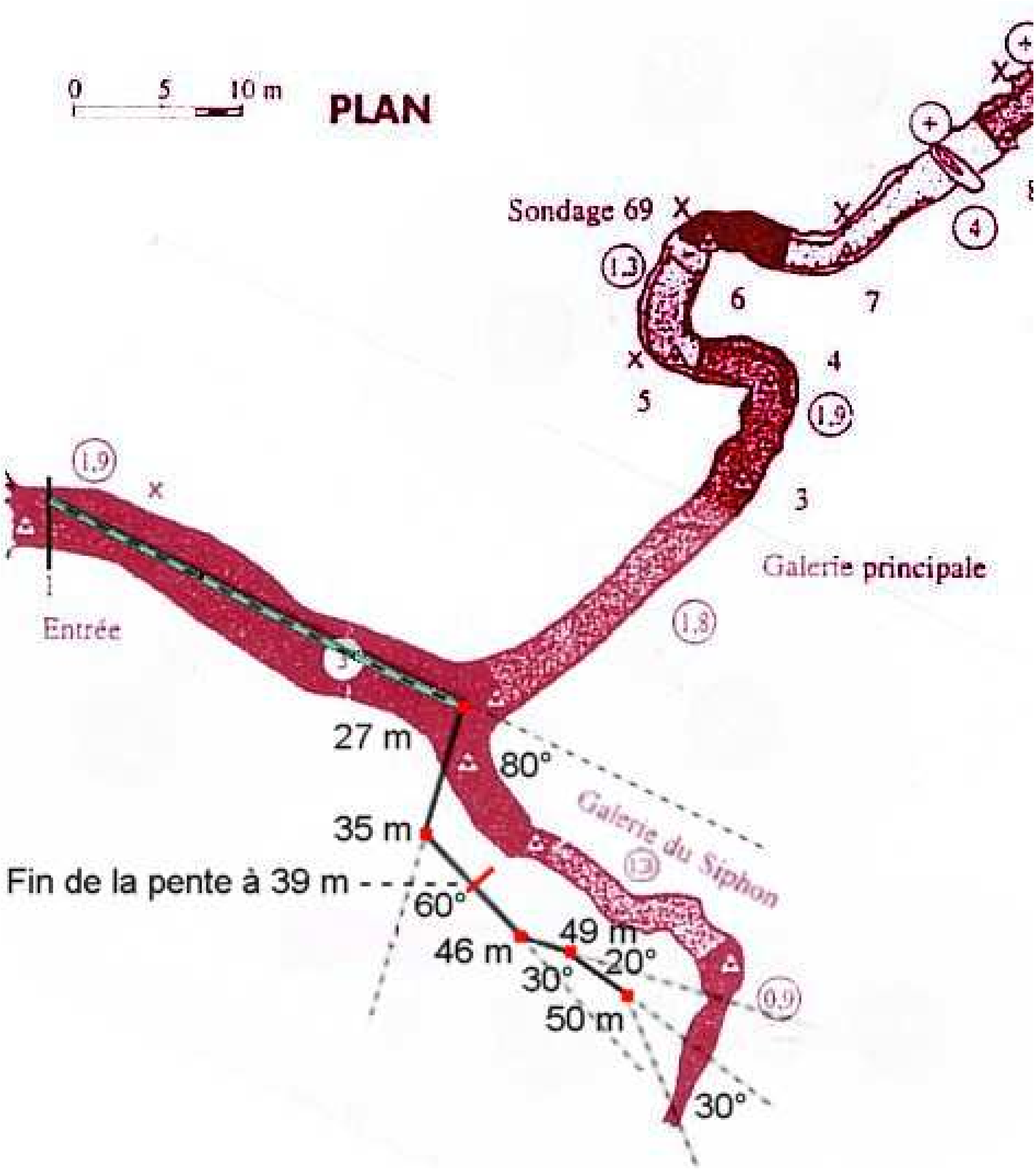
27 m were measured between the point of attachment of the Ariadne wire to the cave inlet gate and the upper part of the Siphon passage. The CRV rope then indicated 11 m for the descent. On the above plan 10 m was drawn to take account the Siphon passage slope. A cosine of 10/11 corresponds to an angle of 25 °. This angle was not measured but estimated. There is very little difference between the measurements and the map. (Doc. J.P. Viard + indications APM)



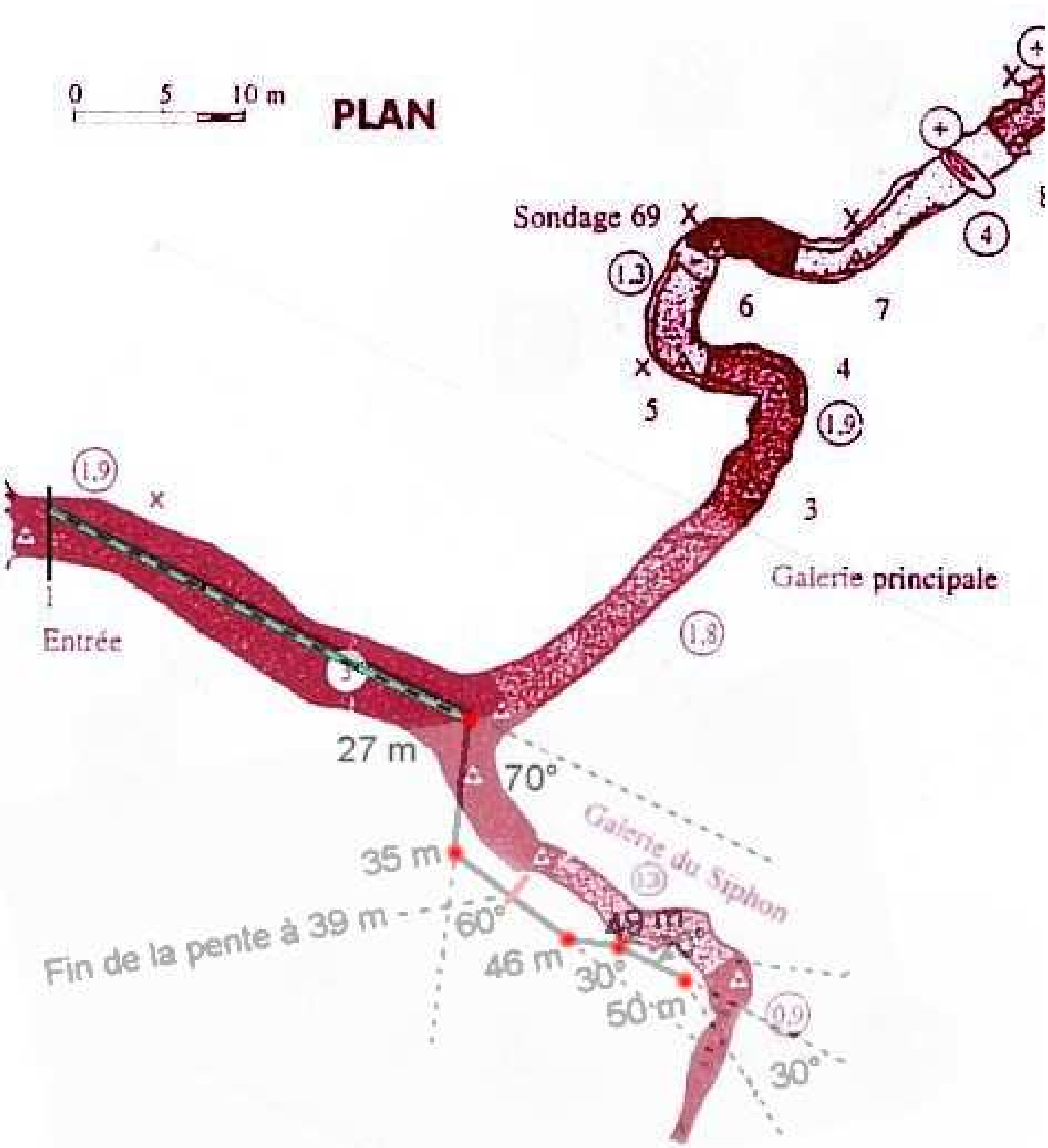
In the piezo well room the measurement indicated 50 m. There is also no difference between measurement and reality. (Doc. J.P. Viard + indications APM)



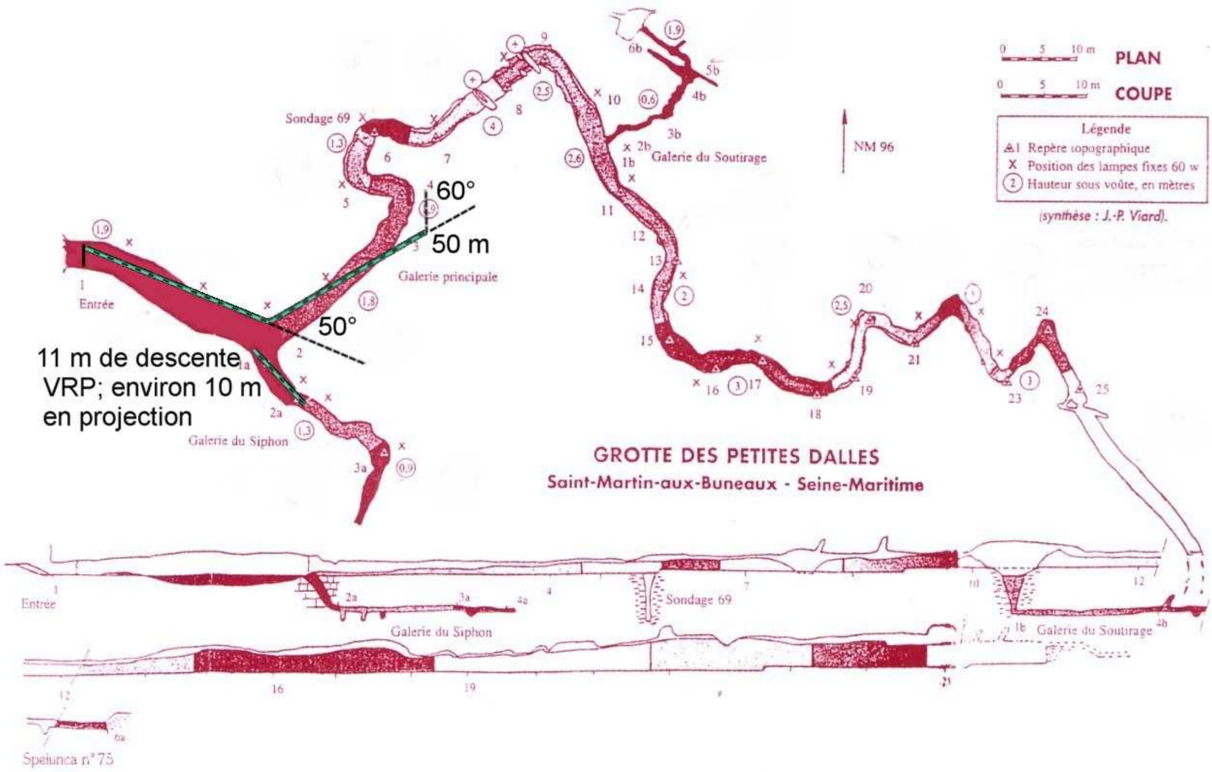
The helmet camera soundtrack indicates a 70 ° angle for the start of the Siphon passage seen from above, which in this view seems a little too high. (Doc. J.P. Viard + indications APM)



Lucie Poulet was able to measure the different segments of the Siphon passage up to the piezo well and the angles, which, once carried over to a map, gives this result. There is an error of 5.5 m on the 50 m traveled at the piezo well which is a 10% error. (Doc. J.P. Viard + indications APM)



Taking into account a rotation of 10 ° from the inlet of the siphon passage according to the 70 ° angle reading noted on the helmet camera soundtrack, this corrected trace is obtained on which the error at the level of the piezo well is only 2.5 m or 5%. (Doc. J.P. Viard + indications APM)



This image shows the measurements made in the main tunnel. After 50 m, the error is about 3.8 m, ie 8%. The measurements stopped on an orientation measurement of the tunnel segment in slight turn after the 50 m indication. (Doc. J.P. Viard + indications APM)

Conclusions

The simple means used apparently make measurements locating the characteristic points of the cave with an accuracy of 10% or even less. The inaccuracy comes of course from the angle measurement, the distance measurement being precise. One can of course estimate that in a real situation in a Martian cave, one would use a small inertial unit to reconstitute the path. There are also instruments that scan the walls and rebuild the galleries by assembling the measurements in the manner of a photo software that combines the photos into panoramas.

It had been hoped to go further into the main gallery by carrying out this mapping, but given the length of the operations to reach cavity 46, the mapping operations of the main gallery had to be shortened. The rangefinder has been used very little, often due to the presence of people in the potential measurement axes. But the rangefinder could have been tested, for example, in the passage continuing after cavity 46. A single measure was made to show that it was feasible despite the difficulty to use the instrument through the spacesuit helmet.

6-3 Simulation spacesuits

The cave simulation was an opportunity to test the Planète Mars association simulation spacesuits under unusual conditions, more severe than the use in the open air. The configuration of the spacesuits used in this simulation is given in reference 7.

The helmets had been equipped with a protection hoop and three lamps, the hoop allowing also to consolidate the attachment of the central lamp located on the top of the helmet.

Weight conditions

The simulated weight conditions are explained in the following paragraphs taking into account the various elements masses.

The different elements masses are given in grams. The helmets were weighed in the configuration of the cave simulation, ie with the three lamps and the hoop, as with the Sony HDR AS 15 helmet camera (182 g)

Elements	Spacesuit 1	Spacesuit 2
Back pack	7035	7639
Helmet	2558	2452
Suit	1210	2848
Boots	985	1350
Gloves	224	338
Total	**12012**	**14627**

For a person of 71 kg (+ 1kg of clothing) the wearing of the spacesuit 2 on Earth corresponds, with the same total apparent weight, to the wearing of a suit of 156 kg on Mars. For a person weighing 60 kg (+1 kg of clothing), the wearing of the spacesuit 1 corresponds to the wearing of a suit of 131 kg on Mars. The two cases above correspond respectively to the case of Alain Souchier and Lucie Poulet.

For comparison, ISS US spacesuits have a mass of 130 kg and Apollo spacesuits had a mass of 85 kg.

The calculation can be repeated, in the case of Lucie, including the weight of the Ariadne wire unwinder and for Alain the weight of the ventral bag (camera, laser rangefinder, various) as well as the lateral bag (rope and descender, redundancy rope) and the harness. These equipments would have been lighter on Mars therefore leading to further increase the weight of the Martian spacesuit that would have led to the weight felt on Earth in this simulation.

With 0.884 kg of Ariane wire unwinder, Lucie operated at a total weight of 74.9 kg, which would have corresponded on Mars to a 135 kg (spacesuit + other equipment transported) equipment.

With 2,875 kg of ventral bag and 2,070 kg of side bag including the harness, Alain initially operated at a total weight of 91.6 kg, which would have corresponded on Mars to a 169 kg equipment (spacesuit + other transported material). Note that from the descent into the siphon passage, there is a lightening of the rope weight and in the return from cavity 46 a lightening of the ventral bag weight.

Helmets

The three lamps per helmet were perfectly suited not only for visibility by the experimenters but also for the videos, even if a video team used in some cases additional lighting. The helmet lamps had a beam width adjustment obtained by longitudinal sliding of an outer ring, but both experimenters remained in the wide beam mode during the simulation.

The helmets fastening to the back packs was a problem because of the crawling operations which lead to a load case that is very different from normal operation. There are two levels of helmet attachment. The low level is a fixation of a cylindrical collar or ring on two horizontal rods passing over the shoulders from the back to the front, both rigidly connected to a horizontal transverse rod located on the top of the dorsal pack. These rods on the shoulders can therefore be rotated by raising or lowering according to the height of the experimenter's shoulders and preventing the helmet from being tilted to the left or right (stabilization of the helmet in roll and yaw, and freedom in pitch). The flange is attached to these rods by two small collar fasteners, one of which is equipped with a notched closure and the other consists of an arc of a circle of 270 ° in which the tube enters by force.

This image shows the horizontal U-shaped assembly which stabilizes the helmet and is formed by a horizontal transverse part fixed to the dorsal pack by collars allowing rotation and two forward extensions passing over the shoulders. It is also well understood that this case of progression is particularly important for helmet fasteners. (Doc. J. Barbier/ I. Ebran/ Gargouille Productions)

The arrow at the top left indicates the position of one of the small "U" collars which should be clamped on the rod located under (helmet camera)

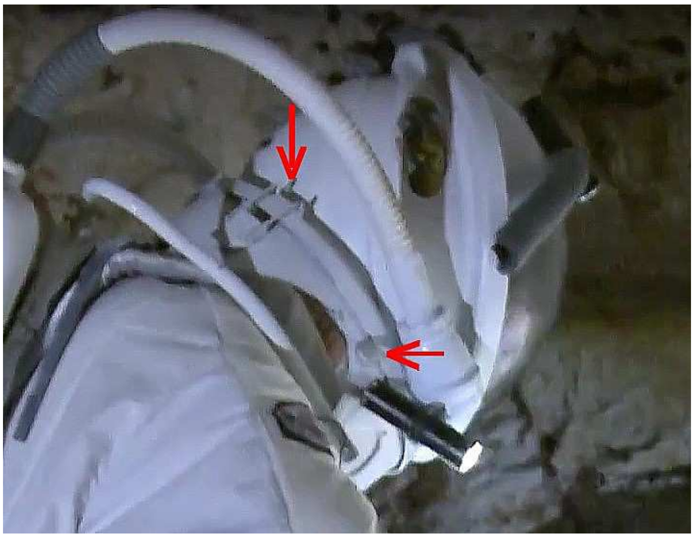
Here at the beginning of simulation, the left U-shaped collar of Alain is in place. It is the one of the two which has a system of closure. (Doc. J. Barbier/I. Ebran/Gargouille Productions)

At the top, the connection between the shoulder ring and the visor or bubble part of the helmet is ensured by two diametrically opposite lever hooks.

The various anomalies concerning the helmet attachment system during the simulation are presented in chronological order in the following lines.

At about 3mn Lucie's helmet right collar which is however the one that includes a closure is already no longer in place (doc J. Barbier / I. Ebran / Gargouille Productions)

- Alain's U-shaped collar (the one that does not have a closing system) is quickly disconnected, before any crawling. This is visible on the images at 8mn 53s below.



On the right is the open collar which is no longer connected to the U-shaped tube. Above the right rear hook is in place. (J. Barbier / I. Ebran / Gargouille Productions)

At around 18mn the left collar is still in place but the collar is opened as shown in the following picture:

(Doc. J. Barbier/I. Ebran/Gargouille Productions)

At 33mn in the piezo well room, Lucie repositions Alain's collars on the U shaped tube.

In the progression through the narrow passage towards cavity 46, Alain's helmet fell despite these actions. It was put back in place in the small cavity at 5m from the exit with the help of Lucie. Previously Lucie encountered problems of the same nature with her helmet and benefited from the help of Jonathan to put it back in place.

In cavity 46 the right collar of Lucie's helmet is still disconnected (doc. J. Barbier/I. Ebran/Gargouille Productions)

When shooting macro towards 68mn, the left collar of Alain is in place but opened (Canon EOS 7D, Lucie in sim)

At 105mn 27s, Alain repositioned the left side of Lucie's helmet whose collar had also disengaged, and it was necessary to repeat the operation a second time 30s later. At 123mn the left collar of Lucie's helmet is still in place while she is back in the main tunnel. At 128 mn the left collar of Alain, also back in the main gallery, is still well engaged around the tube but still open. At 129 mn Alain announces that the Us (the collars) of Lucie's helmet are disconnected. Jonathan steps in to put everything back into place including one (or two?) helmet lower ring hooks. There will be no more interventions on these systems until the end of the simulation but the helmets will also undergo less effort since the displacements will remain of the walking type.

As the helmet can be removed either by swinging backwards the U-tube, which is fixed by a horizontal hinge to the back pack, or by releasing the hooks between the shoulder ring and the helmet, it is possible to replace present collars by screwed collars. It should be noted that the Mars Society simulation spacesuits helmets shoulder rings in Utah are permanently linked (softly) to the back pack, the helmet coming to be fixed on top during the clothing.

The effectiveness of the anti-fog coating by a thin layer of liquid soap (with the added effect of ventilation) was noted during the simulation. Condensation was observed only on uncoated areas

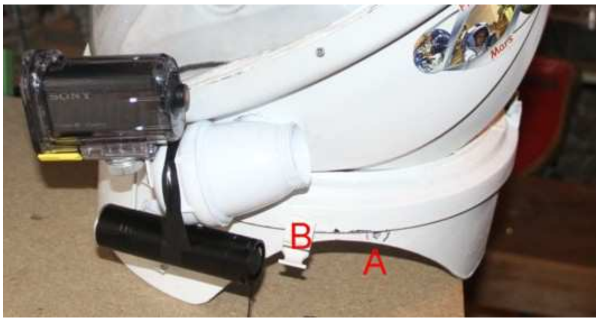
Following the crawl sequences, the helmets visors suffered some scratches.

It will be necessary to find a fixing point for the ventilation control (on a forearm for example) as well as a fixation stronger than Velcro for the suit equipped with a thermometer. The thermometer was also torn off with wires rupturing, when Alain returned from cavity 46 to the piezo well room.

Alain's helmet camera has frequently rotated 90 °. It is actually fastened by a single bolt nut which although tightened and braked with glue nevertheless could rotate. It should be noted that, with regard to the posterior use of camera images, it would be desirable to think of making certain movements of head rotation slowly in order to obtain non-fuzzy panoramas.

Lucie noted that the back of her helmet pushed on the back of her head which became tiring in the long run. It appears that the back pack straps are set too short. The elongation of the shoulder straps would lead to the descent of the pack which in fact would allow the base ring of the helmet not to be pushed up by the back pack and the rear part of the U structure and thus the helmet back part would not be pushing on the back of the head. This correct configuration is visible during the delivery of the suit in 2012 by Armande Zamora and Patrick Sibon and subsequent tests.

Example of passage of the helmet base ring over the rear fixing U-tube (doc. A. Souchier)



The collar attachment points on the flange had been moved forward (from A to B) during the preparation of the 1st Black Cow simulation in 2014 and the modification applied to the second helmet in preparation for the cave simulation but It will probably be necessary to return to the old fixation points with a lower back pack adjustment (doc. A. Souchier)

6-4 Spacesuit operations

As expected, and simulation suits are designed for this purpose, the wearing of the suits increases the difficulties of operations and the clumsiness in general.

A first factor is the volume of the back pack which increases the difficulty of progression by one notch as soon as you are no more progressing upright. Thus, in the descent and the ascent of the Siphon passage, where the visitors progress a little curved, it was necessary (often but not all the time) to shift to a progression mode on knees. In the narrow passage leading to cavity 46 which is about 90 cm high and sometimes a little more, where the visitors progress squatting or even on 4 legs, we had to switch to a crawling mode. Lucie chose the crawling mode on the belly, Alain chose the lateral crawling mode.

The descent into the siphon passage in "normal" outfit on the left at the time of the cave recognition in 2014 (doc. A. Souchier), and in simulation spacesuit on the right (doc. J. Barbier/I. Ebran/Gargouille Productions)

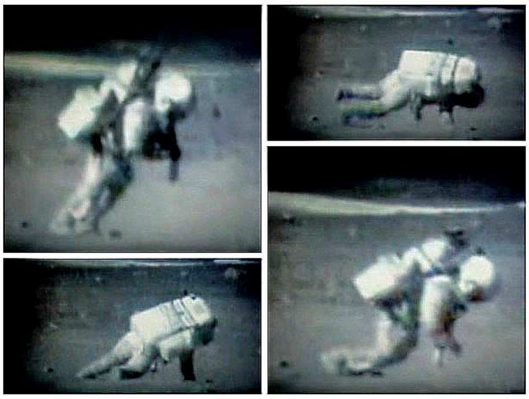
The progression in the passage to cavity 46, in "normal" outfit on the left, and in simulation spacesuit on the right (helmet camera)

As regards the realism of crawling with the spacesuits, one can of course judge that operations of this type will not be undertaken during the first Martian expeditions! It can also be noted that during the Apollo missions on the Moon the suits were subjected to severe conditions during astronauts accidental falls. NASA has of course studied closely the movements of astronauts on the Moon and in particular their falls. Thus, during the Apollo 16 mission, six astronauts falls happened in view of the cameras. Mobility during this Apollo 16 mission was the subject of an analysis paper "Apollo 16 - Time and motion study" (final mission report), which can be downloaded at https://www.hq.nasa.gov/alsj/19730008098_1973008098.pdf, which devotes 8 p (from p 27) to the analysis of the falls in three Apollo 16 EVAs.

Fall on the Moon: Apollo 16 (doc. NASA)

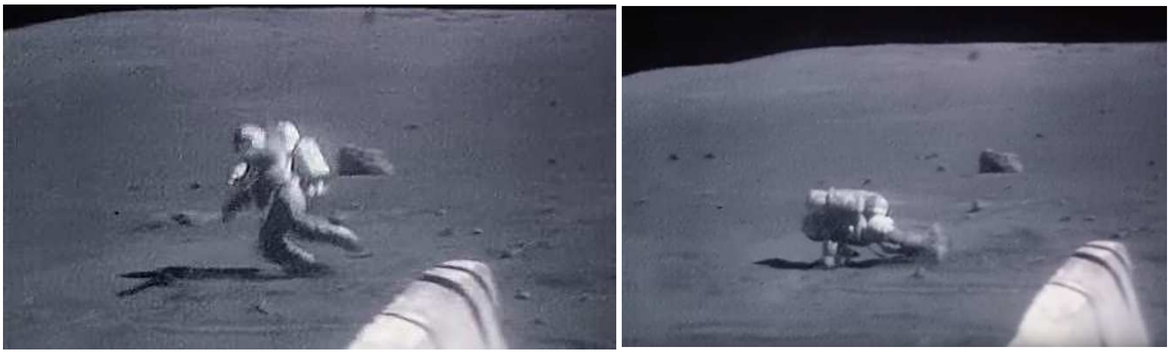
Fall on the Moon: Apollo 16 (doc. NASA)

Fall on the Moon: Apollo 16 (doc. NASA)

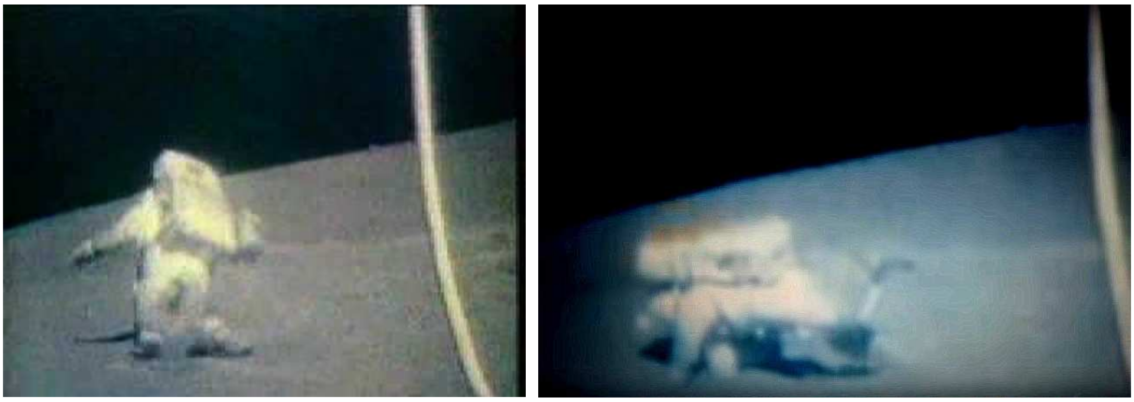


Some steps of the Apollo 16 fall above (doc. NASA)

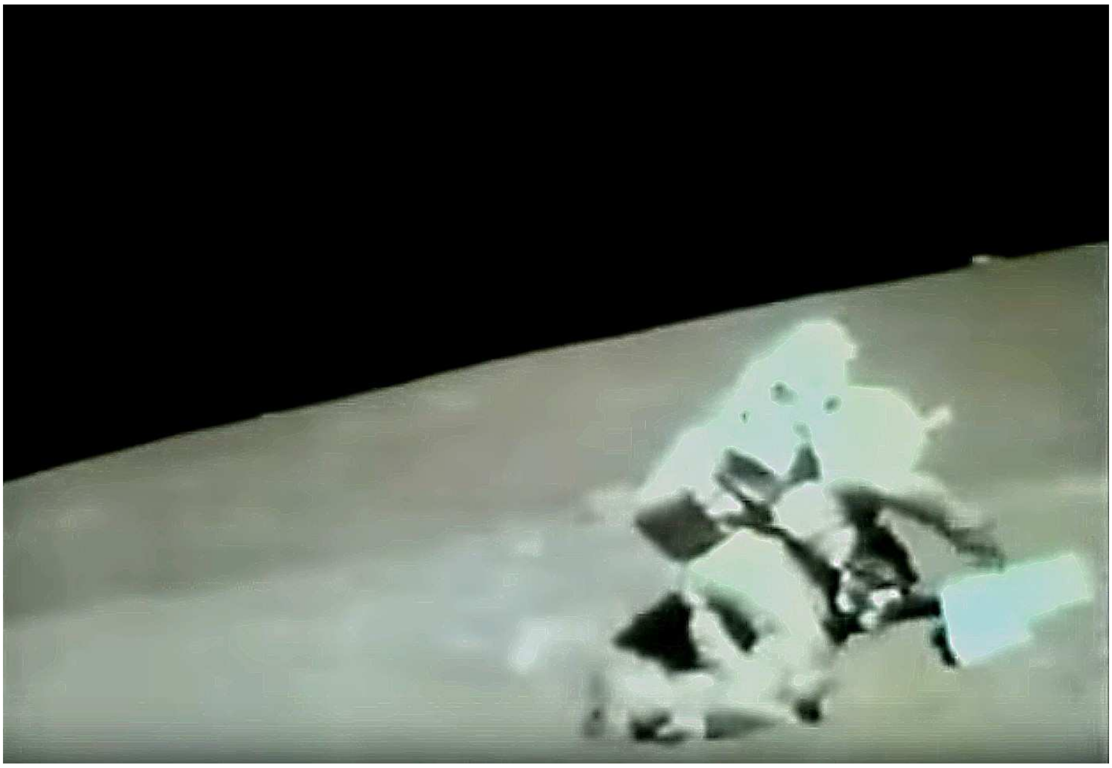
Fall on the Moon: Apollo16 (doc. NASA)



Another example of a fall: Apollo 17 (doc. NASA)



Another example of a fall: Apollo 17 (doc. NASA)



In some cases the astronauts, as here the geologist Harrison Schmitt during the Apollo 17 mission, did not hesitate to kneel in order to work (doc. NASA)

APM spacesuits are not yet equipped with radios, but this has not been a problem. As a reminder, it would seem that the Martian atmosphere, although very low density, could carry the sounds over a few meters.

A certain number of operations must be carried out by one operator for the other or on the other because of the lack of visibility downwards, and in particular for each one, towards his own suit. Examples of interference from one to the other are given hereinafter (excluding the helmet attachment readjustments indicated above).

- Unhooking of the Ariadne wire spool from Lucie's belt towards 4mn

- Re-positioning of the spool on Lucie's belt towards 4mn 50s (but Lucie then unhooks it alone)

- Hooking the spool to Lucie's belt

- Storing the protractor in the Alain's ventral bag

- Hooking the descender to Alain's harness

For the record, some simulation crews in Utah, with the Mars Society simulation suits with pockets on the thighs and shins, chose to put their equipment (camera or other) in the pockets of the colleague and vice versa ; It is easier to see what one seizes in the pockets of a colleague than to see what one seizes in one's own pockets.

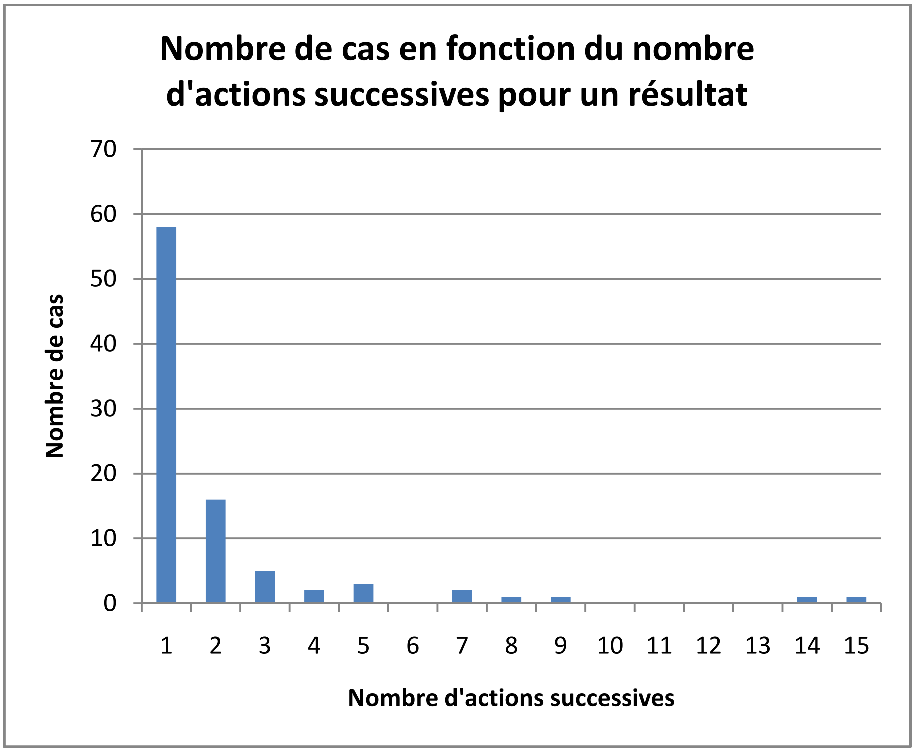
With the gloves, some simple operations require 2, 3, 4 or even 5 attempts before succeeding. Without pretending to completeness (especially for the successful operations at 1st try), because not all operations are visible on the camera, the following table gives some cases.

Nbre of actions	Operation	Number of operations
1	Switching on the CRV lower lamp with lateral push, switching on the lower lamp with the rear pusher, switching on the CRV transmitter n°1 push button, switching on the CRV transmitter n°2 push button, side switch receiver activation, video monitor wire connection, off push button switch n°1 CRV transmitter, off push button switch n°2 CRV transmitter, switching on push button monitor, switching on push button n°1 CRV transmitter, switching on push button n°2 CRV transmitter,	>11
2	Opening zipper protractor pocket, switching again the CRV upper right lamp with rear push button, 12V monitor connection, off camera (small rotary control), removing protective foam from monitor	5
3	Catching the descender lever, reception box opening	2
4	Switching on the CRV upper lamp with the rear push button	1
5	Reception box opening	1

The operations performed in one go are very numerous, in 2 times occur from time to time and in 3, 4 or 5 times are rare. Of course this will depend on the operation difficulty (action on a big button or action on a small button for example).

During the simulation conducted at the Vaches Noires cliffs in 2014 (see reference 2), part of which was devoted to dexterity demonstration with tools on gloves and therefore with delicate activities, the following statistic was noted:

Relation between number of operations and number of trials



Note that the aids to dexterity stored on the gloves were not used in the cave simulation. For some delicate actuations the lugs or pikes used to fix these dexterity aids on the gloves were enough.

Realizing the CRV rope insurance knot did not pose any problem, nor untying it.

The operations duration increase, because of the spacesuit particularly the gloves, was not measured during this simulation. During the previous “Black Cows” simulation in 2014, a duration increase coefficient of 3,4 was identified for delicate operations as replacing a battery or microcard in the cameras. The Austrian Space Forum has more deeply worked on this question in the “Delta” experiment, which was conducted during the Morocco 2013 simulation, where the increase in operations duration is studied versus the operations complexity.

Note also that objects are easily allowed to escape, which has fewer consequences than in a zero G EVA around the ISS since one can pick up what has fallen. Some objects could be hooked by a wire or a strap but watch out for the knots!

The suit carried by Alain is particularly thick so particularly hot. Fortunately the cave temperature is relatively cool, about 12 ° C on the simulation day. The internal temperature stabilized at 33 ° C, the two measurements made during the simulation giving 33 ° C at 24.2 mn and 33.1 at 33.5 mn. The previous Black Cow simulation also showed that the internal temperature of this suit was stabilizing about 20 ° C above ambient temperature. There is no temperature data after the return of cavity 46, the thermometer having been torn off during the return progression in the narrow passage.

6-5 Participants comments

6-5-1 Lucie Poulet comments

Suits

For visual aspects, the suits are realistic, much more so than MDRS.

- I did not have any difficulties to walk, on the contrary, the movements were fluent. I was pleasantly surprised. But for more realism, may be more padding is to be expected.

- The back seam cracked when I stooped down while dressing myself. Problem of size and seam robustness.

- The inside of the suit is a bit abrasive, which is not very pleasant in the long run.

- The ventilation system stopped in the tunnel because the button passed under my body. It would be necessary to provide a button system on the back pack that each astronaut turns on for the other (HI-SEAS suits are like that).

- The back pack is a bit too bulky (which caused difficulties to crawl).

- Armande (suit designer) spoke of adding pockets: very good idea!

Helmet

- The position of the neck forced by the helmet is difficult to hold over time.

- My helmet fell several times while we were crawling. Jonathan fixed it in the middle of the passage but it fell back again. In the cavity 46 it was fixed again but fell back on return. Then the fixations went loose when we walked up. More and stronger helmet attachments devices are required.

- The ventilation works well: almost no mist in the helmet. Except towards the end, after crawling twice, when the ventilation stopped and the helmet was unhooked.

Gloves

- A little big for my fingers but very (too much?) handy. No major difficulty on this side. Perhaps it would be necessary to make them less flexible for more realism.

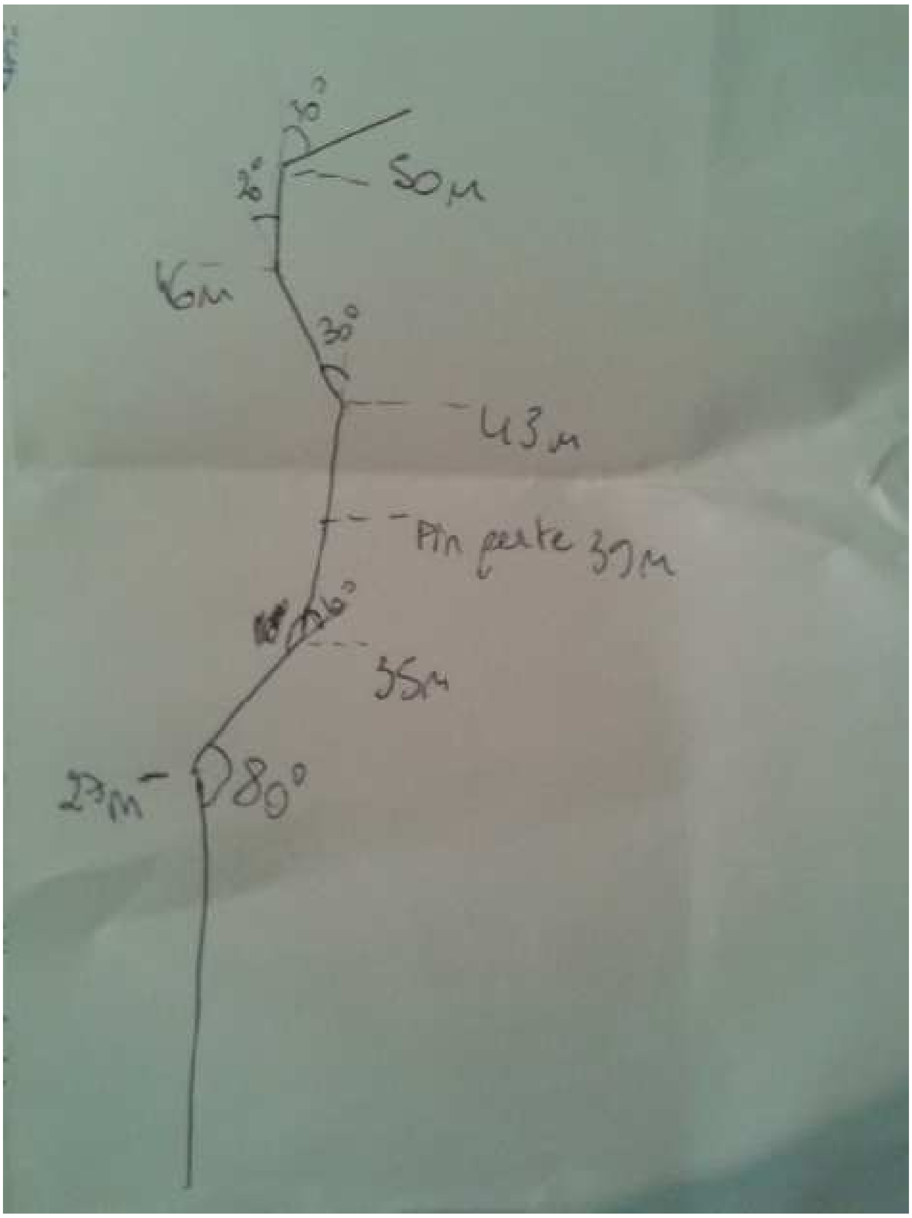
Measures

- The system with the protractor worked well, although it was difficult to lock the wire on the nails. Maybe, think of lengthening the middle nail to make the measurements easier.

- Lifeline: put a label with the number of meters not only every 10m but at 5m too. This will facilitate measurements.

- Provide notebook and pen to make sketches during the simulation next time.

Here is a picture of my sketch right after the cave exit.



<u>6-5-2 Jonathan Barbier comments</u>

As for the material clearly it suffered but I especially noted two points posing problem:
- the attachment of the helmet,

The helmet is fixed on the bars on the side; it would be necessary to see if it can also be fastened in front of the bars (so that the helmet does not come out of the "rail" as soon as the simulator leans too much). Also there could be a piece of fabric connecting the suit to the helmet lower ring (fixed on the ring and slipped in the suit, can be in white mesh to keep the aeration). This will harmonize the connection between the suit and the helmet by presenting an apparently more sealed configuration
- consider making a simple system of unhooking the back pack so that it can be dragged behind in too narrow passages (and therefore envisage reinforcement points on the air pipe connections so that they do not unhook during the operation).

7 Conclusions

This second simulation carried out by the Planète Mars association in France has achieved the majority of its objectives.

The scenario unfolded consisted in the exploration and recognition of a cave a priori unknown. APM had already participated with the Cliff Reconnaissance Vehicle in the cave simulation organized by the Austrian ÖWF in the Dachstein ice cave. But in the latter case it was more a question of carrying out scientific or technological experiments in the cave than to place oneself in the perspective of an unknown cave recognition.

It was also, in this Petites Dales cave, the first APM simulation with two people wearing the two association simulation spacesuits. Of course, many association members participated also in simulations in the USA (Mars Society MDRS station in Utah - see in particular reference 1 - or University of Hawaii HI-SEAS station) and in Canada (Mars Society FMARS station). There was also participation, but only as an experimenter, in the Austrian space forum ÖWF simulations in the Dachstein cave in Austria (2012), in Morocco in the Erfoud region (2013) and on the rock glacier of Kaunertal in Austria (2015).

The simulation in the Petites Dales cave has shown the possibility of crudely mapping the cave even if more sophisticated means than those carried could also be used.

It has also been shown the usefulness of a reconnaissance vehicle sent as a scout in a sloping passage before sending human explorers there. This experiment could be extended with a self-propelled vehicle for flat areas (or with rovers designed for slopes operations)

As usual in these simulations, it has been verified that, despite the wearing of simulated spacesuits, quite complex operations can be carried out, even if the level of clumsiness and the duration of operations are increased. It has been shown that the volume of the spacesuit (more than the weight knowing that it is intended to recreate the equivalent Martian weight) increased the difficulty of progression in delicate passages. The experimentation of progression in a narrow passage was planned but not over a distance as long as 17m. The increase in distance traveled in the narrow passage was justified by the possibility of accessing a fairly large cavity, cavity 46, which served as a studio for interviews by one of the video teams. The crawling progression that was necessary to access and return to this cavity was not so useful for representing the capabilities of actual spacesuits in this domain, as for finding the weaknesses of the current APM simulation suits and possible improvements. The time spent for access and return from cavity 46 most likely limited the mapping operation of the main tunnel.

It was possible to show with photographs with a separating power of one tenth of mm that precise measurements were possible despite the wearing of the suit.

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