24 Telecommunication and Navigation Services in Support of Lunar Exploration and Exploitation

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24.1 Introduction

A structured approach to the design of Space Exploration Systems is fundamental to creating a coherent and sustainable global exploration effort. In fact an extensive robotic and human settlement on the Moon will be achieved only if suitable services will be provided in support of the lunar exploration and exploitation activities. This is even more valid when taking into account the fact that, settlements on the Moon will not be completely autonomous from Earth and therefore will rely on its support in terms of strategic resources and consumables.

Among the different services, like crew and cargo transportation to and from the Moon and industrial logistics for lunar resources on Earth, communication and navigation systems will represent the backbone of any architecture from the early stages of exploration up to the utilization phase. Implementation of a Lunar Navigation and Communication (LNC) System represents a floor capability of any lunar utilization infrastructure by providing basic service to lunar assets. Since the timescale of human lunar exploration extends for several decades, the demand of NavCom services is expected to grow alongside the complexity of the entire lunar exploration system of systems. This chapter presents an analysis into what the future needs of human lunar exploration will be and proposes a system designed to fulfill those needs.

24.2 Lunar Activities and NavCom Evolution

The Exploration Program is still in its formulation stages, however envisioning an architecture that would support such a complex effort as that of exploring and utilizing the Moon requires well founded assumptions to be made. Several studies have recently been performed with the aim of identifying the possible shape of future exploration of the Moon (Culbert et al. 2010; Stanley et al. 2005; Hufenbach and Leshner 2008). Their collective conclusion underlines that a sustainable and
A phased approach to the exploration of the Moon also implies a flexible, phased and modular design of the NavCom architecture. Such a design would minimize for each phase the infrastructure to the strict minimum for each phase costs and therefore speed up construction time.

In the phased approach, the Robotic Precursor Missions would form the first stage in the lunar exploration effort. This phase is expected to last for up to one decade and its main objectives would include but not be limited to accurate mapping, resource prospecting, environment characterization and deployment of infrastructure (Schrunk et al. 2008; Culbert et al. 2010). Typical robotic end users of NavCom services would include for example scientific instruments in orbit, or in small rovers or landers.

Due to the typical requirement of minimizing payload mass, among others in scientific instruments that have a long operational life, the need of minimizing the economical exploration of the Moon and Mars can only be accomplished by a flexible phased approach that takes into account the various associated complexities. Although these studies take into account the large periods of time inherent to human space exploration, the exploitation of lunar resources remains a subject reserved for the end of the exploration timeline. Due to the complexity of the lunar exploration effort and of the NavCom segment in particular, an extended view of the exploration timeline is illustrated in Fig. 24.1 (based on ESA Aurora; http://www.esa.int/esaMI/Aurora/). This revised timeline also takes into account lunar utilization.

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**Extended Lunar Exploration Timeline**

<table>
<thead>
<tr>
<th></th>
<th>First Decade of Exploration</th>
<th>Second Decade of Exploration</th>
<th>Third Decade of Exploration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robotic Precursor Missions Phase</td>
<td>Phase I</td>
<td>First Orbiting Probe</td>
<td></td>
</tr>
<tr>
<td>Initial Human Exploration Phase</td>
<td>Phase II</td>
<td>First Human Landing</td>
<td>Sortie Missions and Short Range Rover Missions</td>
</tr>
<tr>
<td>Long Duration Exploration Phase</td>
<td>Phase III</td>
<td>First Autonomous Outpost</td>
<td>Long Duration Missions</td>
</tr>
<tr>
<td>Lunar Resources Utilization Phase</td>
<td>Phase IV</td>
<td>Extensive Mining of Resources Commences</td>
<td></td>
</tr>
</tbody>
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**Fig. 24.1 Extended View of the Lunar Exploration Timeline**

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