Fiscal Year:	FY 2013	**Task Last Updated:**	FY 10/01/2012
PI Name:	Newman, Dava J. Ph.D.		
Project Title:	Spacesuit Trauma Countermeasure System for Intravehicular and Extravehicular Activities		
Division Name:	Human Research		
Program/Discipline:	HUMAN RESEARCH		
Program/Discipline--Element/Subdiscipline:	HUMAN RESEARCH--Biomedical countermeasures		
Joint Agency Name:		**TechPort:**	Yes
Human Research Program Elements:	(1) **HHC**:Human Health Countermeasures		
Human Research Program Risks:	(1) **EVA**:Risk of Mission Impacting Injury and Compromised Performance and Long-Term Health Effects due to EVA Operations		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
PI Email:	dnewman@mit.edu	**Fax:**	FY 617-253-4196
PI Organization Type:	UNIVERSITY	**Phone:**	617-258-8799
Organization Name:	Massachusetts Institute of Technology		
PI Address 1:	77 Massachusetts Avenue		
PI Address 2:	Room 33-307		
PI Web Page:			
City:	Cambridge	**State:**	MA
Zip Code:	02139-4301	**Congressional District:**	8
Comments:			
Project Type:	Ground	**Solicitation / Funding Source:**	2010 Crew Health NNJ10ZSA003N
Start Date:	11/30/2011	**End Date:**	11/29/2014
No. of Post Docs:	1	**No. of PhD Degrees:**	1
No. of PhD Candidates:	2	**No. of Master' Degrees:**	
No. of Master's Candidates:		**No. of Bachelor's Degrees:**	
No. of Bachelor's Candidates:		**Monitoring Center:**	NASA JSC
Contact Monitor:	Vos, Jessica	**Contact Phone:**	
Contact Email:	jessica.r.vos@nasa.gov		
Flight Program:			
Flight Assignment:			
Key Personnel Changes/Previous PI:	The PI and Co-I remain the same (October 2012 report). Our International Collaborators continue to work with us, however, they have not been funded by ESA nor ASI for the first year. We are actively working with all of the NASA personnel listed below and have a new Technical Monitor (our third, but temporary, we're told). Additional NASA collaborators include Steven Platts, Ph. D.; David Baumann; Amy Ross; Lindsay Aitcheson; Sudhakar Rajulu, Ph.D.; Matthew Cowley; Rick Scheuring, D. O.; Jocelyn Murray; Jason Norcross; Lealem Mulugeta; Arturo Sanchez, III		
COI Name (Institution):	Hoffman, Jeffrey (Massachusetts Institute of Technology)		
Grant/Contract No.:	NNX12AC09G		
Performance Goal No.:			
Performance Goal Text:			

Task Description:	Extravehicular Activity (EVA) is a critical component of human spaceflight. Working in gas-pressurized space suits, however, results in numerous challenges, causing fatigue, unnecessary energy expenditure, and injury. These problems are exacerbated with the additional hours astronauts spend training inside the suit, especially underwater in the Neutral Buoyancy Laboratory (NBL). Although the U.S. has studied space suit performance and improved upon system designs, relatively little is known about how the astronaut moves and interacts with the space suit, what factors lead to injury, and how to prevent injury. The objective of this research is to develop an understanding of how the person interacts with the space suit, and use that information to design personalized solutions to mitigate injury. This will be achieved through the following specific aims. Specific Aim 1: Analyze data for correlations between anthropometry, space suit components, and injury. Our work compiles all known open source injury information from the literature to create an EVA specific database. We then focus on analyzing the most up to date EVA injury database currently used by NASA. The database currently includes information regarding each subject and their selected space suit components. Anthropometric dimensions, spacesuit components, and all recorded EVA injuries will be included in an updated database because a mismatch between body dimensions and suit sizes is hypothesized as a causal mechanism for injury. Data mining techniques will be used to find correlations between anthropometry, suit components, and injury. Specific Aim 2: Develop a pressure-sensing garment. We will develop a pressure- or force-sensing garment worn by astronauts inside the space suit. The pressure-sensing garment will be worn to quantify the locations on the body where the person impacts the space suit to move it. This suit is beneficial to many stakeholders, such as spacesuit designers, engineers, researchers, flight surgeons, and exercise and rehabilitation specialists. In our project, the data will be used to determine areas of discomfort and impingement, which are prone to injury. Additionally, the sensing capability can be used determine the effectiveness of protective devices (Specific Aim 4). Specific Aim 3: Model human-spacesuit interaction. A human-space suit model will be used to understand the biomechanics of movement in a spacesuit. It will be used to quantify changes between unsuited and suited conditions leading to injury. In addition, the human-space suit model will elucidate the differences in the astronaut biomechanics once suit modifications and protective devices (Specific Aim 4) have been implemented. Specific Aim 4: Develop modular protective devices. The ultimate objective of this work is to develop solutions to mitigate injury. The protective devices will alleviate injury prone areas and adjust the person's placement within the suit to improve suit fit. They will be integrated to the space suit and protective garments can be personalized for each crewmember.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	The need to mitigate injury and discomfort is not exclusive to the harsh environment of space. The contributions from this work have the potential to be used in other extreme working environments, such as dry-suit scuba diving and high altitude pilots. In both cases, gas-pressurized suits are worn and have similar rigidity. The envisioned countermeasure and protection system capability may also be used in biomedical and rehabilitation applications. The elderly population often encounter minor trauma, but with much more severe consequences than their younger counterparts. Falls resulting in hip fractures place a disproportionate burden on healthcare costs, recovery, and death (Hayes, Myers et al. 1996). Hip injury is highly variable with position, muscle tension, and individual factors, making predicting and preventing injuries both important and challenging (Hayes, Myers et al. 1996). Injury prevention both in extreme work environments and against fall impacts for the elderly are promising crossover applications. The transferability to each of these environments warrants further study. Our work will also be developed into education and outreach efforts to increase the visibility of human spaceflight and astronaut injury. The effort will be integrated to existing NASA programs to maximize utility. We solicit wide-ranging creative ideas to inform our research as well as to consider and analyze all proposed injury solutions from the public. We are in contact with NASA Education Office at JSC to dovetail our efforts to facilitate public engagement in our project. Education materials such as online modules, a high-school design competition or a virtual classroom, seem to be the most promising avenues for public engagement. Furthermore, an EVA outreach video is also being produced.
	Our project has produced preliminary results used to refine our methodologies and form the basis of our ongoing work. Specific Aim 1: Injury Data Mining. We have completed our database of open-source injury information. In the first step of this process, we performed a comprehensive review of past astronaut injuries studies. For each study, we extracted the data related to EVA and used it to consolidate the initial EVA injury database. Although literature concerning astronaut injuries is fairly large, many of the articles do not specifically address EVA injuries. Hence, only three useful references were found for our research effort. Another important aspect of the astronaut spacesuit injury database concerns the countermeasures used to prevent EVA injuries, and the assessment of their effectiveness. During the first phase of the database development, a list of all current countermeasures has been assembled and associated with the causes and injury locations. Some of the most common countermeasures are the use of dressing and topical applications, the use of comfort pads, and optimal glove and suit fitting. For the second phase of the database analysis, access is currently being sought for the data. Approval is pending but promising. The previously mentioned challenge with the small and varied dataset must also be taken into account. Injury information is only available for the EMU, rather than the prototype suits. Therefore, this work will be limited to the EMU. However, it will lay the foundation for similar analyses to be performed with future suit designs. Specific Aim 2: Pressure Sensing Garment. There are a plethora of technologies commercially available to sense pressure. The driving market is for foot and gait applications, but also medical bed rest evaluation. Recently, there has been a boom in pressure sensing technologies developed for robotics, including sensing fabrics. Two technologies have been used for space suit applications previously. The first is the Tekscan system (Boston, MA) used in the Man Vehicle Laboratory for mechanical counterpressure space suit design and biomedical applications. Tekscan uses a grid of dye-sensitized cells whose resistance changes with application of pressure. Despite the advantage of familiarity and adaptability, the system becomes unreliable at low pressures and is prone to calibration error, especially over a deformable body. The second system previously used for space suit design is Xsensor. Xsensor is a

Task Progress:	pressure-sensing mat using capacitors separated by a deformable elastomer. The system was used in a shoulder injury study to evaluate the effectiveness of the HUT shoulder harness and its ability to distribute pressure. It was used in both pressurized and unpressurized EMUs. The system, however, uses custom made mats and is not easily integrated to an LCVG. Additionally, it had similar issues quantifying absolute values of pressure accurately. These types of systems are limited in that they are not as easily adaptable to clothing applications, not breathable, give less control over their characterization, and are expensive. They would require, however, less developmental overhead than pressure sensing fabrics. There are several categories of pressure sensing fabric designs. They are characterized by continuous or near-continuous pressure sensing capability. Pressure sensing fabrics offer greater accuracy, adaptability, flexibility, and are lower in cost, but require substantially greater effort to develop the instrumentation aspect of the capability. Additionally, there may be a mechanical ambiguity between sensing pressure from impact with the suit, rather than bending and wrinkling of the garment itself. Hybrid designs combine conductive materials such as fabrics and electrically conductive thread to create discrete sensors on a garment, rather than a continuous design. One example uses a capacitive material sandwiched between sensor elements made from conductive thread. Another particularly promising sensor uses microfluidic channels filled with conductive liquid metals. Further study is needed to assess these options and explore the literature more fully. Specific Aim 3: Human-Spacesuit Interaction Modeling. Some preliminary simulations have been already conducted. The analysis focuses on a single joint movement (one degree of freedom): knee flexion/extension. The simulation is based on available motion capture data that had been taken for previous studies conducted in the Man Vehicle Laboratory at MIT and modeled in OpenSim. The data were obtained using a VICON system, and ground reaction force (GRC) and moment data were obtained from two force plates. All available data at MIT correspond to unsuited conditions. To simulate suited conditions, an external torque was applied to the knee joint, based on experimental data previously obtained in the MVL. The data was taken using a robot wearing an EMU Class III. Therefore, torque data was measured internally from sensor placed on the robot joints. The Computed Muscle Control (CMC) algorithm from OpenSim was used to obtain muscle activation during the knee flexion/extension movement. The algorithm consists of three main stages. The first one is the calculation of the desired accelerations in order to drive the generalized coordinates and speed to the experimental kinematics. The second part of the algorithm calculates the muscle excitation that produces the desired accelerations using static optimization. A cost function is minimized to resolve muscle redundancy. Finally, the states advance to the next step in a forward dynamic model, using muscle excitations as inputs. The overall methodology needs to be improved and simulations are still ongoing. Some preliminary muscle activation results have been obtained for knee flexion/extension, although they still need to be validated and consolidated with data from more subjects. Specific Aim 4: Prototype Design. From the first phase of data collection, preliminary design requirements were created. These requirements are based on EVA space suit design requirements, and therefore form a high-level baseline from which to begin generating potential solutions. An initial materials review has been conducted to prioritize advanced materials to be used for the protection devices. To address Placement injuries, thicker padding and volume filling padding concepts have been identified. Some of these concepts also directly address the Hybrid shoulder injuries. HUT restraint systems focus on tiered padding to improve comfort and compressibility as shifting occurs. Load distributing channels are added to the chest and torso to offload weight if the astronaut is working in the prone or supine positions. Other concepts use a semi-rigid structure to prevent body shifting. The harness could be clipped in or integrated to the current restraining hardware. Additional support may be provided at the waist. To address Motion injuries, padding concepts allow for greater breathability and may be segmented to ensure mobility is retained. There is also proposed to be many thickness and sizing options to allow for greater customization.
Bibliography Type:	Description: (Last Updated: 03/20/2019)
Abstracts for Journals and Proceedings	Anderson A, Diaz A, Kracik M, Kobrick R, Trotti G, Hoffman J, Newman D. "Methodology Toward Developing a Spacesuit Trauma Countermeasure System for Extravehicular Activity." 2012 NASA Human Research Program Investigators' Workshop, Houston, TX, February 14-16, 2012. 2012 NASA Human Research Program Investigators' Workshop, Houston, TX, February 14-16, 2012. , Feb-2012
Abstracts for Journals and Proceedings	Anderson A, Newman D. "Modeling Astronaut-Spacesuit Interaction to Develop a Spacesuit Trauma Countermeasure System for Extravehicular Activity." 2012 NASA Human Research Program Investigators' Workshop, Houston, TX, February 14-16, 2012. 2012 NASA Human Research Program Investigators' Workshop, Houston, TX, February 14-16, 2012. , Feb-2012
Articles in Peer-reviewed Journals	Goel R, Kaderka J, Newman D. "Modeling the benefits of an artificial gravity countermeasure couple with exercise and vibration." Acta Astronautica. 2012 Jan-Feb;70:43-51. http://dx.doi.org/10.1016/j.actaastro.2011.07.021 , Feb-2012
Articles in Peer-reviewed Journals	Wessendorf A, Newman DJ. "Dynamic understanding of human skin movement and strain-field analysis." IEEE Transactions on Biomedical Engineering. 2012 Dec;59(12):3432-8. http://dx.doi.org/10.1109/TBME.2012.2215859 ; PMID: 22961262 [Originally reported as Epub ahead of print 2012 Sep 3.] , Dec-2012
Awards	Anderson A, Newman D. "1st Place Student Poster for 'Developing a Spacesuit Injury Countermeasure System for Extravehicular Activity: Modeling and Analysis,' International Conference on Environmental Systems 2012, San Diego, July 2012." Jul-2012
Papers from Meeting Proceedings	Anderson A, Diaz A, Kracik M, Trotti G, Hoffman J, Newman D. "Developing a Spacesuit Injury Countermeasure System for Extravehicular Activity: Modeling and Analysis." 42nd International Conference on Environmental Systems, San Diego, CA, July 15-19, 2012. Poster and talk. 42nd International Conference on Environmental Systems, San Diego, CA, July 15-19, 2012. , Jul-2012

Papers from Meeting Proceedings	Diaz A, Anderson A, Kracik M, Trotti G, Hoffman J, Newman D. "Development of a Comprehensive Astronaut Spacesuit Injury Database." 63rd International Astronautical Congress, Naples, Italy, October 1-5, 2012. Oral session: Life Support and EVA Systems. 63rd International Astronautical Congress, Naples, Italy, October 1-5, 2012. , Oct-2012
Significant Media Coverage	Skowronska M. "Kracik w Kosmosie." Article in Polish newspaper, Gazeta Wyborcza (wyborcza.pl). Nauka, Poniedzialek 22 Sierpnia 2011. Front page and p. 10. http://wyborcza.pl/1 ,75476,10155455,Kracik_w_Kosmosie.html , Aug-2011
Significant Media Coverage	Newman D. "MIT150 Symposia – Earth, Air, Ocean and Space: The Future of Exploration." Exploration Visions, Chair of the Symposium, MIT, April 2011., Apr-2011
Significant Media Coverage	Newman D. "Human Performance: Enabling Astronauts to Athletes." NIKE Creative Strategy, Portland OR, May 2011., May-2011
Significant Media Coverage	Newman D. "Beyond Planet Earth: The Future of Space Exploration." Exhibit at The American Museum of Natural History, November 2011-December 2012., Dec-2012
Significant Media Coverage	Newman D. "An Invitation to Explore: RE:SEARCH from Earth to Mars." 'Disruptive interestingness across creative culture and media arts', PopTech 2011, Camden, ME, November 2011., Nov-2011
Significant Media Coverage	Newman D. "Exploration from the Earth to Mars." Keynote, NASA Innovative Advanced Concepts (NIAC) meeting, Arlington, VA, November 2011., Nov-2011