YET ANOTHER LUNAR SURFACE GEOLOGIC EXPLORATION ARCHITECTURE CONCEPT (WHAT, AGAIN?): A SENIOR FIELD GEOLOGIST'S INTEGRATED VIEW. D. B. Eppler, [1] Exploration Sciences Office, Mail Code XI4, NASA-JSC, 2101 NASA Parkway, Houston, TX, 77058, dean.b.eppler@nasa.gov.

Introduction: Lunar surface geological exploration should be founded on a number of key elements that are seemingly disparate, but which can form an integrated operational concept when properly conceived and deployed. If lunar surface geological exploration is to be useful, this integration of key elements needs to be undertaken throughout the development of both mission hardware, training and operational concepts. These elements include the concept of mission class, crew makeup and training, surface mobility assets that are matched with mission class, and field tools and IT assets that make data collection, sharing and archiving transparent to the surface crew.

Mission Class: Different geological problems call for different solutions, and in order to solve these problems, operational approaches must be matched to the appropriate solution. The idea of mission class is here used to define the operational approaches that can be matched to a given solution. [1] applied a similar concept for lunar robotic missions; here it is extended to longer human lunar missions as well.

A Class I mission involves simple sample return for geochemical and radiometric age determination, conducted robotically, without the need for either human crew or robotic mobility (e.g, sample return from each unit delineated in Ref. 2). These missions are basic sample return missions: land, grab a sample close to the lander, place the sample in a return capsule and depart.

Class II missions involve more detailed robotic exploration and sample return from a complex geological area over the course of a single lunar day. A Class II site may or may not require human exploration on a future mission (e.g. Compton-Belkovitch), based on the results from sample return. The robotic assets would need to be able survive a single lunar day, and have both the speed and a sample manipulative capability similar to the Robonaut/Centaur prototype.

Class III missions would resemble Apollo J-missions, possibly with as many as 4 crewmembers, and with unpressurized mobility assets to allow 10-20 km radius of exploration, 3-7 days duration and up to 150 kg of sample return capability. A class III mission could be sent to a site previously investigated by a Class II robot, or could be a site where it is clear that human crewmembers will result in the best science return.

Class IV missions involve advanced exploration capability, exploring around a semi-permanent outpost or on long (100s of km) surface roves, and involving multiple small pressurized rovers (MMSEV-class) that can, if necessary, robotically pre-positioned into a potential exploration area prior to human crew arrival.

Crew Composition & Training: Geologic exploration requires exceptional training in geological observations in procedures, an insight not lost on Apollo trainers. Once engineering missions (AS-11, -12 & -14) were complete, attention turned to conducting extensive geological exploration of the lunar surface. The J-mission crews received in excess of 1000 hours of science training prior to flight, with over 500 hours spent in field geologic training [3]. Future missions will require a similar training commitment, particularly in the lead up to flight. Further, in order to conduct competent science operations, crew selection will be critical. The AS-17 experience of pilot/engineer Cernan paired with a geologist Schmitt proved exceptional and should be followed in the future. Similar crew mixes have been tested on Desert RATS 2010, and have proven the validity of the Apollo 17 experiences [4].

Transportation Assets: Apollo geologic exploration came into its own when the Lunar Roving Vehicle was brought to the surface. For Class III missions, unpressurized roving assets will be necessary, but advancements in personal transportation, such as the advent of Segway-type off-road vehicles (e.g., http://www.segway.com/consumer/adventurers/), may give crew mobility a smaller landed mass penalty while retaining the utility of the LRV.

For Class IV missions, small, 2-person pressurized rovers in the Multi-Mission Space Exploration Vehicle (MMSEV) class will be essential to provide a shirt sleeve transport, working and living environment, with suit ports and an appropriate EVA suit and cabin-pressure environment to allow quick EVAs. EVAs to sample outcrops would be a follow-on activity that would occur after the crew develops geologic context while remaining in the pressurized environment, as was demonstrated on Desert RATS 2010 [5]. Navigation capability has advanced sufficiently to allow on-board star trackers, potentially eliminating the need for extensive orbital assets or extensive surface infrastructure such as tower based communications (e.g., www.BlueCanyonTech.com). It is envisioned that lunar exploration would, for operations reasons, require some form of communications assets providing far side coverage, but these assets need not also require navigational capability.

Field Tools & IT Assets: In addition to the complement of "hard" field tools (hammers, rakes, etc.), a number of specialized tools will be necessary. First, the ability to take cm-diameter cores of key lunar outcrops will be essential for sampling detailed petrologic relationships such as interfingered melt and breccia inclusions. Second, the ability to take regolith cores of at least three times the Apollo capability (approximately an entire maria regolith column) will greatly enhance regolith-based studies.

The use of hand-held and mast-mounted compositional instruments should be strongly considered, although the efficacy of those instruments in a terrestrial setting is still being evaluated. In particular, the use of portable LIDAR assets, coupled with high-resolution digital imaging systems, such as GigaPan, will allow acquisition of high-resolution topographic and visual data of each outcrop, allowing sample provenance to be established with a high degree of accuracy and enhance post-mission geologic context determination and sample studies.

Lastly, IT assets will be a critical part of data collection, management and archiving, starting on the lunar surface. The crew should be provided with sufficient IT capability (tablet and/or notebook computers, still and video imaging assets) to produce electronic field notebook entries that will be similar to producing an Apollo Lunar Surface Journal page for every day of exploration. This product would link printed transcripts of crew descriptions, comments and debrief notes with photos and videos, making this product the first-order research output for each mission. Posted to the web on a daily basis, these field notebook entries will be the subsequent starting point for detailed sample studies.

Conclusions: These ideas are not entirely new, and only scratch the surface of what an effective lunar geological exploration architecture could look like. Further, none of the approaches or hardware represent extreme advances in technology; in fact, some technologies date back to Apollo.

The key aspect of this approach is that it advocates a pre-planned, strongly integrated system of mission class, transportation hardware, crew selection and training, geologic field tools, IT and imaging assets. This integrated approach carries the overarching ideas through system definition and design, enabling all the parts to work together, and allowing integrated surface geologic exploration where the whole greater is than the sum of the parts, and the surface mission has the hardware, crew and crew skills to match the mission.

References: [1] Taylor G. & Spudis, P., (1988) NASA Conf. Publ. 3070. [2] Hiesinger H. et al. (2011) *GSA Spec. Pap. 477,* 1–51. [3] Love, S. & Bleacher, J. (2013) *Act. Astronautica 90*, 318-331. [4] Lofgren G. et al. (2011) *GSA Spec. Pap. 483,* 33-48. [5] Abercromby A. et al. (2013) *Act. Astronautica 90*, 203-214.