TERRESTRIAL OPERATIONAL ANALOG OF THE MARS MISSION: LESSONS LEARNED FROM THE GLACIER SIMULATION AMADEE-15 BY AUSTRIAN SPACE FORUM. G. Groemer[1], A. Losiak[1,2], A. Soucek[1,3], C. Plank[1], L. Zanardini[1,4], N. Sejkora[1], S. Sams[1]; [1]Austrian Space Forum (gernot.groemer@oewf.org), [2]Planetray Geology Lab, Institute of Geological Sciences, Polish Academy of Sciences; [3]European Space Agency, Headquarters; [4]INSYN AG.

Introduction: Analog studies and analog instrument validation have been supporting all planetary surface missions so far [1] and are considered as an effective tool to prepare for future missions to Mars [2]. Examples of such past analog campaigns include: the NASA DESERT-RATS [3,4], the NASA HI-SEAS [5], the MOONWALK [6], the NASA NEEMO, the ESA CAVES [7] and others.

Austrian Space Forum: The Austrian Space Forum (OeWF, Österreichisches Weltraum Forum) is a non-profit, citizen-science organization of aerospace specialists and enthusiasts. One of its specialisations is Mars Analog research. Since 2006, the OeWF has conducted 11 Mars analog field campaigns in diverse locations representative of: 1) average current Mars conditions such as the Mars Desert Research Station (MDRS) in Utah in 2006 [8] and the Northern Sahara near Erfoud, Morocco in 2013 [9]; 2) resembling the early and wet Mars-analog site of Rio Tinto Spain in 2011 [10]; and also 3) subsurface exploration simulations at Dachstein Ice Caves in 2012. During this time, 68 experiments and major engineering tests were performed. Experiments were mostly focused around astrobiology, robotics, human factors, geoscience and spacesuit operations.

Major assets of the OeWF include two advanced spacesuit simulators (Aouda.X and Aouda.S, Fig. 1, [11], an increasingly evolved Mission Support Center (MSC), a dedicated Remote Science Support (RSS) team [12], and a growing set of Standard Operating Procedures defining major workflows within the team. The spacesuit simulators were operated by a total of 18 analog astronauts, who were selected and trained during a >6 month program. Total EVA time is nearly 600 hours, leading to a significant experience in analog field simulations.

AMADEE-15: The mission took place between 2nd and 14th of August 2015 at the Kaunertal Glacier in Austria. The Kaunertal glacier in Tyrol, Austria was selected as a study site because of its accessibility and high number of micro-landscapes analogous to those expected on Mars in locations where abundant water ice is present. As such it is considered a first-tier Mars analog, according to the classification of [13]. The Base station was located at N 46.86320, E 10.71401 at an elevation of 2800 m elevation, the highest reached location was on elevation of 2887 m.

Eleven experiments were conducted by a field crew at the test site under simulated martian surface exploration conditions, coordinated by a Mission Support Center in Innsbruck, Austria. The fields of research for the experiments encompassed geology, human factors, astrobiology, robotics, tele-science, exploration, and operations research. A Remote Science Support team analyzed field data in near real time, providing planning input for a flight control team to manage a complex system of field assets in a realistic work flow, including: two advanced space suit simulators, four robotic and aerial vehicles. A dedicated flight planning group, an external control center tele-operating the PULI-rover in Budapest/Hungary, and a medical team supported the field operations. A 10 minute satellite communication delay and other limitations pertinent to human planetary surface activities were introduced. A detailed description of the mission should be soon published in [14].

Figure 1. Astronauts: Carmen Koehler and Iñigo Muñoz Elorza wearing (Aouda.X and Aouda.S, Groemer et al. 2012) together with Puli Rover during the AMADEE-15 mission. They are walking on a lateral morain of the Kaunertal glacier in Tyrol, Austria.

Lessons Learned: *It is important to follow a structured process to evaluate the execution of daily mission plans.* To evaluate the validity of the developed plans, to locate deviations from them, and to find possible causes for those deviations, the Flight Plan team performed an analysis of "planned vs. executed" after the mission (Fig. 2). In this analysis, the times allocated for experiment conduction and preparatory activities, such as the donning process, were compared to the times logged for their execution. While for most activities an accurate analysis based on the recorded times was possible, for some, which were not logged sufficiently, some educated guessing based on the memory of participants was required. A structured evaluation procedure enabled us to modify daily activity plan, so that it is more realistic. E.g., time of donning was extended by 60 minutes starting on 7th of August in order to decrease the stress level of the Field Team (who previously constantly felt "late") and Mission Support Center (who previously felt that the plan is not implemented properly).

Special exploration strategies need to be developed and implemented for working in landscapes that can change on *timescales significantly shorter than mission duration.* Previous OeWF missions, such as MARS2013 [9] were performed in a desert environment (Sahara, Morocco), that was relatively stable within timescales of the one-month mission. This meant that scouting for proper sites for exploration was done based on a combination of analysis of satellite images (even few years old) and ground-truth testing performed a few days before the actual research in a given area. Additionally, a spot that was originally confirmed as safe for a rover or analog astronaut, was not changing its properties significantly during the mission. During AMADEE-15 we were working on an active glacier surface intensely melting during the summer. Because of that, the satellite images and digital elevation models were outdated, as they were obtained in July 2010, as well as the digital elevation model (October 2010). Additionally, the surface of the glacier was changing so fast that even data obtained during scouting performed a day before was not up-to-date on the day of the analysis.

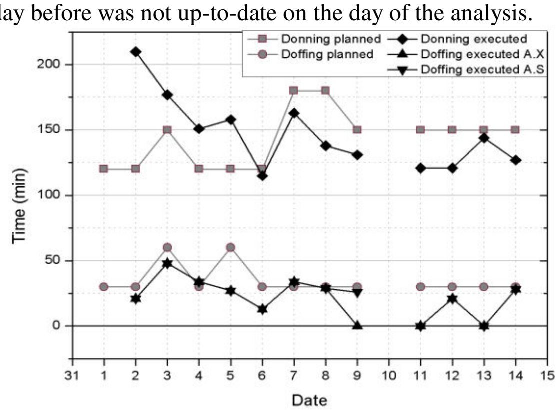

Figure 2. Analysis of planned vs. actual durations of donning and doffing of the Aouda space suit simulators. The abscissa depicts dates from 31st July to 16th August 2015.

Of course the rate of geological processes on Mars is much slower than on terrestrial alpine glaciers in summer. However, we have indications that some processes on Mars can visibly modify the landscape within the time-line of 18 months, the surface sojourn for future Mars missions [2]. Examples for such processes are: sand and dune movement [15], CO_2 variability in the polar regions and related to it morphological changes such as “spiders” [16], gully formation [17], impact crater formation [18] and changes induced by activity of liquid water such as recurring slope lineae [19] or those potentially present on the steep slopes within spiral troughs of the North Polar Residual Cap [20].

The high alpine environment is characterized by a highly dynamic weather. This may cause serious safety issues to Analog Astronauts in heavy Aouda suits. For this reason, during AMADEE-15 we had a dedicated meteorological team. This team of meteorologists was incorporated in the Flight Plan team to make sure that possible implications of the weather forecast are implemented in the daily schedule. The weather team produced forecasts for up to five days in advance, based on publicly available weather models. Additionally they provided the field crew (via the Flight Control Team) with a nowcasting service, i.e. short term updates on current weather developments, especially regarding thunderstorm activity in the vicinity of the test site.

Experiment procedures are a particularly vulnerable point of the analog mission system. We consider this being a consequence of: i) the relatively late availability of final procedures as released by PIs; ii) a relative lack of mission infrastructure knowledge by several PIs, in particular when geographically, topically or timely detached from the core team and field / mission support locations; iii) real-time adjustment of procedures during mission execution without an adequate level of cross-crew visibility. We further observed the need for active guidance by mission support personnel of PIs. We judge that such interaction must start several months before the beginning of the actual field mission.

Need for standardized mission key performance indicators. Comparing analog missions across disciplines and institutions is challenging, due to varying levels of documentation strategies, simulation fidelity and many times a lack of pre-mission success criteria definition. Hence, the Austrian Space Forum is proposing to establish an assessement scheme to measure the mission efficiency, comparable to what is applied during actual robotic and human planetary flight missions.

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