

**ENHANCEMENT OF SPATIAL ORIENTATION CAPABILITY OF ASTRONAUTS ON THE LUNAR SURFACE SUPPORTED BY INTEGRATED SENSOR NETWORK AND INFORMATION TECHNOLOGY.** R. Li<sup>1</sup>, K. Di<sup>1</sup>, B. Wu<sup>1</sup>, A. Yilmaz<sup>2</sup>, M. S. Banks<sup>3</sup>, C. Oman<sup>4</sup>, K. Bhasin<sup>5</sup> and M. Tang<sup>1</sup>,  
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**Introduction:** In manned lunar missions, astronauts' abilities to remain spatially oriented on the lunar surface can have a serious impact on mission success and safety [1]. Astronauts may become disoriented due to lack of distinctive landmarks on the lunar surface, and other factors. They may also experience difficulties in judging distance because the various distance cues we use on Earth are not available on the lunar surface.

A typical example of disorientation occurred during Apollo 14 surface operations [2]. Two astronauts were designated to walk about 1,100 meters east of the primary landing site to the rim of Cone Crater. Figure 1 shows the traverse map; a map was used to get to Cone Crater. Due to the rolling terrain and an absence of familiar objects to serve as points of reference, they had difficulty finding the crater rim. Finally, with oxygen and time running out, they were forced to turn back, not knowing that they had come within a few yards of Cone Crater (upright corner of the base map). Therefore, for future manned lunar missions, it is highly desirable to develop technologies to enhance the spatial-orientation capabilities of astronauts on the lunar surface by providing consistent global and local orientation and navigation information.

We here present the framework for an integrated lunar sensor network and information technology designed to enhance the spatial-orientation capabilities of astronauts on the lunar surface. Designs for a Lunar Astronaut Spatial Orientation and Information System (LASOIS) along with strategies for system development and plans for astronaut training will be discussed as elements of this framework. Psychological and cognitive research on spatial orientation and navigation will be incorporated in the design and implementation of LASOIS.

**Lunar Integrated Sensor Network and Information Technology:** As shown in Figure 2, a lunar astronaut spatial-orientation architecture will be established based on an integrated sensor network comprised of orbital, lunar-surface, vehicle on-board, and on-suit sensors. Orbital sensors include navigation, communication and reconnaissance satellites in orbit around the Moon. For example, in the planned 2008 Lunar Reconnaissance Orbiter (LRO) mission, a Lunar Reconnaissance Orbiter Camera (LROC) and a Lunar Orbiter

Laser Altimeter (LOLA) will be deployed in lunar orbit. Lunar surface sensors will include surface beacons pre-deployed on the lunar surface. This beacon system will use radio frequency, microwave, ultrasonic or visible light sources to transmit the relative positioning between any object and known active surface beacon reference points. On-board vehicle sensors (wheel odometers, engineering navigation cameras) will be mounted on any roving vehicles or robots. On-suit sensors will be mounted on the astronaut's space suit. Light-weight stereo cameras can be mounted on the helmet and will provide real-time visual information used to generate navigation and localization capabilities. A user-friendly interface will be mounted on the astronaut's arm to provide display functions for 2D and 3D spatial information along with any necessary simple interaction functions.

Spatial information technology will be developed and integrated to turn the vast amount of data from this integrated sensor network into usable spatial-orientation information needed by astronauts for lunar surface exploration [3]. A global database will be set up at the Earth-based control center, while different local databases will be deployed on landers, outposts, rover robots, and crew vehicles. Global and local databases will be synchronized, coordinated and updated. On-suit sensors will collect real-time data only, which can be sent to a nearby local server. Key technologies to be employed, which use both pre-collected and real-time data, are: 1) astronaut spatial localization by integrating the measurements from the multi-sensors, 2) astronaut spatial orientation by tracking terrain targets [4], 3) adaptive selection of map and/or navigation information, 4) self-adjusted visualization of map and/or navigation information, and 5) minimization of vergence-accommodation conflict for visual performance enhancement [5]. All the related data processing will be conducted on the server side; astronauts can obtain specific spatial-orientation information through interaction with the interface.

**Lunar Astronaut Spatial Orientation and Information System:** The LASOIS will be developed based on the lunar integrated sensor network and information technology. The system will be realized by integrating the information acquired from the sensors by developing computational models, which in turn

can provide the astronauts with online self-localization and path-generation capabilities. These capabilities include relative positioning, generation of return paths in reverse directions, and memorizing paths during surface expeditions to relocate past positions. This information may be delivered to the astronauts through a liquid-crystal display (LCD) touch screen with an intuitive interface developed in compliance with human-computer interface (HCI) standards.

The LASOIS will have client/server architecture (Figure 3). The client will have a light-weight design with minimal power consumption. The server can reside at the lander. A backup server, needed in case of a failure of the main system due to power or other problems, can reside at the outpost. The LASOIS will include an ultimate server at the Earth-based control center, but with longer latency in delivering orientation information. The main server in the LASOIS architecture performs the communication, processing, data management, orientation, and navigation tasks.

**Astronaut Training:** LASOIS will be tested and astronauts trained in a lunar-like desert environment, possibly at Silver Lake, a site in the Mojave Desert where we previously have collected a large amount of orbital, descent, and ground image data, and produced topographic maps during field tests for our previous Mars rover localization research (Figure 4)[6]. Two types of training sessions, data based and scenario based, will be designed to facilitate astronaut training. Data-based training is designed to: 1) help the understanding of different data sets (e.g., orbital images, rover images, topographic maps, and route maps), 2) help the perception of global and local location and orientation concepts from these images and maps, and 3) aid the comparison of orbital and ground data to identify corresponding landmarks. Scenario-based training will simulate typical scenarios experienced during surface operations, thus enabling astronauts to successfully use the system interface as well as communication with Earth and other astronauts to adapt to different spatial-orientation services.

**References:** [1] Oman C. M. (2007) *Spatial processing in navigation, imagery and perception*, 209-247. [2] Mellberg W. F. (1997) *Moon Missions*, 114-116. [3] Li R. et al. (2005) *PE&RS*, 1129-1142. [4] Yilmaz A. and Shah M. (2004) *IEEE Trans. PAMI*, 1531-1536. [5] Hoffman D. M. et al. (2008) *Journal of Vision*, 1-30. [6] Li R. et al. (2002) *JGR-Planets*, E11, 4.1- 4.8

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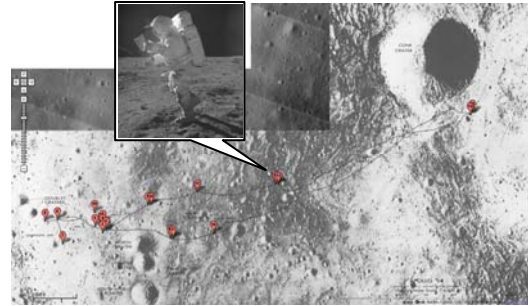


Figure 1. Apollo 14 astronaut traverse map (Photo credit: Google/NASA).

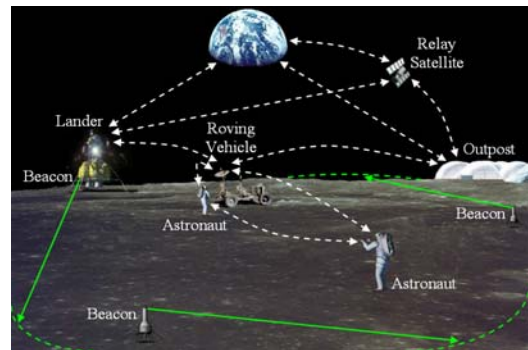


Figure 2. Concept of lunar astronaut spatial-orientation architecture. (Photo credit: NASA/OSU).

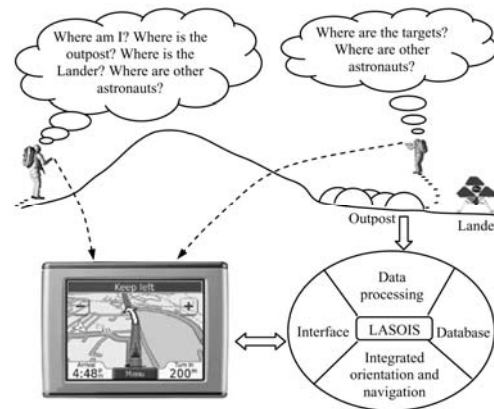


Figure 3. Conceptual architecture of the LASOIS.

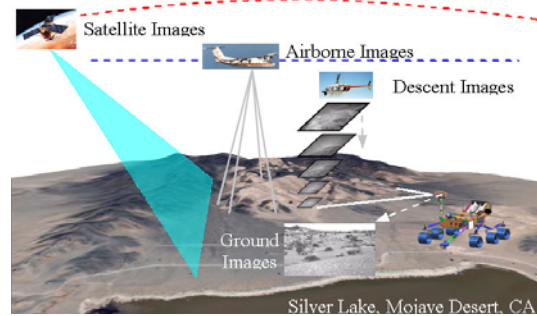


Figure 4. Training site at Silver Lake in the Mojave Desert. (composite image: OSU/JPL/Google).