PRESSURIZED ROVER-BASED IVA FIELD SCIENCE: LESSONS LEARNED FROM MOON AND MARS ANALOG STUDIES AT THE HAUGHTON-MARS PROJECT, DEVON ISLAND, HIGH ARCTIC.

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Summary: Analog pressurized rover field studies at the Haughton-Mars Project (HMP) on Devon Island suggest that productive planetary field science investigations can be conducted by humans from within the confines of a highly mobile, well-equipped, and well-instrumented pressurized vehicle. Being able to conduct quality field work in mostly IVA (*IntraVehicular Activity*) mode on the Moon, Mars, and at other destinations may significantly reduce requirements on the frequency of EVAs and make surface exploration safer, more productive, cost-effective, and sustainable.

Introduction: Compared to non-pressurized mobility systems, pressurized rovers will enable longer duration, longer range, more flexible, and safer human exploration of the surface on the Moon, Mars, and other planetary bodies. Current investigations by NASA of the *scientific use* of crewed pressurized rovers focus on scenarios in which the rovers are used primarily as *transportation vehicles* allowing crews to access sites of scientific interest, where they then go on EVA to conduct field work. Although science payloads are integrated to the vehicles, traverses remain planned as a sequence of EVA stations (Apollo-style), with IVA science operations limited to gathering contextual information en route between EVA stations, and to local scouting once at these stations. At NASA's Desert RATS analog field deployments in 2008 and 2009, for instance, the *Lunar Electric Rover* (LER) supported some IVA science operations, but these consisted mainly in geologic context descriptions and pre-EVA target characterization. *IVA was not the primary mode of science ops and data gathering*.

Thus, pressurized rovers remain viewed primarily as a means of supporting deep field EVAs, and only secondarily as *research vessels* themselves from the confines of which crews would conduct their field science activities in IVA mode. However, based on several field seasons of humvee-based analog pressurized rover operations at HMP, and on P. Lee's experience as scientist pilot in the LER during the DRATS-2008 campaign, the use of pressurized rovers as *research vessels* from which *most* of the field science would be conducted in IVA mode may, in practice, offer a more optimal and general approach to conducting field science using pressurized rovers. We report here on data collected from 2003 to the present during pressurized rover simulations at HMP on Devon Island.

Fig. 1: Top: IVA field science observations from the NASA *Lunar Electric Rover* during the Desert RATS 2008 analog field campaign. (Photo NASA/DRATS-2008); **Bottom:** The Haughton-Mars Project's *Mars-1 Humvee Rover* being used as a pressurized rover analog from which a crewmember conducts field geology in IVA mode. (Photo NASA/Mars Institute/Hamilton Sundstrand/HMP-2009).

Analog Pressurized Rover Traverses: From 2003 to 2010, over two dozen long-range (5 to 500 km) analog pressurized rover traverses were conducted at HMP, with varying degrees of operational fidelity.

A common feature in all traverses was a program of field science investigations conducted at least in part from inside the vehicles. IVA field science activities included geologic visual observations, panoramic imaging, systematic surveys of the external environment using vehicle-mounted sensors (temperature probes, radiation dosimeters), sample selection, examination and collection (including the use of a hypothetical external robotic arm with a limited workspace), IVA hand sample examination and microscopy, geophysical sounding, and drive-by geologic mapping. Traverses were planned and implemented along specific routes inside and outside Haughton Crater, and generally included time for both targeted and opportunistic science observations. Timeline data were logged for selected traverses and IVA field science activities, including sample selection and examination.

Simulated EVAs were also implemented on several traverses using concept spacesuits developed by Hamilton Sundstrand, with a subset of these EVAs being via a Humvee-mounted suitport interface designed for rapid don and egress (15 min), and ingress and doff (10 min)[1]. Single person and dual EVAs were conducted.

Results: From the above traverses and field experience, we find that field geology investigations, including geologic mapping and sampling, can be well performed in IVA mode over barren rocky desert terrain with well-exposed rocks and soils, using a highly mobile field rover affording good visibility such as the HMP's Humvee rovers. Terrain features and geologic formations, including outcrops and individual boulders and rocks, are adequately approached and examined over a range of spatial scales (cm to km) (Fig. 2). Effective rock and soil examination, and sample selection and collection can be performed assuming a 5 degrees-of-freedom robotic arm operating within a 180^o, 1.5 m range workspace outside a ground viewing window.

Fig. 2: Drive-by Geology: A large boulder (a distal impact ejecta block) is examined from the Haughton-Mars Project's *Mars-1 Humvee Rover* during a simulated pressurized rover traverse on Devon Island, High Arctic. (Photo NASA/Mars Institute/HMP-2008).

Independent experiences support the above findings. During a field geology traverse in the *Mars-1*, invited geologist crewmember M. Helper (Chair of the *Field Exploration Analysis Team* or *FEAT*) had the goal of identifying and sampling rocks in the Haughton impact breccia that originated from depth (crystalline basement of Devon Island), as one might seek mantle rocks excavated by large impacts on the Moon. He was given the option of conducting opportunistic EVAs (in addition to planned ones) or to work in IVA mode. Noting that most rocks collected at Haughton occur as float (as on the Moon), he reported: "*If I'm looking for basement, it'd be better to just drive around in the rover*".

[1] Shorter don-egress and ingress-doff times are assumed in *LER* field tests. The minimum time overhead recorded for an EVA through a suitport tested at HMP is 15 min (sum of don/egress and ingress/doff times by a trained suit subject), 25 min being a common value. These times are based on P. Lee's experience at HMP (2000-2010), and are consistent with his *LER* suitport experience at DRATS-2008.

Discussion: The fundamental operational requirement for enabling humans to do field work effectively is not that they be on foot, but that they *be mobile*, *see well*, and *are able to examine, select and collect samples*. EVAs allow these requirements to be met, but so would a pressurized vehicle that is nimble, affords good visibility, is adequately equiped and instrumented (including for hand lens scale imaging) to allow sample collection in IVA mode. Such a vehicle is the functional equivalent of a multiple-person spacesuit.

While EVAs remain essential activities on human missions to the Moon, Mars, and other planetary bodies for a wide range of reasons, including science, exploration, infrastructure set-up, ISRU, maintenance and repair, education and public outreach, they are also a source of significant risk and cost (in time, life support resources, planning requirements, and suit maintenance). Although EVAs can be the best option for conducting field science productively when access to a site is too difficult by rover, or when geologic investigations or tasks are highly complex, these circumstances are likely to be less frequent than commonly imagined during a pressurized rover traverse, mainly because the LER will allow detailed examinations of the surface in IVA mode, and most rocks likely to be encountered during a rover traverse on the Moon will be impact-emplaced float, not bedrock. 95% of the rock samples returned by the Apollo missions are float, most of them collected *without* the use of a rock hammer[2]. At Haughton, 85% of rock samples collected during traverses are also float, as the surface is dominated by impact, freeze-thaw, and glacier generated rubble, not bedrock. HMP traverses teach us that, *in this type of terrain* (where most rocks are float), EVAs can be kept somewhat rare [1]. Reducing the frequency of EVAs will also help Planetary Protection [2].

A sufficiently mobile, well-equipped, and well-instrumented pressurized rover will allow the bulk of field science observations, investigations, and sampling to be conducted in IVA mode, and will help keep EVAs to a safe, cost-effective and sustainable frequency. Further studies should be conducted in which pressurized rovers are designed and tested as IVA *research vessels* primarily.

References: [1] Lee, P et al. (2010). GSA 2010 Annual Meet., Denver, CO. [#181719]. [2] Schuerger, A. & P. Lee (2010). Astrobio. Sci. Conf. 2010, Houston, TX. [#5377].

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[2] On Apollo 17, astronaut geologist Jack Schmitt used a scoop to collect rock samples.