Fiscal Year:	FY 2010	**Task Last Updated:**	FY 08/06/2010
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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		
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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:			
	1. Original aims of project The overall goal of this project is to develop a Lunar Astronaut Spatial Orientation and Information System (LASOIS) that will reduce spatial disorientation risks during future manned lunar landing missions. The detailed objectives are: 1.1 To investigate methods for removal and/or alleviation of astronaut disorientation in a lunar surface operations setting by using integrated information technology, and psychological and cognitive research on spatial orientation and navigation. 1.2 To develop the LASOIS system.		

Task Description:

1.3 To train astronauts to enhance their spatial orientation capability in a LASOIS-supported simulated lunar environment. Supported by LASOIS, astronauts will be capable of overcoming disorientation in lunar surface operations caused by microgravity and the altered visual environment through spatial information provided by the Earth control center and collected by a coordinated group of sensors from lunar orbit, descending path, and ground. The developed spatial orientation strategy, system and training will allow astronauts to have a systematic preparation for 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 lunar operations that will have an extensive traversing region (around 100km).

2. Key findings of the project

2.1 Based on the integrated sensor network established in the first year, we improved the approaches for processing and integrating spatial data collected by the integrated sensor network, and approaches for turning the vast amount of data from the integrated sensor network into necessary spatial-orientation information usable by lunar astronauts.

2.1.1 Further development and systematical evaluation of an Extended Kalman Filter (EKF) to integrate measurements from IMU, step sensor, and stereo cameras, the closure error of a loop traverse of more than one kilometer can be less than 4% of the traverse length (500 m) now.

2.1.2 Improvements of a Kanade-Lucas-Tomasi algorithm for astronaut navigation from video tracking, and explorations about how to utilize various spatial constraints for improving the computational efficiency of this algorithm. An algorithm can run in real-time mode now.

2.1.3 Development of a Star Tracker technology as a navigation solution in emergency to improve the flexibility and robustness of the navigation system. Preliminary finding is that the localization accuracy of this approach is 30 km, but the angle accuracy is about 1 degree.

2.1.4 Development of an approach for matching orbital and ground imagery based DEMs for initial localization of astronauts. The localization accuracy was 12m on Moses Lake data.

2.2 Design and development of LASOIS prototype 2.

2.2.1 Improving the precision, robustness and mobility of LASOIS through incorporating a tactical IMU, the redesign of the astronaut boot and on-suit package. Extensive field experiments show that LASOIS 2 can support long walks of more than 2 km.

2.2.2 Investigation on different on-suit sensor (IMU, step sensor, and stereo cameras) configurations for best navigation capability through extensive experiments.

2.2.3 A set of tests of the LASOIS 2 were performed at OSU. For example, a trajectory was derived using a tactical IMU and a step sensor. Comparing the derived trajectory to a trajectory determined using GPS, a disclosure of 4% was obtained (20 m over 500 m).

2.2.4 Two field tests for LASOIS 2 were conducted at NASA Plum Brook station on March 10, 2010, and at Black Point Lava Flow, Arizona, from June 10th to June 14th. We analyzed and summarized these experiments results as research reports for guiding further developments of the LASOIS prototype system.

2.3 Other research activities.

2.3.1 Study on lunar surface beacon systems for astronaut localization;

2.3.2 Investigations on display formats most frequently used in terrestrial environments for navigation aids (plan view, bird's eye view, wingman view, pilot view).

2.3.3 Training of subjects on how to use LASOIS 2, evaluating displays that the subject will wear when navigating the environment.

3. Impact of the findings on the objectives of the proposal

According to the proposed master schedule, the above mentioned achievements have fulfilled the designated tasks for the second year of this project. We conducted further tests and improvements of the developed technologies for spatial data processing, integration, and spatial information derivation and visualization. These improvements reduce the computational complexity, and improve the precision, reliability and robustness of the system to achieve real-time high-quality navigation information delivery. LASOIS 2 has been developed and tested. A spatial database containing data collected on all LASOIS test sites is being constructed including high-resolution satellite and ground imagery, videos, measurements from multi-sensory data, and ground truth measured by GPS and field survey. This database will be available to other NSBRI funded scientists and NASA researchers. All these results and experiences achieved in the second year will significantly contribute to the further research and development of LASOIS.

4. Proposed research plan for the coming year

4.1 Improvement of LASOIS 2 by integrating additional sensors (beacons) and considering different astronaut locomotion patterns in a micro-gravity environment.

4.2 Development of LASOIS 3 with real-time navigation capability, integrated on-suit navigation package, and robust data integration software for supporting 5 km long traverses.

4.3 Test LASOIS 3 in NASA or NSBRI led field analog testing campaign. 4.4 Explore and evaluate visualization approaches for effective delivery of the navigation information to astronauts on a small display.

Rationale for HRP Directed Research:

Research Impact/Earth Benefits:	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. It will be the first time that such a spatial-orientation and information system was developed and used to improve human performance and human-robotic interaction capabilities in manned missions. Valuable expertise and experience accumulated during the research and development process, especially, the analog field test of the LASOIS system will significantly contribute to the improvement of existing scientific strategies. The outputs of this proposed 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. In addition, with applications developed on the lunar surface, the system could be further extended to support and Mars manned missions in the future. The developed technologies can also be used to support personal navigation tasks on Earth, and substantially influence many application domains. Specifically, the spatial recognition results obtained during the process of testing LASOIS can help people to understand the relationships between acceleration, gravity, and human spatial sensing capabilities. Such relationships can be used in multiple domains, where people work in environments with varying accelerations and require maintaining good spatial orientation in such environments. Examples include first responders working in earthquake site, people working in deep water environment, and pilots of fighters.
Task Progress:	As presented below, the achievements over the second year have fulfilled the designated tasks in the proposal. 1. Data processing and sensor integration: Based on the integrated sensor network established in the first year, we improved the approaches for processing and integrating spatial data collected by the sensor network, and for turning the vast amount of data from the sensor network into spatial-orientation information usable by lunar astronauts. First, we improved an Extended Kalman Filter to integrate measurements from multiple sensors for generating precision walking trajectory of an astronaut, and carried out systematical evaluations of this approach. Second, we improved a Kanade-Lucas-Tomasi algorithm for astronaut navigation from video tracking, and explored how to utilize various spatial constraints for reducing the computational complexity. Third, we studied a Star Tracker technology for obtaining the location and orientation information for astronaut navigation, and evaluated its performance through simulated experiments on Earth. Fourth, we developed an approach for matching orbital and ground imagery based DEMs, which enables initial localization of the astronaut while landing. 2. Development and evaluation of the LASOIS prototype 2: First, we improved the precision, robustness and mobility of LASOIS through incorporating a tactical IMU, the redesign of the astronaut boot and on-suit package. Extensive field experiments show that the new LASOIS can collect data with less noise, high-precision, and can reliably support long walks of more than 2 km. Second, we investigated different on-suit sensor (IMU, step sensor, and cameras) configurations for best navigation capability through extensive experiments. We found that mount stereo cameras on the chest improved the reliability of the vision data based tracking results. Third, we have determined what display formats are used most frequently in terrestrial environments for navigation aids (plan view, bird's eye view, wingman view, pilot view), and have investigated the usefulness of non-visual information presented in a navigation aid (e.g., sound). 3. Field tests, database construction and management, training, and reporting: A set of tests of the LASOIS prototype 2 were performed at OSU. In addition, two analog field tests were conducted at NASA Plum Brook station on March 10, 2010, and at Black Point Lava Flow, Arizona, from June 10th to June 14th. For NASA Plum Brook test, we conducted some basic training of test subjects. A spatial database at our test sites (including the in-door and out-door campus fields at OSU and analog field test sites) is being constructed including high-resolution satellite images, ground images and videos, measurements from multi-sensors, and ground truth measured by GPS and field survey. In addition, we are writing reports on these experiments, and plan to share our database and reports with other NSBRI funded scientists and NASA researchers.
Bibliography Type:	Description: (Last Updated: 09/07/2020)
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Awards	Banks MS. "Fellow of the American Association for the Advancement of Science, December 2008." Dec-2008
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Awards	Li R. "2010 International Space Ops Award, as MER team member, Apri 2010." Apr-2010
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