

RESULTS OF THE FIRST ASTRONAUT-ROVER (ASRO) FIELD EXPERIMENT: LESSONS AND DIRECTIONS FOR THE HUMAN EXPLORATION OF MARS. N. A. Cabrol¹, J. J. Kosmo², R. C. Trevino², H. Thomas³, D. Eppler², M. G. Bualat³, K. Baker⁴, E. Huber⁴, M. Sierhuis⁵, E. A. Grin¹, C. R. Stoker², J. A. Schreiner³, M. H. Sims³, V. C. Gulick¹, and C. S. Cockell⁶, the NASA Ames Marsokhod Rover Team and the JSC EVA I-Suit Team, ¹NASA Ames Research Center, Space Science Division, MS 245-3, Moffett Field, CA 94035-1000. Email: ncabrol@mail.arc.nasa.gov, ²NASA Johnson Space Center. EC5, 2101 Nasa Road 1, Houston, TX, 77058-3696. Email: joseph.j.kosmo1@jsc.nasa.gov. ³Intelligent Mechanisms Group (IMG), NASA Ames Research Center, MS 269-3. Email: hans@artemis.arc.nasa.gov, ⁴NASA JSC-ER4, ⁵NASA Ames, Code IC, MS 19-39; ⁶NASA Ames, MS 239-20.

Introduction: The first Astronaut-Rover Interaction field experiment (hereafter designated as the ASRO project) took place Feb. 22-27, 1999, in Silver Lake, Mojave Desert, CA. The ASRO project is the result of a joint project between NASA Ames Research Center and Johnson Space Center. In the perspective of the Human Exploration and Development of Space (HEDS) of the Solar System, this interaction - the astronaut and the *rover as a complementary and interactive team* - in the field is critical to assess but had never been tested before the Silver Lake experiment.

Overall Goals and Objectives of ASRO.

The overall goals and objectives the project were:

1) To identify the operational domains where the EVA astronauts and rovers are complementary and can interact, thus are more likely to collaborate in a safe, productive and cost-effective way for the surface exploration mission; 2) To identify preliminary requirements and recommendations for advanced spacesuits and rovers that facilitate their cooperative and complementary interaction; 3) To develop operational procedures (*designated as scenarios*) for the astronaut-rover team in the identified domains, 4) To test these procedures during representative mission scenarios [1,2] during field experiments by simulating the exploration of a planetary surface by a human crew interacting with a rover; 5) To train test-subject, simulated Earth-based and/or Lander-based science teams, and automated vehicle operators in mission configuration; and 6) To evaluate and understand sociotechnical aspects of the astronaut-rover interaction experiment in order to guide future technology designs.

Structure of the Experiment.

The exploration site was located on the shorelines of a dry lake bed (Silver Lake), in a type of environment that is expected to be found on Mars. The elements of the experiment were:

- The JSC EVA test subject wearing a pressurized (at 3.75 PSID) I-Suit in real mission configuration and breathing cryogenic air on a portable life support system [1]. The helmet included a system that allowed communications between the astronaut and test conductor, and

the relay to the science team to the EVA-test subject via the test conductor .

- The NASA Ames Marsokhod Rover equipped with science instruments that were used for the Rover Field Experiment [3, 4] during the two previous weeks (with exception for spectroscopy). For scenarios Nos.2 and 4, the JSC stereo visual tracking system was installed on Marsokhod's mast (on-board computer and cameras, rf modem to off-board laptop for manual target acquisition, and rf video transmission for viewing) to allow automatic tracking of the astronaut by the rover;

- support rover team (technicians and engineers);
- support EVA Suit team (technicians and engineers);
- an *in-situ* rover operation center (ROC) located 1.5 km from the exploration site. The rover was remotely controlled from the ROC;
- a remote support science team located at simulated Mission Control Center (MCC1) IMG-NASA Ames Research Center being a support crew and/or science team potentially located in a Lander and/or located on Earth;
- a team of observers located at simulated MCC2-NASA Johnson Space Center;

The communications between the exploration site, the astronaut, the rover, the ROC, and simulated MCC 1 and 2 were established through satellite communications, radios, cellular phones, Web, fax and printer.

The five days of experiment were video-recorded.

Mission Operational Procedures Tested.

Four scenarios were tested during the field experiment:

1) *The rover as a scout:* the rover pre-examined the traverse area and established potentially favorable sites for deploying stations and for science exploration (*e.g.* geology, biology) for the suited astronaut to conduct work in;

2) *The rover as a video coverage assistant:* the rover was used to video document the EVA crewmembers' activity in the field. This task was usually performed by the second EVA crewmember during the Apollo mission. Two runs were performed for this scenario: during run #1, the video camera tracking was performed by the

rover operator; during run #2, the video tracking system was ensured automatically by the JSC stereo tracking system that controlled the camera pointing. In this scenario, the task assigned to the rover will free the second EVA crewmember and allowed him/her to perform other tasks. The video documentation of the operation also allowed to survey the proper deployment of the scientific stations, and to regularly check the status of the astronaut for safety.

3) *The rover as a field science assistant*: the astronaut explored a traverse. When he spotted an area of interest, he placed a color-coded flag to show that the target needed to be documented by the rover. Each flag color corresponded to a specific tasks [1,2]. While the rover was sent to the designated targets, the suited EVA test subject continued his traverse and continued to flag scientifically interesting targets that the rover reached and documented. This “human science on-the fly” scenario optimized the fast understanding that a human has of the environment and site main interests, and the better performance in a hostile environment of a robot performing the more tedious and longer tasks.

4) *The rover as a field technical assistant*: the rover was used to carry tools and samples for the suited-astronaut. The astronaut also used the capabilities onboard Marsokhod (*e.g.* imagery system [3,4]) to document sites of interest and communicated with a support science team remotely located at NASA Ames Research Center. Two runs of this scenario were performed: during run#1, the video camera tracking was performed by the rover operator located at ROC; during run #2, the video tracking system was ensured automatically by the JSC stereo tracking system that controlled the camera pointing.

Results, Lessons Learned and Future Directions.

All the science objectives (as defined in the science plan [1]) were met and all planned science procedures were successfully tested. The results of the field experiments are recorded in two dozens hours of video documentation, several hundreds of photographic documents and several Web pages. Educational and Public Outreaches were also an important part of this project. During the field experiments, school buses brought three-times a day children from the surrounding schools who could watch live the field experiment as it was proceeding. The general public was reached also via the Web, where photographs were posted and daily updated. The public could also follow posted interviews with the field experiment team members and ask questions to the team members. The official Outreach Day was Feb.27, 1999 in Barstow, CA. A demonstration of the rover and a display of the EVA-suit was made for the public. 1700 persons attended this event.

One of the major results of the Silver Lake ASRO

field experiment is that it pointed out a series of domains where more research and testing need to be undertaken in order to make surface planetary exploration by an astronaut-rover team a reality, to produce a safe, and cost effective mission, and to design productive and efficient interactions between the EVA astronauts and rovers.

The identified domains encompass: science (including adapted tools for astronauts, instruments for science onboard rovers, relay between rover and astronaut); rover technology; EVA technology; communications; mission operational procedures; gestion of mission duration and data volume; and information technology. The EVA astronauts and rovers interaction is a new, and critical, domain that requires new and better-adapted tools, and new strategies of exploration that do not exist yet. The ASRO field experiment was the first attempt in this direction. Laboratory and field experiments will be a critical part if we want Mars to be a human destination in the near future.

References: [1] Cabrol, N. A. 1999. The ASRO project, *Science Plan*, (Trevino, R. C., J. J. Kosmo, and N. A. Cabrol Eds.), 53 pp; [2] Cabrol, N. A. *et al.*, 1999. *30th LPSC*, 1069; [3] Cabrol, N. A. 1999. The 1999 Marsokhod Field Experiment, *Science Plan*, (Stoker, C. R. Ed.), 44pp; [4] Stoker C. R. *et al.*, 1999. *30th LPSC*, 1278; [5] The ASRO Project Team, 1999. *Astronaut-Rover Interaction Post Field Test Memo: Results, Lessons Learned, and Directions for Future Human Exploration of Planetary Surfaces*. (in progress).

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