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Assessment of robotic recon for human exploration of the Moon ☆

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ABSTRACT

Robotic reconnaissance ("recon") has the potential to significantly improve scientific and technical return from lunar surface exploration. In particular, robotic recon can be used to improve traverse planning, reduce operational risk, and increase crew productivity. To study how robotic recon can benefit human exploration, we recently conducted a field experiment at Black Point Lava Flow (BPLF), Arizona. In our experiment, a simulated ground control team at NASA Ames teleoperated a planetary rover to scout geology traverses at BPLF. The recon data were then used to plan revised traverses. Two-man crews subsequently performed both types of traverses using the NASA "Lunar Electric Rover" (LER) and simulated extra-vehicular activity (EVA) suits. This paper describes the design of our experiment, presents our results, and discusses directions for future research.

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1. Introduction

The planned human return to the Moon offers new opportunities to advance the scientific exploration of the lunar surface. However, when the new exploration campaign begins, short human missions (lasting a few weeks) will be separated by several months, during which time robots could perform work [1]. A central challenge, therefore, is to coordinate human and robotic activities to maximize scientific return. We believe that one way to do this is with *robotic recon*.

We define robotic recon as "remotely operating a planetary rover to scout planned sorties prior to EVA". Scouting is an essential phase of field work, particularly for geology. Robot instruments can provide observations of the surface and subsurface geology at resolutions and from viewpoints not achievable from orbit. This surface-level data can then be used to improve planning and crew performance.

As a practical example of how such recon would be extremely useful for lunar exploration, we need look no further back than the last human mission to the Moon. During Apollo 17's second EVA, the crew drove from the landing site to the South Massif, then worked their way back. At Shorty Crater (Fig. 1), Harrison Schmitt discovered orange volcanic glass—perhaps the most important discovery of the mission. However, time at the site was severely limited by walk-back constraints (based on consumables). Had the presence of orange glass,

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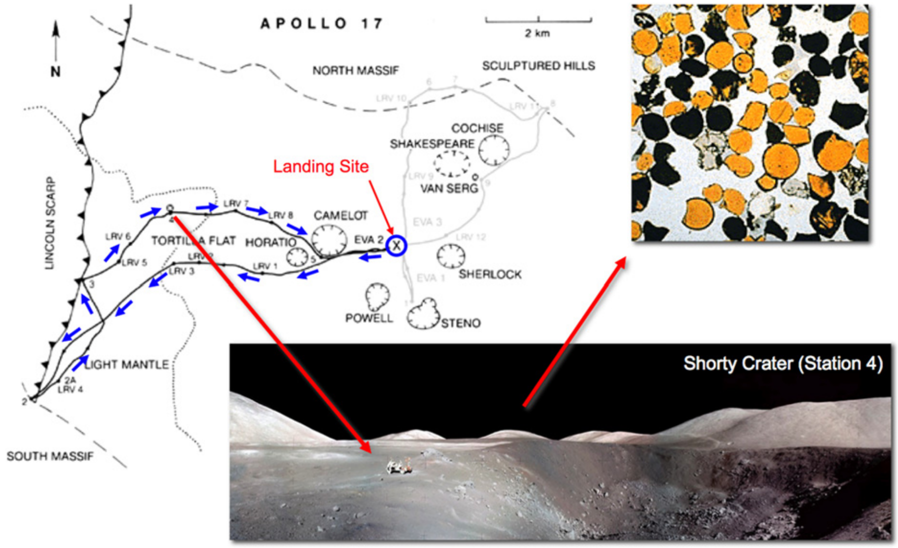

Fig. 1. Orange glass was discovered at Shorty Crater during Apollo 17. Robotic recon could have enabled the crew to spend more time exploring this key discovery by improving traverse planning.

or other pyroclastics, been identified in advance through surface recon, the EVA could have been planned with less time at preceding stations, so that more time could have been spent at Shorty Crater.

Since 2008, we have been developing and evaluating systems, operational concepts, and protocols for robotic recon [2,3]. Our approach is inspired by the Mars Exploration Rovers (MER), as well as human spaceflight, including Apollo, the Space Shuttle, and the International Space Station (ISS). Our ground control, for example, integrates a science team based on both the MER Science Operations Working Group (SOWG) [4] and the Apollo "Science Backroom" [5].

We hypothesize that robotic recon improves human exploration in three ways: (1) it increases scientific understanding so that better traverse plans can be produced, (2) it reduces operational risk by evaluating routes and terrain hazards, and (3) it improves crew productivity by facilitating situational awareness. To test these hypotheses, we conducted a field experiment of robotic recon at Black Point Lava Flow (BPLF), Arizona, during Summer 2009.

In our experiment, we employed a crossover design in which field geology traverses were planned and executed with, and without, robotic recon data. Initially, two "pre-recon" traverse routes were planned using orbital images. We then remotely operated a planetary rover equipped with cameras and 3D lidar to scout the traverses. The recon data were subsequently used to develop "post-recon" traverse plans. Finally, the four traverses (pre- and post-recon in two different areas) were executed by two-man crews using the NASA "Lunar Electric Rover" (LER) and simulated EVA suits. We used several metrics (described below) to assess the impact of robotic recon.

2. Experimental design

We designed our experiment to study: (1) to what extent robotic recon can reduce uncertainty and improve traverse planning prior to human field work and (2) how scouting in advance of human missions can improve crew efficiency and quality of data collection. The experiment involved four phases of activity, which simulated a human–robot exploration campaign.

Initial traverse planning: During the initial phase, a science team developed "pre-recon" crew traverse plans for geologic exploration of the BPLF site using only orbital imagery and "general knowledge" of the region (i.e., what is known about geologic processes and features of the area and at similar sites). The team then identified high priority areas where surface-level observations would help reduce planning uncertainties and developed robotic recon traverses.

Robotic recon mission simulation: In the second phase, we teleoperated a planetary rover to perform recon. A simulated ground control team remotely operated the robot from NASA Ames. The mission simulation included an operational timeline inspired by the MER SOWG and a hybrid operations protocol derived from MER and human spaceflight missions.

Post-recon planning: After the robotic recon mission was complete, the science team created "post-recon" crew traverse plans by modifying the "pre-recon" crew traverses using the recon data. Only details about the site that were contained in the robot data were factored into the traverse replanning.

Crew mission simulation: The final phase involved execution of the "pre-recon" and "post-recon" traverses by crews using the LER and simulated EVA suits. Two crews each performed one traverse with the benefit of recon information and another traverse without. A "science backroom" remotely supported the crews.

2.1. Definitions

The following are shown in Fig. 2:

EVA station—a location where crew performs an EVA,