Addressing International Lunar Surface Operations

Joint Meeting of

LEAG-ICEUM/ILEWG-SRR

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Overview

- Background
- Preliminary Issue Areas & Questions
- Systems Engineering & Integration Approach
- Follow-up Suggestions

Background

Why Worry About International Lunar Surface Operations Now?

- Lunar Surface Operations can be:
  - Complex - especially given international considerations
  - Risky
  - Unpredictable
  - Expensive
  - Critical for Public Support (e.g. safety, engagement and Mission Success)
  - Critical for Mars Forward
  - Architecturally and technologically influential
  - Helpful in determining “what happens when we get there”, and how to adapt…

* Long-duration sustainable human surface operations is something new

- Probably better to be proactive and systemic about as many operational details as appropriate.
- Suggests the need for a forward-looking “Operations Systems Engineering and Integration” approach - preferably full program life-cycle - e.g. through human Mars missions.

Background - con't

- Sorrento Declaration
- Subsequent activities
  - Formulation of some key issue areas and questions
  - Considered an ILEWG session - but didn't pursue
- Some Related Activities
  - Lunar Architecture Team - ops considerations
  - Communications Standards
  - Surface Ops System Engineering presentation to Constellation Program Management
  - Formation of Lunar Surface Systems Project, and Ops Integration within that project

Background - con't

- Some Related Activities - con't
  - ESA: Active on all definition levels (architecture, system and component) dealing with surface operations. For example:
    - Architecture studies looking at conceptual designs of all surface elements and element interactions. Being fed into International Space Exploration Coordination Group.
    - Preliminary design of a pressurised lunar rover with interfaces to communications and navigation systems, lunar base and EVA systems
    - Mission Execution Crew Assistant: design and prototyping of an informational system providing the exploration crew up to date data and decision-making assistance.
  - International Space Exploration Coordination Group (ISECG)
    - Interface Working Group, including architecture work
    - Public Affairs
  - International Space University
    - Operational safety
    - Longer-term governance

Functional Overview: Ops Areas of Interest

- Mission and Outpost Planning
- Landing
- Outpost Assembly
- Science Ops
- Mobility
- Contingency Ops
- Maintenance & Monitoring
- Robotic Ops

* *Adaptability and Flexibility*

Preliminary Issue Areas & Questions

- *Safety*: How will we address safety internationally - e.g. crew and overall operations?
- *Compatibility and Interoperability*: How can interoperability be achieved for international surface assets?
- *Knowledge Management and Information Systems:* How might we develop and manage multi-national sources of Lunar information?
- *Science*: How will sample acquisition and handling be done internationally?
- *Earth-Moon Operations:* How should we manage international "multi-element" operations that includes crew (e.g. crew autonomy issues), robotic assets, and many other diverse lunar assets.
- *Planetary Protection:* What are the PP issues and how should they be addressed?
- *Mars Forward*: In addition to much of the above, how else can the Moon be used to address international issues associated with Mars missions? LEAG has Mars Forward as one of 3 themes for the NASA Advisory Council request for a Lunar Exploration Roadmap.

Preliminary Issue Areas and Questions - details

- ***Safety***:
  - Dust and radiation
  - Site selection process, landing
  - Redundancy and back-up systems
  - Crew rescue
  - Routine health and monitoring

- ***Compatibility and Interoperability***:
  - What are the key assets requiring interoperability? E.g. Comm, data formats, docking systems, EVA systems, robotics systems, engineering units (SI vs English - important for tools as well), power, information systems.

- ***International Knowledge Management and Information Systems:***
  - How should international sources of lunar information be developed, structured, managed? E.g. considering aspects such as language, lessons learned, real-time operational needs, real-time use of information systems on the lunar surface, data formats, organization, culture, history, proprietary/commercial information.
  - How can information be effectively shared between Earth and Moon?

- ***Science***:
  - Data, sample return/sharing, preliminary assessment, curation, & publication
  - Role of scientists in surface operations
  - Protecting science (e.g. preliminary controversial proposal made to COSPAR Commission B to “protect” lunar north pole)

Preliminary Issue Areas and Questions details - con't

- ***Earth-Moon Operations:***
  - To what levels might there be crew autonomy?
  - How will we make decisions regarding international surface ops?
  - To what extent should there be non-governmental participation in surface operations?
- ***Planetary Protection:***
  - Moon is now Planetary Protection Category II.
  - How can the Moon be used to better address Mars planetary protection issues? Tempe mtg addressed this, PP subcommittees, etc. But trade studies need to be done to address operational implications.
- ***Common language:***
  - English is the official language on ISS. Russian used too. Both are used in ops.
  - How should the issue of language be handled for lunar surface operations with an international crew?
  - How can we ensure effective communication via a common operational, engineering, and science language?
- ***Public Engagement:***
  - What specific kinds of international public engagement can be done for lunar surface missions?
  - How can the global public community participate - directly and indirectly?

Systems Engineering and Integration Approach

- Issues areas and questions inform systems engineering approach - e.g. by pointing to possible attributes, metrics, operational emphases, etc.
- Integrate:
  - Lunar elements
  - Operational metrics
  - Requirements
  - Mission scenarios
  - Systems, technology, and operational alternatives
- Assess system-wide requirements compliance
- Assess system-wide interdependencies
- Conduct “what if” analyses and trade studies
- Refine & optimize ops concepts, requirements compliance & verification, and systems
- Adapt and re-assess surface ops
- Consider Earth-Moon system

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Potential Operational Attributes/Metrics

- Attributes are areas of interest for which ops metrics might be defined.
- Functions, issues areas, and questions can point to attributes and metrics.
- Ops metrics can help with analyses - e.g:
  - Safety
  - Reliability
  - Cost
  - Schedule
  - Science
  - Interoperability
  - Training
  - Maintainability
  - Work Efficiency Index
  - Usability
  - Mars Forward
  - Logistics
  - Autonomy (crew autonomy)
  - Human Factors
  - Complexity
  - Flexibility (ops alternatives)
  - Public Engagement

An Example of a Operations Systems Engineering and Integration Approach

Integrate: (a) lunar surface systems, (b) operational metrics, (c) requirements, (d) mission scenarios, (e) system, technology, and operational alternatives

Requirement Compliance is indicated by “stoplight” colors in the matrix. Key is pointed to here, matrix is below metrics.

Operational Metrics reflect a broad range of operational considerations.

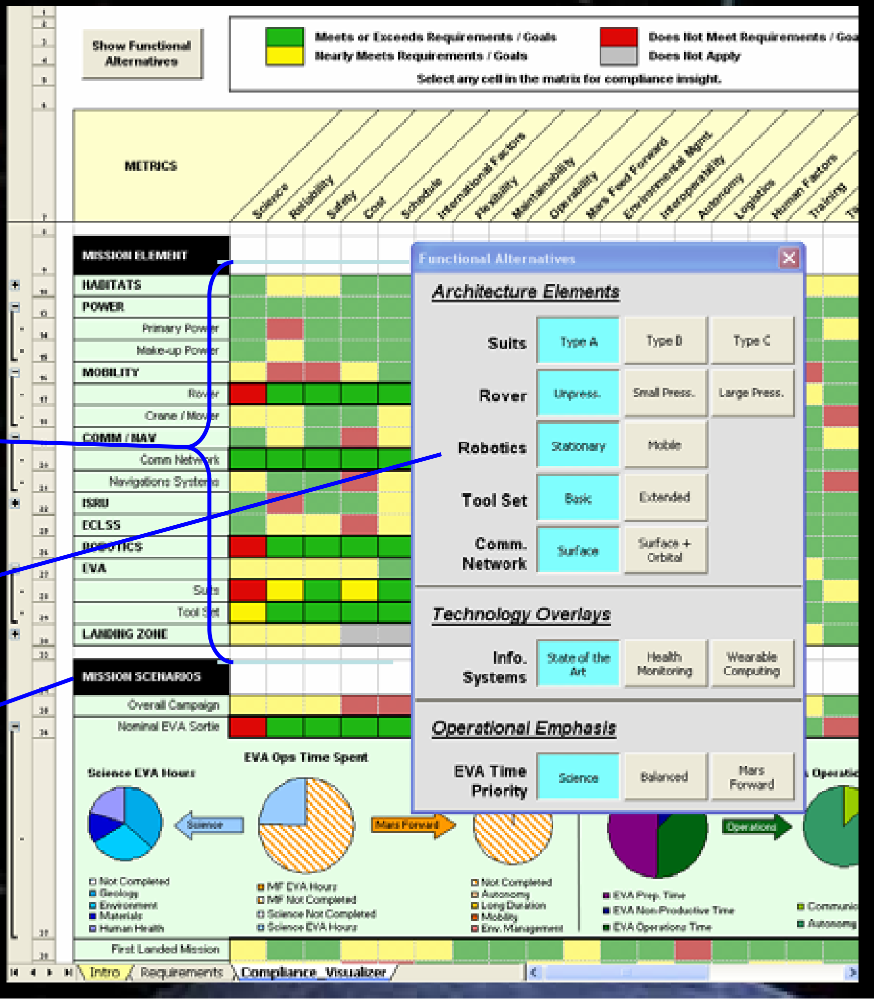
Mission Elements are the major surface system elements.

Compliance Matrix updates instantly for real-time trade space exploration. Selecting a cell shows detailed sub-metric information.

Functional Alternatives are architecture elements, technology overlays, and operational emphases that impact the compliance matrix.

Scenarios capture details of specific scenarios and/or parts of a multi-mission scenario.

Data Charts provide detail about mission scenarios.



Follow-up Suggestions

- Continue with surface ops issue areas and questions
- Consider a surface ops session for future mtgs
- Focus on metrics initially - driven in part by issue areas and questions
- Perhaps focus on science - and science ops? operations - “science systems engineering”, “science operations systems engineering”
- Obtain review, guidance, approval from stakeholders and others
- Respond to, provide input to stakeholders, customers, interested parties.