A PRELIMINARY EXAMINATION OF SCIENCE BACKROOM ROLES AND ACTIVITIES FOR ROBOTIC LUNAR SURFACE SCIENCE. T. Fong[1], M. Deans[1], T. Smith[2], P. Lee[1], J. Heldmann[1], E. Pacis[3], D. Schreckenghost[4], R. Landis[5], J. Osborn[5], D. Kring[6], E. Heggy[6], A. Mishkin[7], K. Snook[8], and C. Stoker[1]. [1]NASA Ames Research Center, [2]Carnegie Mellon University, [3]SPAWAR Systems Center, [4]TRACLabs, Inc., [5]NASA Johnson Space Center, [6]Lunar and Planetary Institute, [7]NASA Jet Propulsion Laboratory, [8]NASA Headquarters.

Motivation: When NASA returns to the Moon, one challenge is going to be the same as it was during the Apollo era: How can scientific return be maximized for any given period of surface activity? Unlike Apollo, however, the current lunar architecture involves a mixture of crewed and robotic surface missions, which will be used to establish infrastructure and eventually an outpost. Initially, crewed missions will be short in duration (2-3 weeks), interspersed by lengthy periods (6-12 months) without human presence. During these periods of time, it is expected that teleoperated robots will be used to perform surface tasks, including scientific exploration.

Towards the end of Apollo, an organizational structure known informally as the “Science Backroom” supported lunar surface science operations. This team was located at mission control and helped astronauts make real-time decisions by reviewing audio and video transmissions and providing recommendations (e.g., for geologic sampling). Given the success of the “Science Backroom” at improving science return during Apollo, an important question is: How can such a structure support future lunar missions, especially if *both* human and robotic activity are involved?

Objectives: To understand the utility of a science backroom for the current lunar architecture, we are conducting a series of analog field tests to identify organizational issues, explore team structure and roles, and develop operational protocols and metrics. Our research is guided by three objectives. First, our work is intended to inform NASA's lunar architecture team about surface science: Which of the lunar science priorities recommended by the National Research Council [1] can be addressed? What are the definining characteristics (e.g., comprehensive area coverage vs. targeted traverse sampling)? What resources (communications, EVA/IVA time, etc.) are needed?

Second, we are interested in learning how to efficiently and effectively coordinate humans and robots during surface activity [2, 3]. In particular, we believe it is critical to understand: What surface science tasks can humans and/or robots efficiently perform? How can robotic activity (before, between and with crews) improve human productivity? What are the trade-offs when using different human-robot team structures?

Third, we are concerned with understanding the differences between conducting remote robotic science on Mars and the Moon. Specifically, the operations model used for Mars (i.e., scripted sequences for daily command cycles) may not be appropriate for lunar operations, especially given differences in communications bandwidth and transport delay [4]. Thus, we are examining how to manage *interactive* robotic science operations in real-time, when there is significantly more data available (than for Mars surface operations), and when a range of autonomy is available.

Approach: The design of our ground control structure (Figure 1) draws inspiration from ground control used for Apollo, the Space Shuttle program, the International Space Station, the Mars Exploration Rovers, and the planetary rover field tests that we have conducted during the past fifteen years [5–8].

Team members have several roles:

• *Flight director*. Executive in charge of ops decisions. The flight director coordinates and reviews information from the flight control team and passes decisions to robot ops team via the robot communicator.

• *Robot communicator (RoboCom)*. Passes information from flight director to robot ops team. This role (minimizing distraction of surface team) is similar to that of “CapCom” in human flight missions.

• *Engineering officer*. Represents the engineering ops team to flight director. Monitors engineering telemetry from robot, ensures safety, and performs short-term planning. Example roles: ensuring battery levels are sufficient to reach next goal, approving attempt to cross a hazard.

• *Science officer*. Represents the science ops team to flight director. Monitors science telemetry from robot, watches for interesting targets that require follow-up, and performs short-term planning. Example roles: prioritizing data products for downlink based on science team interest, suggesting follow-up observations on particular targets.

• *Experiment officer*. Represents experiment ops team to flight director. Monitors instrument telemetry from robot, ensures good data is collected. Example roles: advise camera pointing based on lighting and focus constraints, command power up and warm up of instruments as necessary, diagnose and mitigate bad data.

• *Robot commander*. Directly operates robot mobility, also commands "real-time" science ops, such as panning cameras to look at specific targets as the robot is moving.

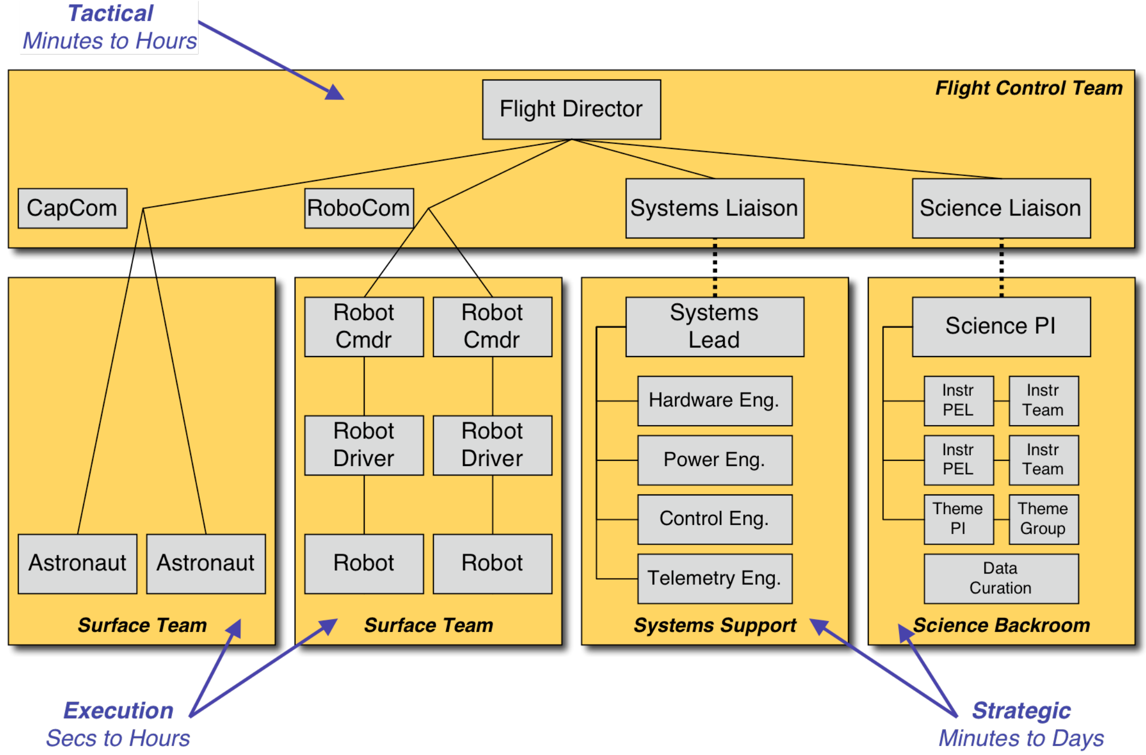

Figure 1. Prototype ground control structure for lunar surface science. The Science Backroom and Systems Support teams operate strategically; the Flight Control team operates tactically; and the Surface Teams execute tasks.

• *Robot pilot*. Has access to same controls as robot commander. Normally performs as a 'second pair of eyes' advising robot commander, or at commander's discretion may operate some controls (e.g., panning secondary cameras while the commander drives).

In our analog tests, we are examining how the above roles (and their associated duties) are influenced and vary due to several factors:

• Use of shared vs. dedicated resources (e.g., camera systems may be used for robotic navigation, hazard detection, and/or science data collection)

• Science conducted in (continuous) real-time vs. intermittent strategic planning and tactical operations (task execution)

• Single-pass vs. multiple-pass investigations at a given site and/or given scale

• "Comprehensive" vs. "targeted" vs. "opportunistic" data collection and study

• Time-delayed teleoperation (e.g., remote driving) vs. supervised autonomy (e.g., scripted command sequences)

• Single vs. multi-robot system

Moses Lake Sand Dunes Field Test: During June 2008, we conducted a field test at Moses Lake Sand Dunes in central Washington. Two NASA Ames K10 rovers were used to perform two types of scientific field work. K10 "Black" performed systematic surveys of subsurface structure with ground-penetrating radar. K10 "Red" was teleoperated as an "advance scout" to: (1) verify traversable routes for crew and (2) "high grade" a site (identify and prioritize science targets) for follow-up human activity. A ground control team at NASA Johnson remotely operated the K10 robots for several days. Time-based activity profiling and work efficiency metrics were used to assess team operations.

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