

A Perspective on Human-Robot Interaction for NASA's Human Exploration Missions

Debra Schreckenghost¹, Tod Milam¹, and Terrence Fong²

¹TRACLabs, 16969 N. Texas Ave, Webster, TX 77598

²NASA Ames Research Center, MS 269-3, Moffett Field, CA 94035
ghost@ieee.org, tmilam@traclabs.com, terry.fong@nasa.gov

Abstract

As astronauts move deeper into space they must also become more autonomous from mission control on Earth. As a result, astronauts must take on additional responsibilities for jobs typically performed by flight controllers today and crew workload and training requirements are expected to increase. Robotic automation has potential to reduce crew workload and training needs. Additionally robots with some level of autonomy can reduce human risk by performing hazardous tasks that crew would otherwise have to perform.

For these operational changes to have the intended effect, we must understand how humans can interact effectively with robotic autonomy in situations characterized by high workload, high risk and impact, and limited resources, including:

- What are the roles and responsibilities of humans and semi-autonomous robots when performing NASA missions in space?
- How are these roles and responsibilities shared and shifted among humans and robots in different situations?
- How and when are these activity allocations and agent (human and robot) interactions effective at accomplishing shared work?

We are working with NASA to investigate new concepts of operation for astronauts interacting with autonomous robots in space, including remote supervision of a planetary robot by an astronaut orbiting the planet and remote understanding of robotic activities without eyes-on monitoring. We also are developing techniques for computing and analyzing agent performance for the roles and responsibilities needed for these ConOps, and have developed

software to compute these performance measures for humans and robots in-line during mission operations. We do this by monitoring robot instrumentation and human interaction with the robot, computing metrics from these data, and detecting operational events of importance. We used this software to perform in-line monitoring of the K10 rover performance during NASA robotic field tests and analog mission simulations at Moses Lake, WA, in June 2008 [5, 10], at Black Point Lava Flow AZ, in June 2009 [6, 9], and at Haughton Crater, Devon Island, Canada, in 2010 [8].

Recently we worked with NASA's Intelligent Robotics Group (IRG) to define and evaluate a concept of operations for the HET Surface Telerobotics project. This project conducted three flight tests to examine how astronauts in the International Space Station (ISS) can remotely supervise a semi-autonomous planetary rover. These flight tests simulated portions of a proposed lunar mission, in which an astronaut in lunar orbit would remotely operate a planetary rover to deploy a radio telescope on the lunar far side. Over the course of Expedition 36, three ISS astronauts remotely operated NASA's K10 planetary rover in the Roverscape, an analogue lunar terrain located at the NASA Ames Research Center in California [1]; see Figure 1.

Figure 2 shows astronaut Chris Cassidy operating the K10 rover from the International Space Station during the first session of the 2013 HET Surface Telerobotics test.

The astronauts used a "Space Station Computer" (crew lap-top), a combination of supervisory control (command sequencing) and manual control (discrete commanding), and Ku-band data communications to command and monitor K10 for 10.5 hours. During operations with the rover, we assessed astronaut workload using the Bedford Workload Scale [7] and situation awareness levels [4] using SAGAT [11]. We also used recorded rover telemetry and human interaction with rover software, and computed measures for mission success, robot asset utilization, task

sequence success, system problems, and robot performance for all sessions of Surface Telerobotics [2, 3, 12].



Figure 2. K10 Rover in NASA Ames Roverscape



Figure 1. Astronaut Chris Cassidy on ISS operating K10

We are currently researching the use of these techniques to develop anytime summaries for orienting remote personnel quickly about robot operations performed without continuous, eyes-on monitoring. An anytime summary will characterize progress on robot operations using whatever data are available when the summary request is made. It will compute performance measures for robot mission success and the efficiency and effectiveness of robot operations over various time periods, and will provide a launch point for interactive exploration of historical and current performance data. We plan to evaluate our approach to anytime summarization using data from NASA's Mojave Volatiles Project (MVP), a field test that will use a rover to search for water in the Mojave Desert in October 2014.

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