PLENARY PRESENTATION: SCIENCE OPPORTUNITIES IN NASA'S LUNAR ARCHITECTURE. L.A. Leshin[1] and T.H. Morgan[2], [1]NASA Goddard Space Flight Center, Sciences and Exploration Directorate, Greenbelt, MD 20771, [2]NASA Headquarters, Science Mission Directorate, Planetary Science Division, Washington DC 20546 (laurie.leshin@nasa.gov).

In 2006, NASA led an effort to construct, refine and review a set of *themes* and *objectives* for lunar exploration. This broad-based effort expressly included significant participation from many international space agencies, the science community, commercial entities and other interested parties – over 1000 people participated in the process. The resulting set of lunar objectives is meant to encompass a diverse array of activities that could be accomplished at the Moon. Because of its grand scale, and the fact that many space agencies and other constituencies are becoming involved in lunar exploration, this set of themes and objectives are referred to as the "*Global Exploration Strategy*" for the Moon (see http://www.nasa.gov/exploration to find a listing of the themes and objectives).

NASA has taken these themes and objectives as a starting point for creating its *Lunar Architecture*, a set of reference missions and scenarios for planning and scoping NASA's future lunar exploration program. This Architecture was created by an internal NASA Lunar Architecture Team (LAT).

"Scientific Knowledge" is one of the 6 themes of lunar exploration in the Global Exploration Strategy, and 45 of the nearly 200 objectives fall into the Science Mission Directorate science areas of Astrophysics, Heliophysics, Planetary Science and Earth Science. In addition, many of the other objectives can be characterized as "applied science" for the purposes of advancing the exploration program.

The LAT has produced an architecture centered on activities at an outpost in a polar location. The architecture begins with the upcoming Lunar Reconnaissance Orbiter and proposes several additional lunar robotic missions to the outpost location in advance of human missions. If implemented, these missions would primarily scout the site and its surroundings, test key technologies, and reduce risk for the outpost. The reference human missions in the architecture begin by 2020 with short-stay "sortie" (7 day) missions to the outpost location, followed by more extended stays (up to 180 days) for 4 crew.

The outpost focus for NASA's architecture was driven primarily by the key themes of the program (from NASA's perspective) which are about learning to live and work on another planetary object, and preparing for eventual human missions to Mars and other destinations. The polar location was driven largely by dynamical and operational considerations, such as energy availability. It is important to note that, although the current architecture is focused on a polar outpost, the reference designs developed are capable of exploring other locations on the Moon.

Although science did not drive the architecture to a great extent, our return to the Moon certainly creates many science opportunities. On the LAT, the two authors co-chaired the Science Capability Focus Element. One of the main activities in this focus element was to determine the capabilities required to achieve each of the science objectives from the Global Exploration Strategy and then to map the "goodness of fit" of the science objectives to the architecture.

For each objective, we determined the basic capabilities required to achieve it: for example, approximate payload mass and power needed, location on the Moon (polar, equatorial, etc., one site or multiple sties), sample mass required, EVA required. Then, we rated each objective against the architecture using the following rating scheme:

1 – Green	Objective can be substantially accomplished by 2025 within the current architecture assuming the priority and funding are allocated
2 – Orange	Objective will very likely take longer than the 2025 time horizon to accomplish, but could be accomplished in an outpost-based architecture
3 – Yellow	Some substantial part of the objective can be accomplished within the current architecture by 2025
4 – Pink	The objective can be accomplished with a combination of outpost-based science and robotic missions to non-outpost locations
5 – Red	The objective can really only be accomplished through some additional capability not present in the current architecture (such as human sorties to non-outpost sites)

Note that we did NOT prioritize science objectives. Rather, we sought to understand which objectives could be more readily achieved within the architecture, and which would require additional capabilities to achieve if they were determined by the community to have high science priority.

The ratings for the objectives in each of the four science areas are shown in the histograms on the next page. Overall, 24 out of the 45 basic science objectives are GREEN (53%). Clearly, the architecture provides many opportunities for science! In fact, it is unlikely that we can accomplish all of the GREEN objectives due to resource limitations, and of course, all the GREEN objectives may not be of high science priority. In addition, there are undoubtedly high science priority activities that are not GREEN. Nonetheless, the ratings provide a useful starting point for prioritization discussion and trades.

Geology: Most Geology objectives are GREEN (69%), requiring field work that is either non-site specific (such as geologic *process* studies) or polar-focused (volatiles) and that could be accomplished robotically and by humans. YELLOW objectives are largely field mapping and sampling objectives, where much progress can likely be made at the outpost site, but that will *absolutely require* human visits to non-outpost locations to fully achieve the objective. PINK objectives require deployment of sensors (seismometers, heat flow, etc.) at non-outpost sites – this could be done robotically, at least for initial instruments.

Astronomy & Astrophysics: A & A has a relatively large fraction of "non-GREEN" objectives (44% are GREEN) due to the complexity of emplacing large telescopes. GREEN objectives are those requiring only small telescopes or other limited sensors that could be deployed near the outpost site. ORANGE objectives would require more complex deployments, possibly further from the outpost site (large, farside radio telescopes or interferometers at other wavelengths). 2 PINK objectives require deployment of fairly simple sensors at multiple non-outpost sites, which could be done robotically.

Heliophysics: Most Heliophysics objectives are GREEN (87%), requiring relatively small sensors that could be deployed either robotically (some in orbit) or by humans. The lone YELLOW objective is to perform low-frequency radio observations of the Sun – a partial array could likely be emplaced on the 2025 timescale, but a larger array would require more time.

Earth Observation: Many Earth Observation objectives require continuous view of Earth – therefore most are NOT achievable at a polar outpost location where Earth is in view only about 50% of the time. Only 2 out of the 12 Earth Observation objectives are GREEN (17%). PINK objectives require deployment of modest Earth observing telescopes/sensors at an Earth-facing, non-outpost site – these could be accomplished robotically. RED objectives require very ambitious telescopes and sensors that would likely require humans to deploy -- this would necessitate sending humans to a non-outpost location.