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Introduction:
Many countries are sending missions to the Moon in the next few years. With even a small amount of coordination between these missions, the science, engineering, and exploration results will dramatically increase through decreased duplication of effort and increased collaborative efforts not possible with one spacecraft.

An overarching strategy is another way that the efforts of many can be better focused and the results improved. An establishment of an International Lunar Way Station – as a first step toward a Planetary Outposts exploration strategy. This strategy systematically builds sustained robotic, and then human presence at selected sites on a given planetary body. A Lunar Way Station would serve as a test bed for operational aspects of Planetary Outposts in a closer-to-home environment and would focus lunar missions in the coming decade. This strategy would also serve to focus and organize future Martian exploration. In addition, Planetary Outposts would maximize science and engineering effectiveness, bridge robotic and human exploration, improve safety of human missions, and engage the public, while being flexible to budget variations, new scientific and technical results, and international cooperation.

A *Lunar Way-station* is a test bed for operational aspects of a planetary outpost, which provides a closer-to-home environment and experience not available in Earth-based simulations. It should not be considered as a space station, but a base on the surface of a planetary body.

Mission statement:
"Establish and determine an architecture for future strategic navigation system, common geodetic net, timeframe and landing sites on Moon with a view to promote international cooperation for lunar exploration."

Objectives:

The main thrust of this document is what needs to happen soon to make sure we are paving the way to a lunar way station and international cooperation at the Moon The issues that fall out of this study are relevant to almost any exploration strategy, and are relevant with or without international cooperation. What are the first steps? We are especially interested in exploring and understanding the interfaces between missions because these interfaces create opportunities (and needs) for international cooperation. Here is our list of issues that should be addressed early to facilitate efficient lunar exploration in general, and particularly in the case of an International Lunar Way Station. The issues are ordered loosely in terms of priority here, and near term prioritization is addressed explicitly in the following section.

1. Complete Lunar Gravity Model:
Our current knowledge of the lunar gravity field is severely limited because we do not have far side orbital tracking.

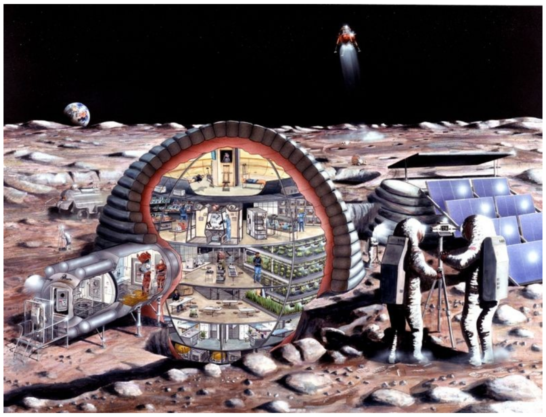
Lunar gravity mapping can be achieved relatively easily because of the wealth of orbiters planned in the coming years, *if* some things are coordinated soon. An accurate gravity model requires two cooperating lunar orbiters. The conventional approach for gravity mapping would be to design, launch and operate two satellites simultaneously in lunar orbit (one satellite in a low circular orbit for gravity sensing and the second satellite in an elliptical or similar parking orbit for the tracking relay).

The exciting benefit that can be achieved with international cooperation is to use two different satellites from two different countries to provide complete tracking data for the lunar gravity model. More than two satellites and multiple frequencies, in a variety of configurations providing differential measurement, could generate even more robust measurements.

This opportunity requires a detailed interface agreement between the involved parties (two satellites and a ground network) regarding the orbits, RF signal characteristics (compatible frequencies, bandwidth, SNR), data protocols and range/range-rate navigation performance. Ideally, it also requires coordination of orbits and events in the mission plans. But, it may be possible to arrange such coordination even without major perturbations to existing plans.

2. Lunar Navigation System:
A two-layered system has been considered for tracking and navigation purposes: the primary layer consists of local navigation systems for both flat land (maria) and highlands.

The technology identified for use on flat land is the non directional beacon (NDB). With the exception of mountainous terrain NDB navigation should be adequate for use in EVA equipment and beacon arrays. Further research must still be carried out, as some adverse effects associated with NDB navigation could be very dangerous on the Moon. These include terrain, magnetic and electrical effects. In terms of wave propagation, we have assumed that we can use line of sight and horizontally aligned transmiters/ receivers, butthis means that propagation distance will be minimal as there is no ionosphere to bounce signals off and thus increase propagation distance. The most accurate signals should be ground waves that follow the lunar surface.



Photograph: Future Lunar Waystation.

The secondary layer serves as a back-up system, so a long distance navigation system (the LORAN) was chosen, this could be placed to surround areas of exploration. Adaptation of equipment may be necessary before any of these systems can be used for none aviation/marine situations. Also a global positioning system based on satellite data was considered, but due to the lack of a complete gravity model for the Moon it can only be implemented in the future.

3. Common Lunar Timeframe:
Both Earth and Lunar based timeframes were considered, but in order to achieve synergy between Earth-based mission control systems, the Lunar Waystation and human biorhythm a 24 hour based timeframe has been selected, which equals GMT. This would be referred to as the Standard Global Lunar Time. This point needs further discussion.

4. International Landing Sites:
Several landing sites have been discussed in the past and in the present according to different mission priorities. Therefore we currently address criteria that would be applicable to these different scenarios, for example:

• In-situ Resource Utilization (ISRU) - *all surface terrain*
• Testing facilities - *inhospitable terrain, mission specific, underground experiments*
• Scientific - *South Pole Aitkins Basin, areas of eternal sunlight and the far side*
• Touristic goals - *historical landing sites, far-side*

In addition we have tried to identify some possible landing technologies already used on Earth that could be used to land under poor visibility and could be used to land in inhospitable terrain. These include radar, microwave, radio and infrared imaging technology used by modern Spacecraft in poor or reduced visibility.

Landing systems that are in current use include Instrument landing system (ILS), Transponder Landing System (TLS), Microwave Landing System (MLS), Beam Approach Beacon System (BABS). TLS and MLS have the advantage of being all weather precision landing systems.

5. Cooperative surface operations:
Are important and exciting areas for future international involvement in the context of several specific issues. One of the principal purposes of lunar surface operations (robotic and human) will be to test and gain experience for Mars operations which will have to be carried out with long time-delays and transit times from Earth, in a much more autonomous fashion. The lunar way station would serve as a Martian test-bed – this may be its principal function.

References:
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