DEVELOPMENT OF A LUNAR ASTRONAUT SPATIAL ORIENTATION AND INFORMATION SYSTEM R. Li[1], S. He[1], P. Tang[1], B. Skopljak[1], A. Yilmaz[2], J. Jiang[2], M. S. Banks[3], C. Oman[4]. [1]Mapping and GIS Laboratory, CEEGS, The Ohio State University, 470 Hitchcock Hall, 2070 Neil Avenue, Columbus, OH 43210-1275, li.282@osu.edu; [2]Photogrammetric Computer Vision Laboratory, CEEGS, The Ohio State University; [3]Visual Space Perception Laboratory, University of California Berkeley; [4]Man Vehicle Laboratory, Massachusetts Institute of Technology.

Introduction: In previous human space missions, astronauts experienced occasional disorientation in 0-G [1], and Apollo crews had difficulty navigating on the lunar surface due to the lack of familiar landmarks, loss of aerial perspective, and ambiguous depth and shading cues, and other factors, [1, 2]. Geographic disorientation ("becoming lost") may limit astronauts' capabilities for completing scientific tasks and exposes them to various kinds of serious risk. Therefore, 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 spatial orientation and navigation information [3].

Supported by the National Space Biomedical Research Institute (NSBRI), the Mapping and GIS Laboratory at the Ohio State University, working with partners at OSU, UC Berkeley, MIT and NASA/GRC, is currently developing a Lunar Astronaut Spatial Orientation and Information System (LASOIS) to continuously provide spatial orientation and navigation information to astronauts and thereby reduce spatial disorientation [4]. The LASOIS system includes a hardware component (integrated sensor-network) for data acquisition and a software component for the integration of multiple algorithms for data processing, integration, and display.

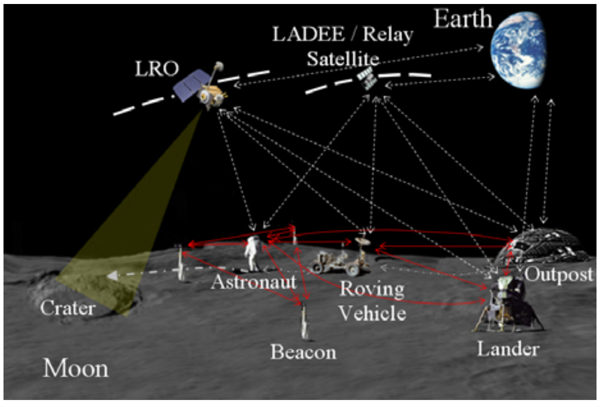

Figure 1. Conceptualization of the integrated sensor network for LASOIS. (Photo credit: NASA/OSU).

LASOIS Sensor Network: The integrated sensor-network for LASOIS incorporates data from multiple sensors hosted on orbit, on-suit and on ground (Figure 1). Orbital sensors, such as LROC (Lunar Reconnaissance Orbiter Camera), capture high-resolution imagery for extensive regions of the lunar surface (e.g., an entire mission landing site including landing and traversing areas). On-suit sensors include an IMU (Inertial Measurement Unit) mounted on the heel of one astronaut boot (right or left), one step sensor mounted on the bottom of the boot with the IMU, and stereo vision sensors (Figure 2). The IMU measures both acceleration and the angular rate of the astronaut at high frequency (100 Hz). The step sensor counts the number of strides the astronaut takes and gives the zero velocity phase of the astronaut foot during the traverse. The stereo vision sensor computes the local DEM as well as the astronaut trajectory by matching and tracking ground features. The ground-based sensor network can be extended to include multiple beacon transmitters on the ground as well as receivers mounted on the astronauts' suits; this beacon-based sensing can provide astronauts with absolute position information at a lower frequency than that used by the IMU and vision sensors.

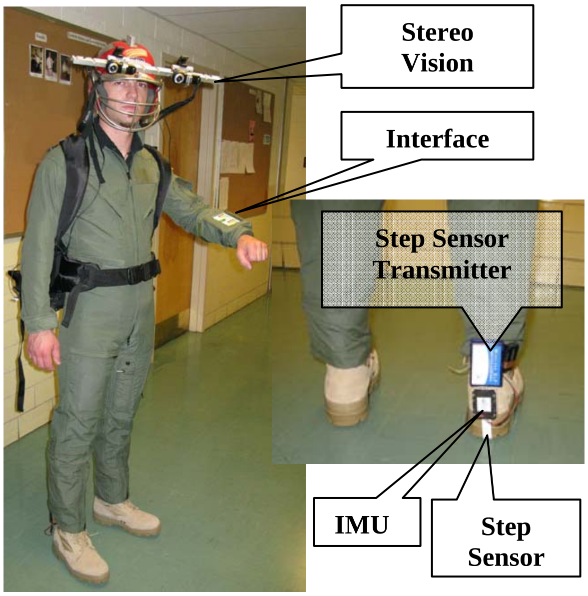

Figure 2. Prototype of the on-suit sensors

Data Processing and Integration: At the beginning of each Extravehicular Activity (EVA) traverse, the local DEM (Digital Elevation Model, which is generated based on data collected by on-suit stereo vision sensors) is registered to the global DEM (which is generated based on orbital imagery) to obtain the initial position and orientation of each astronaut. During a traverse, an Extended Kalman Filter is utilized to integrate signals from the on-suit and ground-based sensors to obtain the changing positions and orientations of the astronauts in real time. The on-suit IMU continuously updates acceleration and angular rate into the astronaut position and orientation data after any bias in the IMU signal is removed using information from additional observations taken by the step sensor and the stereo vision sensors. To achieve this, an algorithm for zero velocity updates (ZUPTs) is employed to detect bias in the IMU signal and remove it from the derived velocity, pitch and roll information whenever the step sensor detects a zero velocity phase for the astronauts. Since the vision sensors provide better heading determination, bias in the IMU signal in the heading direction can be compensated for with data from the vision sensors. In order to provide an emergency back-up system for astronaut localization, the vision sensor is designed also to be able to rotate upward so that it can serve as an auxiliary star tracking system. After integration of all of the available sensing data, individual astronauts can retrieve precise localization information in terms of spatial position, orientation and bearing through a wrist-mounted interface.

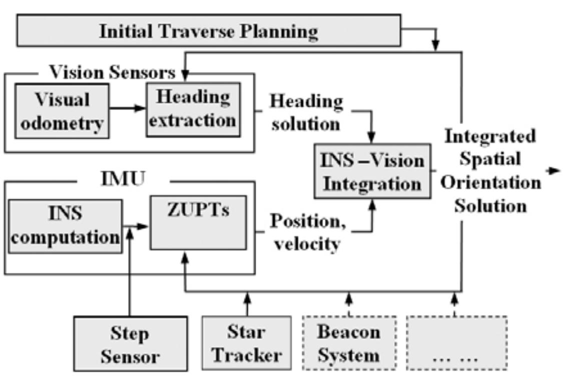

Figure 3. Conceptual flowchart of the LASOIS.

Experiment Result: To test the feasibility of the LASOIS prototype, a field experiment was conducted at Moses Lake, WA during the summer of 2009. The Moses Lake Sand Dunes are a desert area that represents a moon-like environment. In this experiment, GeoEye images were used to simulate the LROC imagery necessary for generating an orbital DEM. The developed orbital-to-ground DEM matching algorithm matched a DEM generated from ground-based on-suit vision-sensor data against a DEM generated from GeoEye orbital imagery to identify the initial position and orientation of the experimenter. Localization accuracy was found to be 12 m for positioning and 5˚ for orientation. In the current version, a low level MMS IMU is used. Overall, the approach integrating data from IMU, step sensor, and vision sensors achieved an error of closure of 6% over a trajectory of 107 m (Figure 4). In the future, a better IMU will be used and the vision based localization algorithm will be improved; the ground beacon system will be implemented and the performance of the LASOIS system under different types of astronaut locomotion will be analyzed. We expect to achieve an overall accuracy of 2% or better for long traverses (up to 10 km) with the improved LASOIS system.

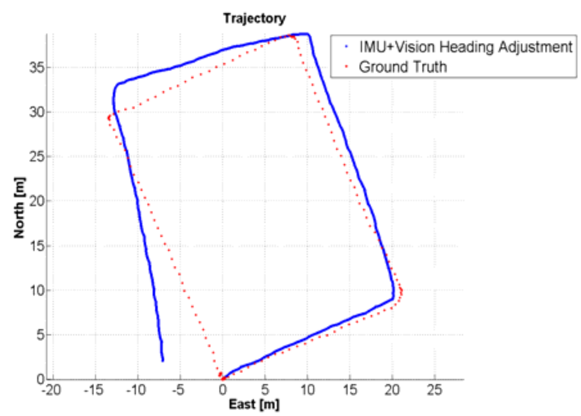

Figure 4. Reconstructed result from LASOIS (solid line) compared to ground truth (dotted line).

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. (2008) *NLSC*, Abstract #2069. [4] Li R. et al. (2010) *NASA Human Research Program Investigators' Workshop*, Abstract.

Acknowledgements: This work is supported by the National Space Biomedical Research Institute through NASA NCC 9-58.