Remote science work support, context, and approach on NASA's VIPER mission. Z. Mirmalek[1,2], D.S.S. Lim[3], A. Colaprete[3], [1]Bay Area Environmental Research Institute, P.O. Box 25, Moffett Field, CA, 94035, zara.mirmalek@nasa.gov, [2]Harvard University, Cambridge, MA, 02138, [3]NASA Ames Research Center, Moffett Field, CA 94035.

Introduction: Returning humans to the Moon, sending humans for the first time to Mars will necessarily include an accompaniment of robotic vehicles. A mission work system will be needed that supports remote teams of humans and robots in co-operation (synchronous and asynchronous) with earth-bound systems, engineering and science teams. All of these elements have individual development contexts and manners of operation; at the same time, all are in varying degrees conjoined during mission development stages and operations. As such, the assembly of elements (people, activities, disciplinary knowledge, and machines) that constitute a mission work system can be developed independently and cooperatively. Current missions and those in development, in keeping with NASA's history of employing prior mission knowledge, will shape how and by which organizational schemas, or elements of, future missions will draw from, or wholly rely.

NASA's Volatiles Investigating Polar Exploration Rover mission, VIPER, presents an opportunity for a unique operational schema within the history of space exploration and remotely conducted science research. VIPER's lunar rover will operate on the Moon to identify and characterize water ice and other potential resources. Set to land in 2023, the rover will be tele-operated, controlled in near-real time, by personnel at NASA Ames Research Center (ARC). VIPER mission operations include multiple NASA centers and other organizations (e.g., Kennedy Space Center, Johnson Space Center, Honeybee Robotics). During the mission, one hundred earth days in duration, VIPER Science Team members will operate payload instruments and engage in data collection and analysis to enhance mission surface operations and meet VIPER mission goals.

VIPER will be NASA's first tele-operated robotic mission on the Moon. Previous, and current, NASA missions to Mars that utilize remotely operated robotic vehicles are being drawn upon to shape VIPER. One key difference between the Moon and Mars, in relation to Earth, is time delay, for communication and telemetry. The physical distance between Earth and the Moon allows for a shorter time delay, marked by the seconds it takes to send information between these astronomical bodies. For operations this means that the VIPER team can make near-real time decisions directing the lunar rover's traversing and use of instruments.

It is common to imagine that an operational configuration that allows earth-bound humans to remotely control a lunar rover and collect data in near-real time is akin to "joy stick driving." However, this short-hand analogy is not accurate, from operations and science work perspectives. The existence of communication latency via the Deep Space Network means that in the colloquial sense driving via joy stick, receiving instant real-time visual or haptic feedback, is not possible. With respect to science, this descriptor excises the presence of scientific reasoning that is part of the traverse process. Scientific research fuels space exploration; accordingly, the work of conducting science research remotely in outer space requires continuous development and refinement.

Extreme environments, such as the Moon, are by nature sites where conditions provide constant challenges to machines, humans, work activities and goal completion. Material technologies are designed to endure local lunar conditions, which are developed in part by drawing from previous lunar projects, including first-hand accounts from Apollo astronauts and data products from lunar landers and spacecraft. Surface operations, which refers to activities that commence with the lunar robot's egress from the lander, are composed, questioned and refined over a number of years. To achieve mission success, material technologies and surface operations are inextricably coupled (unless the goal is for an instrument to reach an extreme environment and cease communication).

This opening section gives the context, described with some but not all details, in which the work of conducting science research remotely in outer space using a tele-operated lunar rover for VIPER is being developed. The goals of this work are two-fold: 1) to support VIPER mission goals for lunar robot traverses and scientific data collection using payload instruments, and 2) to contribute methodical research on science operations for a mission work system schema for use in future missions.

VIPER science and mission system work support, ethos and approach: At this stage of VIPER, there has been almost one year of focused development on an ethos used to shape questions and pursue data on the matter of conducting science research remotely in outer space using a tele-operated lunar rover. These are matters in the purview of VIPER science operations but also explicitly recognized as being shaped by the entire science team and other mission workgroups. One task for science operations is to produce what it means for the mission's science team to be integrated within the mission work system. It is a task that can be pursued in a number of ways, and can be informed by a number of successful missions and space exploration projects.

A challenge to developing a flexible work system – one that provides stability in known conditions, e.g. high-pressure goals, distributed work timelines, extreme terrains, and in unknown conditions still to come, e.g. changes to activities, lunar robot state, lunar data – is composing one according to many. The team to be supported will almost certainly include personnel/workgroups that are similar in some respects and different in many ways. Part of the task is to approach the question of how to conduct science research remotely in outer space using a tele-operated lunar rover for VIPER from multiple perspectives. For this to be translated into actions, there needs to be a shared understanding that outcomes will neither be informed by any single individual nor subject to a single interpretation.

VIPER science operations development within the last year has been driven by an interdisciplinary approach and personnel work experiences on lunar and Mars missions (to name a few, see LCROSS [1], LADEE [2], RP [3], Mars2020, MER, MSL) and planetary analog expeditions (MVP [4], SUBSEA [5] BASALT [6], Pavilion Lake [7]). Across VIPER, there are many with work experience in the aforementioned projects, as well as ones that are not listed here. Some share experience on one or more previous, or concurrent, space exploration projects. Against this background, the VIPER team draws from shared referents, to operate with heritage language and activities, to posit refinement and innovation on work support technologies, communication, and interactions.

Science operations development employs methods from applied anthropology, sociology, and social studies of science and technology. VIPER is not the first mission to utilize social science research for the development of work support. VIPER has the opportunity to build and refine a novel approach for long-term and immediate development of a work support system for conducting science research remotely with robots that contributes to VIPER mission goal success, mission systems and public interests. In the past year, work ethnography was employed for data collection and analysis for work system development. It was not assumed that this approach would necessarily benefit the community or if the community was befitting these approaches in the long term. Previous use of ethnographic methods for work development, including a NASA Mars mission and a multi-year planetary analog project [5], provided grounded research and reasoning for this choice.

Ethnography is the study of culture, a term that, in brief, refers to a community's norms, habits, values, language and other constitutive features that are used to make meaning and foster social connection, group membership. NASA's Mars Exploration Rovers mission included ARC Work System Design and Evaluation researchers. Their primary methods were ethnographic; and, the long-term involvement, 2001 – 2004, included producing analysis for enhancement of the tele-robotic scientific process and for the design of computer technologies used for planning and information dissemination. It allowed for ethnographic research that adhered to the best practice of long-term engagement, building understandings of the meaning-making specific to the work environment and development of patterns [8][9][10][11].

VIPER science operations development benefits from a studied conjoining of ethnographic methods used in contemporary institutions with studies on culture and human-technology interaction within work environments in which scientific knowledge making is part of organizational production goals. In lieu of a comprehensive review, these studies are identifiable by a few categories including social studies of science and technology, anthropology of work, and computer-supported cooperative work. Of significant contribution are research and findings on social and technical dynamics that can shape the difference between adoption and dust bin for competing technologies and group decisions.

VIPER science operations research continues developing work support for conducting science research remotely in outer space using a tele-operated lunar rover. A choice of methods and sources for analytical reasoning is composed of work experience from previous space exploration projects, novel yet seasoned methods and the goals of supporting an integrated mission science team for VIPER and potentially other complex distributed team operations.

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