DETERMINING TECHNOLOGY PRIORITIES TO ENHANCE LUNAR SURFACE SCIENCE MISSION PRODUCTIVITY.

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Introduction: The Exploration Technology Development Program (ETDP) of the ESMD (NASA Exploration Systems Mission Directorate) has supported the evolution of a capability intended to systematize and quantify the relative priorities of advanced capabilities needed for lunar science in concert with human return to the moon. The product is a quantified list of sensitivities (percent change in mission productivity with respect to potential percent change in advanced capability). These sensitivities would then be folded with estimated achievable technology improvements to determine achievable mission improvement. Initial application of this approach is in support of the OSEWG (Optimizing Science and Exploration Working Group) surface science scenarios; a joint effort of the NASA Directorate Integration Office of ESMD and the NASA Science Mission Directorate.

Mission Scenarios: This study based its analyses on a hypothetical 14-day mission to the lunar surface, in which a specific set of experiments is to be accomplished at each of 5 localities (each of which is about 3 km across) among four geographical sites. Shackleton Crater, Shoemaker Crater, Sverdrup Crater, and de Gerlache Crater. Each of the 5 localities has 7 science activity sites, for a total of 35 places where the astronauts and robots stop to conduct experiments. This initial study examined two mission architectures. One consists of four astronauts and two small, pressurized rovers (SPRs), and the other consists of four astronauts and two unpressurized rovers (UPRs).

Assumptions, Constraints, and Productivity: The assumptions and constraints are in the full paper, and in Reference (1). Mission productivity is the value of the activities performed (number times relative importance) divided by the marginal cost of completing those activities. The experiments to be conducted at each locality consist of the following activities: collecting rocks and regolith, digging shallow trenches, hammering a "drive tube" into the soil, drilling soil and rock cores, and raking. All of the data for the total number of samples to be collected, the average mass of each sample, and the amount of time required to perform the experiments, are given in the full paper.

Initial Results: Our HURON optimization tool (2) was used to recommend the temporal schedule for astronauts working with each of the two kinds of rovers, it was found that the operational cost of the SPR scenario is about twice that of the UPR scenario, but that the value provided by the SPR scenario is about 14 times that of the UPR scenario. Thus, in our study's model, the SPR delivers about 7 times the productivity of the UPR. Importantly, neither scenario fills the 14 days that were envisioned for the mission. (See section on Further Work for additional activities which have been added.).

Technology Impact: For the mission configuration and associated assumptions and constraints described above, we compute the relative impact (Fig. 1) as:

$$\text{Impact} = \frac{\Delta\ \text{productivity/productivity}}{\Delta\ \text{performance parameter/performance parameter}} \quad (1)$$

Activity Name	Agent Type	Units	Nominal Value	Impact in two UPR case	Impact in two SPR case
Drive UPR	eva astronaut	km/hr	10	100.0	n/a
Drive SPR	astronaut	km/hr	10	n/a	100.0
DriveTube	eva astronaut	hr	0.25	12.9	44.1
Regolith	eva astronaut	hr	0.25	12.9	44.1
Rock	eva astronaut	hr	0.25	12.9	44.1
Trench	eva astronaut	hr	0.25	12.9	44.1
Rake	teleop	hr	0.4	6.5	22.2
DrillCore	teleop	hr	2.5	5.8	19.8
RockCore	teleop	hr	1.5	3.5	11.9
DrillCore	eva astronaut	hr	1.75	n/a	n/a
DriveTube	teleop	hr	0.4	n/a	n/a
Rake	eva astronaut	hr	0.25	n/a	n/a
Regolith	teleop	hr	0.3	n/a	n/a
Rock	teleop	hr	0.75	n/a	n/a
RockCore	eva astronaut	hr	1	n/a	n/a
Trench	teleop	hr	0.6	n/a	n/a

Figure 1. Estimated impact of changes in capability performance. Yellow rows do not have impact because analysis precluded those agents performing those activities in the scenarios included.

Further Work: In consultation with the SMD science community and the Constellation Architecture Team, we explicitly added as activities time for documentation; other experiments (microscopic imaging, ground penetrating radar, lidar imaging etc.); margins for unexpected events; and astronaut free time. These analyses are now underway, and the results are reported in the full paper. We are relating the sensitivities of functional parameters which appear in the model (e.g. rock acquisition time) to their various constituent individual technologies (e.g. sample identification, mobility to sample, sample acquisition; sample analysis and preservation.

References

[1] Human-Robot Lunar Exploration: Pressurized vs. Unpressurized Rovers", C.R. Weisbin, J. Mrozinski, H. Hua, K. Shelton, J.H. Smith, A. Elfes, W. Lincoln, V. Adumitroaie, R. Silberg}, 19th International Conference on System Engineering, August 19-21,2008,University of Nevada, Las Vegas, USA.

[2] H. Hua, J. Mrozinski, K. Shelton, A. Elfes, J. Smith, W. Lincoln, C.R. Weisbin, V. Adumitroaie, "Analyzing Lunar Mission Architectures Using An Activity Planner for Optimizing Lunar Surface Human-Robot Operations", Conference on System Engineering Research, Los Angeles, CA, April 4-5, 2008.