Fiscal Year:	FY 2011	**Task Last Updated:**	FY 03/08/2012
PI Name:	Li, Rongxing (Ron) Ph.D.		
Project Title:	Enhancement of Spatial Orientation Capability of Astronauts on the Lunar Surface		
Division Name:	Human Research		
Program/Discipline:	NSBRI		
Program/Discipline--Element/Subdiscipline:	NSBRI--Sensorimotor Adaptation Team		
Joint Agency Name:		**TechPort:**	Yes
Human Research Program Elements:	(1) **SHFH**:Space Human Factors & Habitability (archival in 2017)		
Human Research Program Risks:	(1) **HSIA**:Risk of Adverse Outcomes Due to Inadequate Human Systems Integration Architecture		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
PI Email:	li.282@osu.edu	**Fax:**	FY 614-292-2957
PI Organization Type:	UNIVERSITY	**Phone:**	614-292-6946
Organization Name:	The Ohio State University		
PI Address 1:	Mapping and GIS Laboratory, CEEGS		
PI Address 2:	470 Hitchcock Hall, 2070 Neil Avenue		
PI Web Page:			
City:	Columbus	**State:**	OH
Zip Code:	43210	**Congressional District:**	15
Comments:			
Project Type:	GROUND	**Solicitation / Funding Source:**	2008 Crew Health NNJ08ZSA002N
Start Date:	08/01/2008	**End Date:**	07/31/2011
No. of Post Docs:	1	**No. of PhD Degrees:**	0
No. of PhD Candidates:	3	**No. of Master' Degrees:**	0
No. of Master's Candidates:	0	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	0	**Monitoring Center:**	NSBRI
Contact Monitor:		**Contact Phone:**	
Contact Email:			
Flight Program:			
Flight Assignment:			
Key Personnel Changes/Previous PI:			
COI Name (Institution):	Banks, Martin (University of California, Berkeley) Bhasin, Kul (NASA Glenn Research Center) Yilmaz, Alper (The Ohio State University) Di, Kaichang (The Ohio State University)		
Grant/Contract No.:	NCC 9-58-SA01602		
Performance Goal No.:			
Performance Goal Text:			

Task Description:	1. Original aims of project The overall goal of this project was to develop a Lunar Astronaut Spatial Orientation and Information System (LASOIS) able to reduce spatial disorientation risks during future manned lunar landing missions. The detailed objectives were to: 1) Investigate methods for removal and/or alleviation of astronaut disorientation in a lunar surface operations setting by using integrated information technology along with psychological and cognitive research on spatial orientation and navigation; 2) Develop the LASOIS system; and 3) Train astronauts to enhance their LASOIS-supported spatial orientation capabilities in a simulated lunar environment. Supported by LASOIS, astronauts engaged in lunar surface operations will be capable of overcoming disorientation caused by microgravity and the altered visual environment through spatial information provided by the Earth-based control center after data collection by a coordinated group of lunar orbital, descent, and ground-based sensors. The spatial-orientation strategies, technology, and training program here developed will allow astronauts to successfully complete complex mission scenarios where spatial operations and efficient interactions and communications are required among the Earth-based control center, lander(s), lunar vehicle(s), outposts, and astronauts. This capability is critical for future lunar operations, which are expected to cover an extensive region. 2. Key findings of the project The following summarizes the key findings, research activities, and results over the three years of the project: 1) Investigation of the typical scenarios and constraints of EVA (Extra Vehicular Activity) operations experienced by astronauts during previous lunar missions to provide a baseline for the design of LASOIS; 2) Investigation of different astronaut locomotion patterns (including walking, jogging, and hopping) as observed on the lunar surface during Apollo mission surface operations to develop new astronaut spatial orientation capabilities through LASOIS; 3) Design and development of LASOIS prototype. In LASOIS prototype Version 3.0, we miniaturized the hardware system using a palm-sized computer and display, stabilized the communication system by replacing wireless data transfer with a secure cable system, and improved sensor integration strategies in the developed software for real-time operation and improved performance. LASOIS prototypes were tested in multiple lunar-like field sites, simulated lunar EVA scenarios, and differing step patterns. The field experiment in the third year successfully supported a 6.1 km traverse with only a 2.42% relative disclosure error based on an experiment simulating the Apollo 14 traverse. 4) Development of an additional star tracker technology to be used as a navigation solution in emergencies to improve the flexibility and robustness of the navigation system; and 5) Execution of additional research activities including a study of lunar surface beacon systems for astronaut localization, investigation of display modes most suitable for terrestrial environments for navigation aids (plan view, bird's-eye view, wingman view, pilot view), and training of subjects on how to use LASOIS. 3. Impact of the findings on the objectives of the proposal According to the proposed schedule, the above-mentioned achievements have fulfilled the designated tasks for this project. We studied lunar EVA scenarios and astronaut locomotion patterns based on past Apollo missions to investigate the lunar environment and potential factors that contribute to astronaut disorientation. A LASOIS prototype was designed and developed to provide technical assistance to alleviate astronaut disorientation during EVA traverses. We designed and conducted field tests in multiple lunar-like environments based on lunar EVA scenario criteria such as terrain type, surface land cover, traverse distance, and step patterns, using test results to improve the prototype in both hardware and software efficiency. The final system has been miniaturized into a light-weight system with real-time operational control through the arm-mounted display unit. LASOIS has proven to be able to support a 6 km simulated EVA with only a 2.42% relative disclosure error. We have trained subjects to operate the system. We have tested various combinations of display modes based on psychological and psychophysical research techniques into spatial orientation and navigation to determine the best setting to enhance the spatial orientation capabilities of astronauts on the lunar surface. In addition, we developed a star tracker system to be used as an alternative localization system in case of emergency situations during lunar surface exploration.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	The Lunar Astronaut Spatial Orientation and Information System (LASOIS) will greatly enhance astronauts' spatial-orientation capabilities, reduce or even eliminate disorientation problems, decrease sensorimotor risks, and, ultimately, improve astronaut performance and safety while on the lunar surface. We have developed an applicable combination of sensors in the network workable on the lunar surface for astronaut navigation. LASOIS represents the first time that such a spatial-orientation and information system has been developed for use to improve human performance and human-robotic interaction capabilities for future manned lunar missions. Valuable expertise and experiences accumulated during the research and development process, especially during the analog field test of the LASOIS system, will significantly contribute to the improvement of existing scientific strategies. The outputs of this project will provide NASA with data and knowledge supporting lunar surface science and lunar operations scenarios and help understanding and optimization of human performance capabilities to maximize scientific return in future lunar missions. The psychological and cognitive influence on spatial orientation and navigation are other aspects studied in this project. Different types of visualization for effective delivery of navigational information on a handheld audiovisual display were investigated. Human subjects in the field used different versions of map visualization and user performance using psychological and psychophysical techniques were evaluated. As a result, this research ultimately can provide EVA planners, engineers, and astronauts with design suggestions and recommendations using human-systems integration principles for navigational display to be used in lunar-like environments. In addition, the experience and findings from this project can provide valuable information for solving the orientation problem facing astronauts in future Near Earth Asteroid (NEA) manned missions. Considering the rapidly changing lighting conditions caused by the fast spinning speed of asteroids and the zero gravity on the asteroid surface, astronauts in future NEA missions may experience severe disorientation. Research results from this project can provide useful ideas in solving this issue. The developed technologies can also be used to support personal navigation tasks on Earth and substantially influence many application domains. For example, this project team tested the developed system in an indoor environment at the Eastland Shopping Mall in Columbus, Ohio. The spatial recognition results obtained during this

	LASOIS test can help people to understand the relationships between acceleration, gravity, and human spatial orientation capabilities. Such relationships can be used in multiple domains where people work in environments with varying accelerations and that require the maintenance of good spatial orientation. Examples include first responders working at the site of an earthquake, people working in deep-water environments, underground mining, and military pilots of fighter planes.
Task Progress:	The achievements over the third year have fulfilled the designated tasks in the proposal. 1. Data processing and sensor integration Based on the integrated sensor network established in the second year, we improved the approaches for processing and integrating spatial data and for turning the vast amount of data from the sensor network into spatial-orientation information usable by lunar astronauts in real-time scenarios. First, we improved the efficiency of the LASOIS software to collect and process data and display the spatial information in real time. Second, we improved the robustness of the vision-tracking algorithm. The situation where the vision system may lose its feature tracking ability was investigated and resolved. In addition, the sampling rate of the vision-sensor system was reduced for computational efficiency. Third, we studied a star-tracking technology for obtaining location and orientation information for astronaut navigation in emergency situations; several experiments were conducted to evaluate the performance of this star-tracking technology. Fourth, we developed an approach for locating and orienting the astronaut at the beginning of an EVA using geographic landmarks. Fifth, the psychological and cognitive influences on spatial orientation and navigation were studied and tested in field experiments. 2. Development and evaluation of the third LASOIS prototype First, we miniaturized the hardware system and optimized the placement of the instruments. Compared with the configuration of Prototype 2, the hardware system weighed less and took up less space when mounted on the suit. More importantly, the current configuration is more efficient for operations, allowing for real-time control on an arm-mounted display unit. Second, a seven-inch audiovisual display was developed to display the spatial information to the astronaut in real time. Third, we determined what spatial information to display on the interface according to results from multiple field experiments: these include optimal path (automated routing), current heading and trajectory, path deviation intensity (in different colors), time elapsed and remaining (oxygen supply simulation), distance to waypoints, and final target. 3. Field tests, database construction and management, training, and reporting A set of tests of the LASOIS prototype Version 3.0 were performed on the Ohio State University (OSU) campus and at Haleakala National Park in Hawaii in 2011. The volcanic formation of this national park forms an environment similar to the lunar surface. In addition, experiments were performed in Cesar E. Chavez Park, Berkeley, CA to test the interface displaying spatial information. A spatial database at our test sites (including indoor and outdoor sites on the OSU campus as well as analog field test sites) has been constructed including high-resolution satellite images, ground images and videos, measurements from multi-sensors, and ground truth measured by GPS and field survey.
Bibliography Type:	Description: (Last Updated: 09/07/2020)
Abstracts for Journals and Proceedings	Li R, He S, Skopljak B, Meng X, Yilmaz A, Jiang J, Banks MS, Kim S, Oman C. "Development of a lunar astronaut spatial orientation and information system." 18th IAA Humans in Space Symposium, Houston, TX, April 11-15, 2011. 18th IAA Humans in Space Symposium, Houston, TX, April 11-15, 2011. , Apr-2011
Abstracts for Journals and Proceedings	Li R, He S, Skopljak B, Meng X, Yilmaz A, Jiang J, Banks MS, Kim S, Oman C. "LASOIS: enhancing the spatial orientation capabilities of astronauts on the lunar surface." Eighth Symposium on the Role of the Vestibular Organs in Space Exploration, Houston, TX, April 8-10, 2011. Eighth Symposium on the Role of the Vestibular Organs in Space Exploration, Houston, TX, April 8-10, 2011. , Apr-2011
Abstracts for Journals and Proceedings	Li R, He S, Skopljak B, Meng X, Yilmaz A, Jiang J, Banks MS, Kim S, Oman C. "The latest progress of LASOIS: a lunar astronaut spatial orientation and information system." 42nd Lunar and Planetary Science Conference (LPSC), The Woodlands, Texas, March 7-11, 2011. 42nd Lunar and Planetary Science Conference (LPSC), The Woodlands, Texas, March 7-11, 2011. http://www.lpi.usra.edu/meetings/lpsc2011/pdf/2100.pdf , Mar-2011
Awards	Li R. "Fellow of the American Society of Civil Engineers, July 2011." Jul-2011
Awards	Li R. "Senior Member of the Institute of Electrical and Electronics Engineers, July 2011." Jul-2011
Papers from Meeting Proceedings	Li R, Skopljak B, He S, Tang P, Yilmaz A, Jiang J. "A Spatial Orientation and Information System for Indoor Spatial Awareness." 2nd ACM SIGSPATIAL International Workshop on Indoor Spatial Awareness. In conjunction with 18th ACM SIGSPATIAL International Conference on Advances in Geographic Information Systems (ACM SIGSPATIAL GIS 2010), San Jose, CA, November 2-5, 2010. In: Proceedings. Indoor Spatial Awareness - ISA 2010, 2nd International Workshop, San Jose, CA, USA, November 2, 2010. p. 10-15. New York : Association of Computing Machinery, 2010. ISBN: 978-1-4503-0433-7/10/11. http://dx.doi.org/10.1145/1865885.1865889 , Nov-2010
Significant Media Coverage	Wall JS. "All the Right Moves: Engineers Accelerate Development of Personal Navigation Systems. News report about LASOIS Earth application test at Easton Town Center, Columbus, OH." News in Engineering, 2010;82(3):14., Dec-2010
Significant Media Coverage	Wall JS. "Ohio State Engineers Test Navigation System at Easton." The Ohio State University, College of Engineering News, 2010. Updated September 8, 2011. http://engineering.osu.edu/news/2010/07/ohio-state-engineers-test-navigation-system-easton ; accessed 9/7/2020., Jul-2010