ENHANCING THE PROBABILITY OF MAKING SERENDIPITOUS DISCOVERIES FROM A PRESSURIZED LUNAR ROVER

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Introduction: Many future human lunar exploration activities will benefit from the provision of a pressurized rover, and some aspects of geological field activities will be impractical without one. Example exploration sites include the South Pole-Aitken Basin [1] and the young basaltic lava flows of Oceanus Procellarum [2]. The scientific benefits of a pressurized rover are recognized by NASA, which has developed the Lunar Electric Rover (LER) concept (Fig. 1; [3]) to satisfy the need for testing such a vehicle. One undoubted, but notoriously difficult to quantify, benefit of rover-facilitated mobility on a planetary surface is the additional opportunitity that will result for making unanticipated discoveries. While, by definition, serendipitous discoveries cannot be predicted in advance, it is possible to address the kinds of rover design and/or instrument suites which would enhance the probability of making such discoveries. In terms of rover operations, the probability of making a serendipitous discovery will increase with the ability to identify interesting, but unanticipated, targets of opportunity at a distance from the rover (or below the surface), as the rover traverse will already have been planned to maximize the scientific return with respect to what *is* already known about a particular locality.

Fig. 1. NASA's LER concept under test (NASA).

Designing for serendipity: Having considered this question, we list below our thoughts on equipment and capability which would enhance the probability of making serendipitous discoveries from a pressurised lunar rover (such as the LER). We note that these capabilities would also enhance the scientific usefulness of the rover even in the absence of serendipitous discoveries. The list is in order of increasing sophistication and capability. We have listed these on a numerical scale that attempts to grade the potential for increasing the probability of making serendipitous discoveries on a scale of 0 to 5 (where 0 is a basic rover and 5 is the most heavily instrumented option). From a rover designer's perspective, the list should be seen as a cumulative priority list; i.e. *any* rover should ideally be equipped with the capabilities identified in items 1-2, with items 4-5 being of lower priority (but only in the sense that, while still highly desirable, they may be less easy to justify given realistic mass, power and operational constraints).

Cumulative rover instrument priority list:

1. Basic pressurized rover with transparent bubble in the front windows (as implemented on the current LER concept; see Fig. 1 and ref. [3]) or floor of the vehicle, to permit close-up inspections of the lunar surface (from a range of < 1m) without requiring astronaut egress from the rover. This should be backed up by appropriate hand-held optical aids which can be used through both the bubble and the other windows – e.g. magnifiers, binoculars, rangefinders, etc. Note that astronaut observations from a rover led to notable events during Apollo, e.g. the sampling of a vesicular basalt (15016) by Dave Scott, who stopped a traverse to sample the "seatbelt rock."

2. External manipulators such as those commonly implemented on submersibles. Note that, in the example from Apollo 15 noted above, the need to sample while seated on the rover led to the development of the LRV sampler for Apollo 17 – in the case of a pressurized rover it is clearly desirable that such sampling be performed without the need to egress the vehicle. External manipulators should thus include the ability to collect samples and hold them close to the windows for visual inspection, and place them in an external sample cache for return to base and more detailed study. Other manipulators would also be desirable, e.g. a rock abrasion tool/rock splitter and/or duster (to reveal fresh surfaces), a scoop (for fine regolith), a rake (for small rocklets), and a plough or trenching tool for investigating below the surface.

3. Some means to remotely detect mineralogically/compositionally unusual soils or rocks at a distance from the rover, such that a detour could be made to investigate. An ideal instrument would be a multi-spectral camera and/or IR spectrometer that could au-detect distinct or unusual lunar mineralogies (e.g. highly evolved lithologies, hydrated silicates, etc). Ideally such an instrument would routinely scan the lunar surface out to the local horizon in real time, and automated software would alert the crew to unusual spectral signatures worthy of more detailed examination. Of course the whole data set would ideally also be recorded for subsequent scientific exploitation.

4. Additional instruments would also be useful in making the initial follow-up observations of something flagged as unusual. For example, an optical telescope (perhaps mounted on the roof of the rover; for an interesting, albeit fictional, example of the value of such an instrument see [4]). At a higher level of sophistication, a rover-bourn laser-induced breakdown spectrometer, operating at a distance (such as the ChemCam instrument originally proposed for Mars Science Laboratory [5]) would be very useful in confirming the composition of the target before deciding on whether to divert the rover from its pre-planned route.

5. A means of probing and sampling the sub-surface may be desirable in some environments. Ground penetrating radar (GPR) might be suitable for the former [6], and a drill or mole for the latter [7]. Other more specialist investigations might benefit from other instruments, e.g. magnetometers, neutron spectrometers, etc. Because these more sophisticated instruments will not be required all at the same time, and in different combinations, we would suggest that the rover be equipped with an external pallet provided with power and data links (as infact already included in the LER concept [3]), and on to which different instruments could be attached through a standard interface as required. In some ways this would be analogous to the Scientific Instrument Module (SIM) bays installed in the Apollo service modules.

Conclusions: One of the scientific benefits of returning humans to the Moon, and other planetary bodies, is the increased opportunities for serendipitous discoveries (see [8] for a discussion of the wider scientific case for human lunar exploration). Mobility over 10's-100's of km will increase the chances of such discoveries, and this will entail the provision of a pressurized rover. Although, by definition, serendipitous discoveries cannot be predicted in advance, it is possible to identify design requirements and instrument provision which will increase the chances of such discoveries. The potential for serendipity increases, perhaps substantially, as the number of capabilities outlined in 1-5 above increases – in part because they will facilitate in-situ analysis and reduce the need for sample return. Serendipity is a soft, but potentially significant, concept that needs to be traded along with other considerations in determining how a surface asset such as a pressurized rover can be improved to increase the potential for returning high-value science.

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