Applications Chapter For "New Views Of The Moon II" On Lunar Surface Science Exploration Approaches –DRAFT Plan for Chapter Implementation

Proposed Writing Team:

- Jake Bleacher (overall concept, lunar surface geologic field operations)
- Ernie Bell (lunar surface operations concepts (overall, geophysical field ops, EVA ops & engineering)
- Barbara Cohen [surface geophysical monitoring, surface science operations]
- Matthew Deans (IT assets for geologic exploration)
- Dean Eppler (overall concept, lunar surface geologic field operations)
- Cindy Evans (sample curation emphasis, lunar surface compositional analysis)
- Trevor Graff (lunar surface geologic field operations)
- Jim Head (historical perspective, crew geologic training)
- Mark Helper (crew geologic training, IT assets for geologic exploration)
- Kip Hodges (crew geologic training, lunar surface geologic field operations)
- José Hurtado (crew geologic training, IT assets for geologic exploration)
- Kurt Klaus (overall concept, mission class development, engineering input)
- David Kring (lunar surface geologic field operations)
- Harrison Schmitt (historical perspective, lunar surface geologic field operations)
- Jim Skinner (cartography, lunar surface geologic field operations)
- Paul Spudis (historical perspective, lunar surface geologic field operations)
- Barb Tewksbury (crew geologic training, IT assets for geologic exploration)
- Kelsey Young (lunar surface geologic field operations, lunar surface compositional analysis)
- Aileen Yingst (lunar surface geologic field operations, lunar surface compositional analysis)

Chapter Concept:

"New Views of the Moon II" will be largely devoted to assessing our present knowledge of the Moon from the perspective of geology, geochemistry, geophysics and history of the Moon. This chapter proposes to consider what we need to do, upon the return to the Moon, to answer the open scientific questions that will be raised in the other chapters. In particular, the scope of the chapter will be to lay out the exploration approaches that utilize robotic and human assets from the vantage point of what assets and mission approaches fit each open question. In addition, it will discuss approaches to executing lunar surface operations, both human and robotic, based on the mission experience, crew training operations and analog testing that has been done since the publication of "New Views of the Moon," in 2006.

In some ways, this chapter will be more of systems engineering than it will be science, but I think that's fine. In particular, a number of communities (EVA in the main) have expressed a great deal of support that a document like this gives them guidelines for design that has been lacking up to now. Consequently, we should think about how each section we write could be summarized is a short set of requirements that could form a final sub-section for each area discussed. We can talk more about this later, but it is important to emphasize that our section is likely to be used by non-scientists to drive operations concept development and initial design.

We have a specific "no architecture specific advocacy" rule that Clive has levied on this chapter. The reasoning behind this is that, quite simply, the architecture we advocate today (e.g., use of the Space Launch System, particular lander or rover concepts like Altair (God forbid) or LERs) are as likely to be in the dustbin by the time the book is published as they are likely to be the approach used – consequently, we're trying to ensure our chapter doesn't become old news before it is even in print. I think this is a fundamentally good idea that we will implement, but there are certainly operations that we have had experience with in the past ten years that are architecture-specific, and that could be used as examples. The key in using these examples is that we emphasize this is being done for illustration purposes, not advocacy of a particular design. One example is the use of LERs – we have enough experience now from DRATS/10 that an LER concept vehicle is fundamentally a good idea. That experience could used as an illustration of how small pressurized vehicles could be used to execute a particular set of mission plans. A second example is the use we've made of xGDS over the years – again, without advocating that specific product, we can use it as an example of how science data can be collected, collated and managed in real time in a way that makes the geologic context and sample provenance easier to keep track of.

<u>Chapter Outline</u>

1) Chapter Concept
    a) Develop approaches for lunar surface and supporting orbital investigations that will be necessary to answer the open questions about the Moon that have been raised by the previous chapters within NVotMII
        i) The approaches should be sufficiently developed that they can be used by the engineering teams, both within NASA and partner space agencies (e.g, ESA, JAXA, CSA), that will be responsible for implementing a program of lunar exploration
            (1) These teams include EVA, robotics, surface operations development, IT, crew training
        ii) This chapter should provide the first level systems engineering product (generally called an operations concept) best suited to accomplish the science objectives outlined earlier in NVotMII
        iii) Approaches presented will be independent of any particular engineering architecture, such that the outcome of the chapter will be useful to mission planners and engineers regardless of the vehicle or operations architecture contemplated.
            (1) The key here is that the outcome of this chapter will be useful for mission planners and engineers in the future, regardless of the vehicle or operations architecture contemplated
2) Previous work
    a) "Lunar Bases and Space Activities of the 21st Century", edited by W. Mendell, 1985
    b) "Geosciences at a Lunar Base", workshop report from 1988, edited by G. Taylor and P. Spudis and published in 1990

   c) "A Global Lunar Landing Site Study to Provide the Scientific Context for the Exploration of the Moon", edited by D. Kring and D. Durda, published by LPI in 2012
   d) Acta Astronautica Special Issue on the Desert RATS 2010 mission, edited by D. Eppler and J. Bleacher, v. 90, no. 2, 2013
   e) Other literature sources will be developed in the early stages of chapter preparation
3) Mission Concepts
   a) Concept Ia – basic robotic sample return mission
      i) Robotic sample return from a restricted area
      ii) Used for geologic problems that have well understood field relations and need only sample return to elucidate major questions
      iii) An example of the kind of problem that can be solved using this approach is sample return to support radiometric age dating of mare surfaces with different crater count populations identified by Hiesinger, et al., (2011, G.S.A. Special Paper 477, pp. 1-51)
   b) Concept Ib – geophysical network emplacement
      i) Emplacement of a Moon-wide geophysical network for long-term monitoring of the Moon
      ii) Numerous attempts have been made to implement this over the last couple of decades – none have succeeded, but that doesn't invalidate the basic concept
      iii) Key issue – can this be done "simply" – deployment off a lander, with only an arm to implement emplacement?
   c) Concept II – complex robotic sample return mission and site exploration
      i) Robotic geologic field exploration and sample return conducted with a dexterous teleoperated rover
      ii) Used for geologic problems that require complex field operations but may not initially warrant a human surface mission
      iii) Class II missions are reconnaissance-type missions that could lead to a Class III human mission, depending on the results of post-mission terrestrial sample analysis
   d) Concept III – human sortie exploration mission
      i) Short duration human surface exploration
      ii) Essentially an Apollo J-mission that has a duration of up to 2 weeks
      iii) Includes crew surface transport for all crewmembers simultaneously (no "rock-paper-scissors" to see who rides each day…)
      iv) Plan for 2 crewmembers, but could be increased to 4 depending mission goals and lander down mass capabilities
      v) Could also include robotic assets that could be operated after completion of the human mission
   e) Concept IV – extended duration human/robotic exploration mission
      i) Extended duration human mission with two possible sub-classes
      ii) Concept IVa
         (1) Human lunar outpost at a fixed location
         (2) Build to permanent human presence
         (3) Essentially a "lunar McMurdo Station" concept
         (4) Science exploration by both humans and robotic assets to explore an increasing radius from the permanent outpost site

iii) Concept IVb
(1) Long duration rover ranging over extensive areas of the lunar surface, similar to those envisioned by Cintala, Spudis and Hawke (1985, Lunar Bases and Space Activities of the 21st Century, pp. 223 -238)
(2) May either begin and end at a permanent outpost, or possibly extend away from previously positioned assets by a landed crew
(a) The key aspect of these missions would be extensive range from the starting point and long duration – weeks to months

4) Samples Analysis and Management
a) Curation approaches
i) Historical perspective – Apollo curation history
ii) Future requirements
b) Sample analysis
i) Approaches
(1) Hand-held EVA analysis tools
(a) Terrestrial experience
(i) Instruments used
(ii) Geologic settings where analysis tools were employed
(iii) Results
(b) Overall usefulness and limitations
(c) Requirements
(i) Precision and accuracy
(ii) Operation implementation
(2) Habitat analysis capabilities
(a) Analog experience
(i) Instruments used
(ii) Analog setting where tools were employed
(iii) Results

5) Surface Measurements
a) Active survey and long term monitoring
i) Long-term monitoring
(1) Potential instruments
(a) Seismic activity
(b) Heat flow
(c) Surface exospheric composition and properties, including solar wind
(d) Surface electrical field
(e) Sediment transport environment and activity
(2) Requirements
(a) Station emplacement, distribution, duration and sensitivity
ii) Active surveying
(1) Potential instruments
(a) LIDAR
(b) GPR
(c) Rover-mounted radiometric remote sensing tools
(d) Seismic surveying
(e) Electrical resistivity surveying

(f) Other broad area survey instruments
(2) Overall usefulness and limitations
(3) Requirements
(a) Precision and accuracy
(b) Operation implementation
b) Overall assessment
6) Information Assets and Data Management
a) How to manage images, field notes, geographic data, scientific data in a way that organizes surface science return
b) Field notes
i) Voice vs. written/keyboard note generation
ii) Integrating field notes with geographic information and images
c) Requirements
i) Cartographic products
(1) Form
(2) Scale
(3) Accuracy
ii) Geographic location knowledge
(1) Precision
(2) Accuracy
(3) On-board capability or global/orbital infrastructure - options
iii) Developing an integrated notes/images/geographic data set on a continuous and timely basis
(1) Generating an "Apollo Lunar Surface Journal" page per EVA
7) Mission Operations Management
a) Crew scientific training
i) Summary of Apollo history, particularly the role of crew pre-mission training in science mission success
ii) Potential program for crew geologic training
b) Science mission operations management
i) MER/MSL experience
ii) DRATS 2010 experience
iii) Science mission management approaches and requirements for future lunar surface missions
(1) The critical role of flexicution in the conduct of future surface operations
(a) Hodges & Schmitt (2012)
8) Potential conclusions and wrap-up
a) Application
i) Analysis of the open lunar science questions generated by each chapter team, with parsing into the various mission classes to show the minimum approach to solving each
ii) A development of a high-level mission operations concept that can be used by engineering and operations teams to begin their systems engineering requirements work
b) Final conclusions

How We'll Do It – The Plan for Producing the Document

One thing I've been struggling with is how to produce a chapter "by committee" and still have it read well. In addition, I know everyone is busy with their day jobs, and I'm acutely sensitive that I come to the table with empty pockets – I have no support for producing this. Consequently, my approach to producing the document will be has follows: each team (listed below) will produce a set of bulleted charts with the pertinent information and illustrations that the team wants to see in their chapters. These charts should be to whatever detail the team feels appropriate, but I'm expecting the detail should be pretty high so we have as much specifics as we can in the chapter. Once I have that input, I'll take the bullets and turn them into prose. That way, the majority of the writing will be on my back, which I'm hoping will help everyone concerned. Once I produce a draft, we'll circulate amongst the team for comments.

Producing this chapter will be a two-part process – what we produce between now and the middle of May will be the first part. The second part of the process involves the rest of the chapter teams. The other teams have the charge to produce a list of open questions that they will pass on to us in late May for our consideration. The second part of our job will be to take those inputs and analyze them relative to the various mission concepts and activities that we produce between now and May. I'm not sure what that will look like, so we'll have to wait to map out that part of our chapter.

Proposed Sections

Section I – Background and mission concept development (10/15/16 through 2/1/17) (Sub-sections 1, 2 & 3)

- Suggested team - Eppler, Klaus, Spudis
    - Suggested Lead - Eppler
- Literature search to establish past concepts
- First draft of this section to be prepped for review by the team in late-January

Section II – Development of Lunar Surface Activities (Sub-sections 4, 5, 6 & 7) – each section works in parallel to produce a set of input data for me by 4/1/17; at that point, I will take each team's input and craft it into a chapter

- Sampling, sample processing, sample analysis and sample curation
    - Suggested team - Evans, Bleacher, Kring, Young
        - Suggested Lead - Young
- Surface remote sensing
    - Suggested team – Bleacher, Graff, Young
- Operations management, including surface operations management and crew training
    - Suggested team –Bleacher, Bell, Eppler, Graff, Head, Helper, Hodges, Schmitt, Kring, Tewksbury, Young, Yingst
        - Suggested Leads: Helper for training, Graf for surface operations management
- IT/information management/field data asset requirements, including crew data collection concepts, imaging and image management, cartographic/navigational/positional information needs, communications needs

- Suggested team – Deans, Helper, Tewksbury, Hurtado, Schmitt, Skinner
  - Suggested Lead: Tewksbury

Section III – Analysis of NVotMII chapter team outputs

- This will come after ≈5/15/17, when each chapter team completes its first draft and passes this data on to out team
- This will be a whole-team effort, conducted roughly in June 2017, estimated completion of this section of the chapter sometime this summer; again, I will take the lead in writing up the section with everyone's input.