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THE MISSION AND ACTIVITY PLANNING STRATEGY FOR THE MARS2013 MISSION

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In February 2013, the MARS2013 Mission was conducted by the Austrian Space Forum in partnership with the Ibn Battuta Center in Marrakesh. MARS2013 was an integrated Mars analogue field simulation during which a small field crew conducted various experiments in the Moroccan desert directed by a Mission Support Centre in Austria. It served as a platform to test a planning strategy that was developed to cope with the characteristics of the mission, such as the duration of 28 days, about 20 experiments, each with its own scientific operational constraints and a 10 minutes time delay in the communication in order to simulate the long distance between Mars and Earth. On future Mars missions, time and resources will be even more limited. In order to ensure the maximum scientific research within the operational limits and experimental constraints, detailed and well-thought-through Mission and Activity Planning is of significant importance. Developing a method for how to properly plan all the necessary and desired activities in advance and how to react to inevitable changes due to contingencies and complications is a necessity.

Here we would like to present the theory behind this so-called "3-Days-in-Advance-Planning" strategy, its evolution during the mission, and the results gained regarding the efficiency of this method.

I. INTRODUCTION

The dream of exploring Mars is as old as mankind, but the first serious plans of sending probes to Mars started in the 1960s. Since then, a variety of different Mars missions have been planned and launched. Recent missions, such as the Mars Science Laboratory ("Curiosity Rover"), continue to address the most thought-provoking, yet so far unyielding question: "Has there ever been life on Mars?"

Both the international scientific community as well as private, non-profit and commercial organisations (e.g. Austrian Space Forum, Mars Society, Mars One, Inspiration Mars) are involved in research and activities that enable missions to Mars. Despite the great success of rover explorations some questions still remain unanswered and can only be addressed by manned missions. This gives rise to a demand for a fully operational Mars mission design. In order to meet this demand scientists, engineers, planners and operators need to test new strategies in Mars-like conditions and environments, e.g. analogue missions.

One important operational aspect of a mission is the planning method, namely how activities during the mission are scheduled. Efficient planning of a mission can be key to success, with effective use of time and manpower reducing its overall cost [1]. A good planning strategy needs to consider science, operations and crew personnel objective, including crew discretionary time [2]. In our case, the mission planning strategy consists of three main components that are all tasks of the Flight Plan team (FP) as part of the Mission Support Centre (MSC): the Mission Planning before the mission (rough schedule and resource allocation), Activity Planning (activity schedule during mission) and Traverse Planning (planning of travel routes between different locations). A number of various software is already available for planning rover and manned orbital missions (e.g. [3],[4]) however these are not yet fully developed for both real and analogue manned Mars missions.

Here, we present the "3-Days-in-Advance-Planning" strategy developed for MARS2013. We discuss its concept, its evolution during the mission as well as mission efficiency.

II. BACKGROUND INFORMATION MARS2013

The Austrian Space Forum (OEWF) conducts manned Mars analogue missions in order to improve planning strategies and mission operations for Mars exploration. The Mars Analogue Field Simulation MARS2013 took place in Morocco in February 2013 over a duration of four weeks. An overview of the experiments that were fulfilled during the MARS2013 can be found in [5].

The "3-Days-in-Advance-Planning" strategy was tested, particularly with respect to its implementation, but also scientific mission performance and efficiency. Important for the planning method was that the MARS2013 mission included a simulated time-delay of 10 minutes in communication between the Field and the Mission Support. This reflects the challenges that arise for missions to Mars due to the large distances between Mars and Earth.

Fig. I: Activity Plan development; Figure taken from MARS2013 Mission Manifest

Communication is then restricted by the speed of light: the one-way communication time-delay varies between 3 minutes (at a distance of 54.6 million km) and 22 minutes (at a distance of 401 million km), with an average distance of 225 million km yielding a 12 minute delay [6][6]. As a consequence of the time-delay, a mission operation in real-time is impossible. For robotic missions, this issue can be resolved by planning in advance and uploading all commands for the mission, making the instrument operation independent of the time-delay. During future manned planetary missions the same delay issue will be encountered, but with higher impact on mission planning and mission success.

To simulate this situation and investigate potential dangers along with probable solutions, a 10 minute time delay was implemented during the MARS2013 mission. Previous OEWF missions were performed using real-time planning and adjustments (Rio Tinto Mission, Dachstein 2012 Mission) and therefore provide the ground for comparison.

III. "3-DAYS-IN-ADVANCE-PLANNING" STRATEGY: CONCEPT

The design of the "3-Days-in-Advance-Planning" strategy has to provide a high level of activity preparation. At the same time it has to remain flexible enough to allow for the adjustments to be implemented over the course of the mission.

III.I Starting point: Mission Plan

Before the activity planning begins, an overall Mission Plan (MP) is created. The MP is based on all known requirements of individual experiments along with their limitations. This results in a preliminary schedule with estimated fuel, power consumption and personnel requirements, which has to be outlined before the mission starts.

III.II Planning sequence (FP planning schedule)

A key component of this method is the detailed Field Activity Plan (FAP), which is created three days before its application on the "Target Day" (T – 3 days). Thus, on the first day of the mission the planning for the first three days is already completed and planning of day four begins. For this and the following days the feedback, which is provided straight from Field and from Mission Support is already taken into consideration.

The Flight Director (FD) examines and approves the FAP two days before the Target Day (T – 2 days). One day before the Target Day (T – 1 day), the FAP is sent to Field.

Following these steps, the plan for day five is

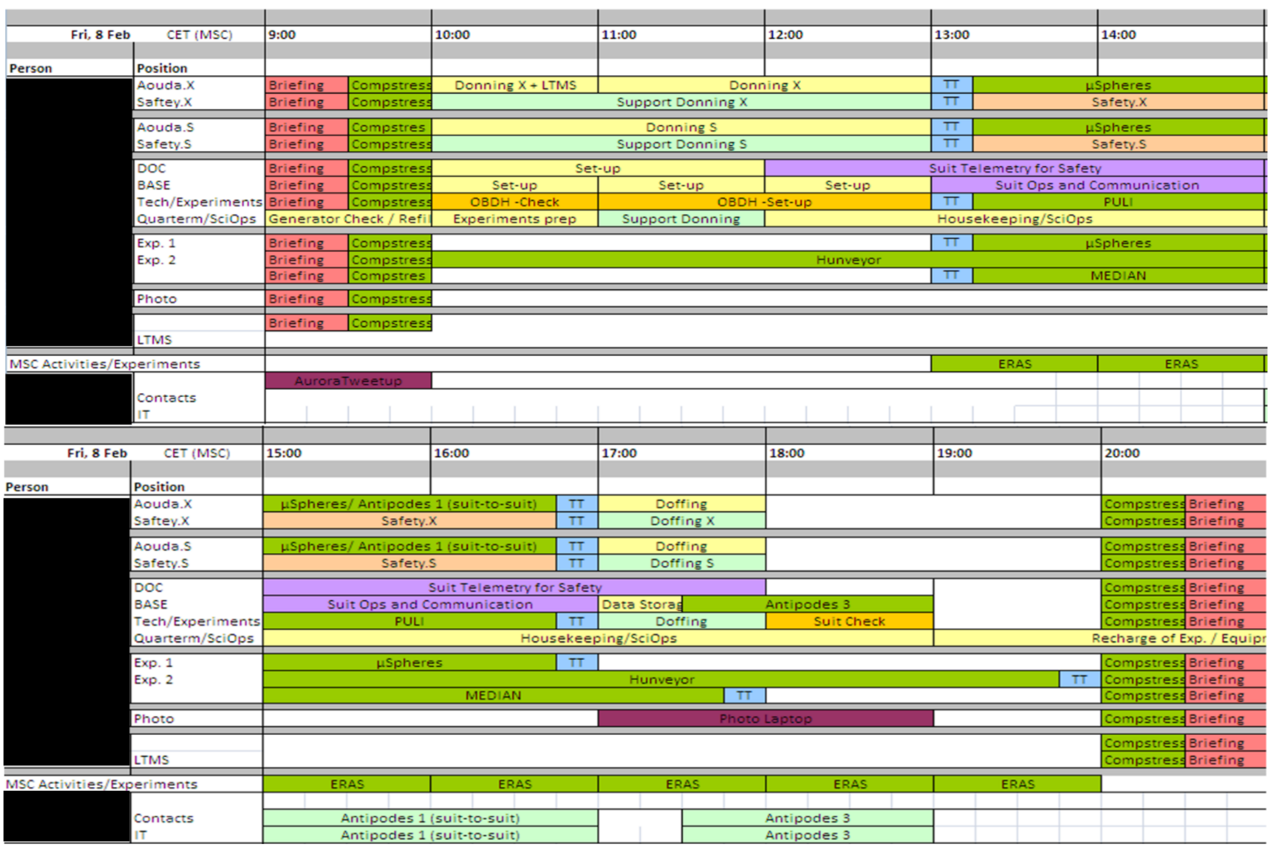

Fig. II: Sample Field Activity Plan (FAP) for MARS2013. It is sent to Field as part of the Daily Activity Package (DAP).

prepared on the second day of the mission and so on. A schematic representation of this planning system is presented in Fig. I, which includes the first 10 days of the mission.

III.III Planning content

The FAP indicates which crew member is responsible for filling the specific position on the Field (e.g. Aouda.X space suit simulator, Safety, Doc) for every day of the mission. All activities (e.g. experiments, scheduled equipment checks) for each occupied position are arranged in 15 minute intervals. A sample FAP is shown in Fig. II.

The FAP shows all activities, including scheduled briefings, donning/doffing and any Extra-Vehicular Activities (EVA, e.g. suited/unsuited experiments, activity assistance/safety tasks) as well as – where necessary – the traverse times. In order for those activities to be planned appropriately, all important requirements regarding field crew, location and duration have to be known. They determine the activity schedule as well as experiment locations and traverses. Such well-defined FAP then becomes part of a larger document: the Daily Activity Package (DAP). This document additionally includes safety warnings, important information about the experiments as well as the traverse and experiment locations on the map along with their coordinates. For details of experiment locations and all maps used during MARS2013 see [7].

The final part of this planning method includes listing backup activities. These can be performed by astronauts in case the primary activities cannot take place or take less time than accounted for. This is an important feature of advanced planning, as real-time suggestions for backup experiments are impossible. Information provided in the DAP and FAP together with individual procedures for specific experiments can be used by the crew for autonomous decisions regarding activity re-scheduling when real-time support from Mission Support is not available. In theory, no real-time changes are necessary for the “3-Days-in-Advance-Planning” strategy.

Implementation of the planning strategy and obtained results are discussed in the following section.

IV. RESULTS

IV.I Development during mission

At the start of the implementation of the “3-Days-in-Advance-Planning”, we encountered some difficulties. These were caused mainly by preparatory activities, operational test runs and the novelty of this system, which required that each member had to become accustomed with its operations, especially since all previous OEWF missions were conducted in real-time. After the first 11 days during which some modifications were applied, this planning strategy started to become successful and proved to be beneficial. The most important modifications concerned the communication and discussion of the FAP/DAP as well as restrictions regarding change requests.

It was expected that the planning system should be flexible, allow for necessary adjustments and fit the schedule according to the needs of the analogue astronauts. To enable this flexibility, the “T-23” meeting was introduced, which included the Flight Plan Lead, Expedition Lead (Field), Biomedical Engineer and Flight Director. The “T-23” meeting took place every evening after operations, discussing the planning of the Target Days two and three days thereafter. Its main task was to cross-check the DAPs for potential issues or conflicts. In case of urgent requests that occurred one day in advance at the latest, the schedule was adapted. On the Target Day itself, no updates were allowed. In this case, the field crew had the autonomy to decide to deviate from the schedule if necessary.

IV.II Science output

The planning strategy helped to create a successful science output during the MARS2013 mission: nearly twice as many science goals were successfully fulfilled during MARS2013 as during the previous Dachstein 2012 mission, which used real-time planning (75.8% compared to 41.7%, respectively) [8]. With only two exceptions, all of the 18 analysed experiments that took place during the mission were completed. This means that they delivered 100% of the minimally required runs and samples requested by the experiment’s Principle Investigator (PI); some even exceeded those expectations. Part of this success results from including experiment time margins in the planning process and from tracking the number of completed experimental runs more thoroughly during the mission. Overall, 45.7% of the EVA time was used for experiments. For a more detailed efficiency analysis see [8].

IV.III Workflow

The improved planning strategy for MARS2013 mission also included changes in work-flows and procedures for other Mission Support Centre duties. A close collaboration between Flight Plan and Remote Science Support was established during the first week of the mission, yielding work-flow procedures that made the planning and re-planning less turbulent. These inter-team work-flow procedures will be used in the future as a basis for extending and increasing interactions between different MSC teams.

IV.IV Time management

In comparison to the real-time planning strategy used in previous missions, the "3-Days-in-Advance-Planning" strategy resulted in increase of time available for planners, which was used for re-scheduling activities. Better time management allowed for well-designed and thoroughly considered solutions, which were examined beforehand. This is in contrast to and a replacement for hurried, real-time decisions that can interrupt mission activities by making analogue astronauts wait for an answer. It also helped to avoid potential clashes with follow-up activities and it allowed for better management of critical resources like the battery power of the life-support system for the Aouda Space Suit Simulator. With respect to efficient time management, the results in [9] show that continuous communication – similar to our real-time planning scenario - leads to a less productive EVA in comparison to alternative communication methods (twice a day communication). This complies with the results from our efficiency analysis in [8].

V. CONCLUSIONS

Applying the "3-Days-in-Advance-Planning" strategy to the MARS2013 mission, 45.7% of the total EVA time was used for scientific experiments satisfying 75.8% of the planned scientific goals. Problems encountered at the start of the mission resulted in modifications, e.g. implementation of the "T-23" meeting and enforcements of change request deadlines. After these adjustments the "3-Days-in-Advance-Planning" strategy proved to be a suitable tool for manned analogue missions with time-delay. It supports the field crew by taking field feedback into account and adjusting the FAP and DAP for the Target Days ahead. Activity planning can be optimised and suitable backup activities pre-selected.

The difficulties during implementation show how much more complex and demanding planning for a manned mission with time-delay is, compared to either real-time missions or unmanned robotic missions. The need for feedback and interaction between field crew and MSC as well as the sheer amount of people involved also raises the question of whether software planning, as investigated for robotic missions ([3], [4]), can be useful. In the future, a combination of hands-on and automatic planning should be explored.

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