Fiscal Year:	FY 2014	**Task Last Updated:**	FY 09/30/2013
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 Injury and Compromised Performance Due to EVA Operations		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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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
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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
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Flight Program:			
Flight Assignment:			
Key Personnel Changes/Previous PI:	The PI and Co-I remain the same. Our International Collaborators continue to work with us; however, they have not been funded by ESA nor ASI for the first year. October 2013 report: We are actively working with all of the NASA personnel listed below: Terry Hill, Crew Health & Safety Deputy Manager, NASA Johnson Space Center; Jason Norcross, EVA Discipline Co-Lead Scientist, Wyle Science, Technology and Engineering Group; David Baumann, Project Manager, Exploration Medical Capabilities, Johnson Space Center; Jessica Vos, Multisystem Portfolio Manager, NASA Johnson Space Center; Amy Ross, Technical Manager, Space Suit Technology Development Group, Johnson Space Center; Shane McFarland, Senior Engineer, Space Suit Technology Development Group, Johnson Space Center; Sudhakar Rajulu, Ph.D., Technical Manager, Anthropometry and Biomechanics Facility, Johnson Space Center; Matthew Cowley, Senior Design Engineer, Anthropometry and Biomechanics Facility, Johnson Space Center; Rick Scheuring, D. O., Flight Surgeon, Johnson Space Center; Jocelyn Murray, Longitudinal Study on Astronaut Health, Johnson Space Center.		
COI Name (Institution):	Hoffman, Jeffrey (Massachusetts Institute of Technology)		
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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 assess and 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. We perform a statistical analysis to relate anthropometry, space suit HUT components, and training time to shoulder injury. A new database was compiled by personnel at the Longitudinal Study on Astronaut Health (LSAH) and is the most comprehensive of its nature. The database includes 3 major components: Anthropometric measurements, Training record, and the Injury record. Data mining techniques will be used to find correlations between anthropometry, suit components, and injury.

Specific Aim 2: Develop a pressure-sensing tool. We will develop a pressure-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 tool is beneficial to many stakeholders (i.e., spacesuit designers, engineers, researchers, flight surgeons, and exercise and rehabilitation specialists). In our project, the data will be used to determine areas of discomfort, which are prone to injury. It will also be the first time space suits will be characterized using internal human measurements.

Specific Aim 3: Model human-spacesuit interaction. The purpose of SA3 is to gain a better understanding of the EVA injury mechanisms, particularly strain injuries caused by the EMU. The objective is to determine the extent to which muscle activity is affected by the presence of the highly-pressurized spacesuit. A musculoskeletal human-spacesuit interaction model is developed in order to quantify musculoskeletal performance of astronauts during Extravehicular Activity, and to assess their injury susceptibility.

Specific Aim 4: Design and Develop modular protective devices. Our work develops conceptual solutions to mitigate injury. As part of this effort, we identify promising materials and built prototype protective devices. We aim to alleviate injury prone areas and improve the person's comfort within the suit. Protective devices will be integrated to the protective garments and 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 team is very active in bringing our work and passion for human space flight to the general public through outreach. Our education and outreach efforts increase the visibility of human spaceflight and astronaut injury. We have participated in informal education through talks at museums, such as at the ExplorationWorks museum in Helena, MT where human spaceflight exhibits were developed by our team and bring space education to a chronically underserved area. We have also provided extensive outreach through many talks to the public, media, and general audiences, such as Think2012 (Goa, India), Suited for Space (American Textile History Museum; Lowell, MA), Business Innovation Forum 9 (Providence, RI). We have also given numerous tours of our lab and facilities to elementary, middle, and high school students, as well as international visitors and students from other universities. Finally, our team members have volunteered to participate in classroom teaching programs for middle and high school students. One such example is the SEED Academy developed at MIT where high school students come for 10 Saturdays and take a course in Aeronautics and Astronautics, learning about human space flight. Our efforts are always geared toward improving STEM education, whether that be in a formal classroom setting or through interactions with the general public.

Our research effort was productive of the reporting year, moving forward in collaboration with our NASA colleagues to gain access to critical data we have not had previously. We also moved forward in new, interesting areas of research not requiring detailed data requests from NASA. Our project is on track to successfully address CPR questions and contribute to a successful and safe human spaceflight program.
Specific Aim 1: Injury Data Mining. The Shoulder Injury Database has been compiled and acquired from the Longitudinal Study on Astronaut Health. An initial characterization of the data has been completed. Data analysis to compare astronaut anthropometry and suit components to injury is ongoing. Rigorous criteria for categorizing astronauts as injured or uninjured are being created and will be done in conjunction with NASA subject matter experts.

This is the first time anthropometry has been statistically analyzed with spacesuit components for injury. The data set represents the most comprehensive of its nature and may provide a wealth or results once analysis has completed. This information may be have bearing on improving matching astronaut to HUT sizes, modifying training session planning, or selection criteria based on previous shoulder injury.

Specific Aim 2: Pressure Sensing Garment. The pressure sensing system was over the course of the reporting period. Sensors were developed and optimized for human use inside the spacesuit to be conformal and sensitive to the lower spectrum of anticipated pressures. The entire system was created and functions as a standalone pressure sensing instrument. Additional components were also created. The Novel sensor was acquired and integrated into the pressure sensing suite. Future work will include fully characterizing the pressure sensors and verifying all design requirements were met.

Task Progress:	This capability will be a valuable tool serving several functions. First, it provides information directly measuring where a person's body impacts the suit, aiding to answer the EVA 11 gap. Spacesuit designers can use this information to assess and compare suit designs and to create additional comfort/protection equipment. Future iterations of the system may be useful for suit sizing personnel to optimize fit and comfort. Flight surgeons may use it as a monitoring tool to prevent injury. Finally, the tool can be used for biomechanics research, going beyond space applications. Developing pressure-sensing capability will greatly increase our understanding of movement inside the spacesuit. Specific Aim 3: Human-Spacesuit Interaction Modeling. A new framework has been developed to analyze human-spacesuit interaction during EVA. The musculoskeletal analysis being developed will provide new insights into the human musculoskeletal performance inside the spacesuit, and will contribute to the assessment of astronaut health and safety during EVA. Ongoing research includes analysis of data in the MarkIII-suited conditions, together with knee flexion/extension motion capture data from subjects wearing the EMU and MKIII collected at Johnson Space Center. Future work includes refining the spacesuit model by incorporating EMU torques in other joints, and using a more accurate human musculoskeletal model that contains musculotendon actuators in the upper torso and arms. The primary advantage to this approach is that it allows to us model the biomechanics of an astronaut inside the spacesuit, without needing to model the spacesuit itself. This would be both time intensive and limited in accuracy, given the current state of spacesuit models and dimensions. The modeling research effort will address the EVA 11 gap by providing a biomechanical understanding of how the human interacts with the spacesuit. The biomechanical and musculoskeletal analysis will provide information about kinematics and muscle activation to accomplish specific tasks, either single joint movements or more complex movements representative of EVA activity. As the simulations improve, a more accurate muscle activity analysis will give an understanding of how muscle injuries occur during EVA, both in training and in-flight. Specific Aim 4: Prototype Design. The second year research commenced in materials requirements definition, an extensive materials review, and initial prototype designs. The development of new composite pads yield the most promising injury prevention systems to date. Initial concepts and evaluation of a Universal Protection Support Garment (UPSG) and integration in to an LCVG were also accomplished. Further garment design, development and testing is slated for the next period of performance. Given the constant innovation, invention, and introduction to the market of new materials, we will also continue to investigate all new materials that meet the requirements of this project. Our initial prototype protection padding design work addressed the EVA11 research gap by providing new materials, design and prototypes to help alleviate crew injury. Lectures/Presentations given by the PI and others in PI's lab in 2013: February 5, 2013. Suited for Space Exhibit. American Textile History Museum, Lowell, MA. An evening with Dr. Dava Newman, Professor of Aeronautics and Astronautics and Engineering Systems at MIT, where her team is working to develop a new kind of spacesuit allowing for greater freedom and flexibility: the BioSuit. May 28, 2013. Future Human Space Exploration: Human Discovery. Distinguished Space Speak Series Exploration Works Museum, Helena, MT. May 10, 2013. Designing for Humans in Extreme Environments. University of Santiago, Depts. Industrial Design, Graphics, Illustration, and Fashion. Santiago, Chile. Others: April 21, 2013. Spacesuit Exhibition at the MIT Museum's Science Festival. The station consisted of different spacesuits such as the Gravity Loading Countermeasure Skinsuit (GLCS), the BioSuit™, as well as a slide show showing the EMU and Mark III. We had discussions about extravehicular activity, astronauts injuries inside and outside the suit, as well as more generic discussions about muscle atrophy and bone loss in space with adults and kids as young as six years old. June-August 2013. Human Performance in Space Department at International Space University. During the summer 2013, Ana Diaz was Teaching Associate of the Human Performance in Space (HPS) Department at the Space Studies Program (SSP13), International Space University (ISU) in Strasbourg. This is a very international program, with more than 100 participants from 24 different nationalities. During this program, she shared with participants her knowledge about spacesuits and EVA injuries. In addition, she gave a more formal presentation about the topic to the participants enrolled in the HPS Department.
Bibliography Type:	Description: (Last Updated: 03/20/2019)
Abstracts for Journals and Proceedings	Anderson A, Menguc Y, Wood R, Newman DJ. "Hyperelastic Pressure Sensor Development for Use in Extravehicular Mobility Unit." Presented at 19th IAA Humans in Space Symposium, Cologne, Germany, July 7-13, 2013. 19th IAA Humans in Space Symposium, Cologne, Germany, July 7-13, 2013. Abstract #329. , Jul-2013
Abstracts for Journals and Proceedings	Anderson A, Diaz A, Kracik M, Trotti G, Hoffman J, Newman DJ. "Understanding Human-Space Suit Interaction to Prevent Injury During Extravehicular Activity." Presented at 2013 NASA Human Research Program Investigators' Workshop, Galveston, TX, February 12-14, 2013. 2013 NASA Human Research Program Investigators' Workshop, Galveston, TX, February 12-14, 2013. , Feb-2013
Abstracts for Journals and Proceedings	Diaz A, Anderson A, Hoffman J, Newman DJ. "Modeling Musculoskeletal Human-Spacesuit Interaction." 19th IAA Humans in Space Symposium, Cologne, Germany, July 7-13, 2013. 19th IAA Humans in Space Symposium, Cologne, Germany, July 7-13, 2013. Abstract #330. , Jul-2013
Abstracts for Journals and Proceedings	Diaz A, Anderson A, Kracik R, Trotti G, Hoffman J, Newman DJ. "Development of a musculoskeletal human spacesuit interaction model." 2013 NASA Human Research Program Investigators' Workshop, Galveston, TX, February 12-14, 2013. 2013 NASA Human Research Program Investigators' Workshop, Galveston, TX, February 12-14, 2013. , Feb-2013

Abstracts for Journals and Proceedings	Marreiros SP, Domingues AR, Martins JM, Silva MT, Newman DJ. "Computational Calculation and Representation of the Lines of Non-Extension of the Ankle-Foot Complex." Congress on Numerical Methods in Engineering - CMN 2013, Bilbao, Spain, June 25-28, 2013. Congress on Numerical Methods in Engineering - CMN 2013, Bilbao, Spain, June 25-28, 2013. Paper Ref: 372. , Jul-2013
Abstracts for Journals and Proceedings	Newman D. "Human Exploration: The Desert as a Metaphor for Space." Conferencias del Desierto (Conference of the Desert), San Pedro de Atacamo, Chile, May 6, 2013. Conferencias del Desierto (Conference of the Desert), San Pedro de Atacamo, Chile, May 6, 2013. , May-2013
Abstracts for Journals and Proceedings	Duda K, Vasquez R, Newman DJ. "Wearable Control Moment Gyroscopes as a Spaceflight Adaption Countermeasure." 84th Annual Scientific Meeting, Aerospace Medical Association, Chicago, IL, May 12-16, 2013. Aviation, Space, and Environmental Medicine. 2013 Apr; 84(4):411. , Apr-2013
Papers from Meeting Proceedings	Kobrick R, Carr CE, Meyen F, Dominques R, Jacobs SE, Tufts DB, Newman DJ. "Using inertial measurement units for measuring spacesuit mobility and work envelope capability for intravehicular and extravehicular activities." 63rd International Astronautical Congress, Naples, Italy, October 1-5, 2012. 63rd International Astronautical Congress, Naples, Italy, October 1-5, 2012. Paper code IAC-12,A1,6,6,x13275. , Oct-2012
Papers from Meeting Proceedings	Diaz A, Trigg C, Jethani H, Tritchler S, Newman DJ. "Physiological Assessment of the Gravity Loading Countermeasure Skinsuit during Exercise." IAC 64: 64th International Astronautical Congress, Beijing, China, September 23-27, 2013. IAC 64: 64th International Astronautical Congress, Beijing, China, September 23-27, 2013. Paper code IAC-13,A1,P,21.p1,x20225. , Sep-2013
Papers from Meeting Proceedings	Domingues AR, Martins SP, Silva JM, Newman DJ. "Analysis of the Human Ankle Impedance for the Design of Active Soft Orthosis." XXIV Congress of the International Society of Biomechanics, Natal, Brazil, August 4-9, 2013. XXIV Congress of the International Society of Biomechanics, Natal, Brazil, August 4-9, 2013. https://isbweb.org/images/conferences/isb-congresses/2013/poster/ps1-15o.pdf ; accessed 7/24/15. , Aug-2013
Papers from Meeting Proceedings	Duda K, Newman DJ. "Variable Vector Countermeasure Suit (V2Suit) for Space Exploration." 2013 IEEE Aerospace Conference, Big Sky, MT, March 2-9, 2013. In: 2013 IEEE Aerospace Conference, Big Sky, MT, March 2-9, 2013. http://dx.doi.org/10.1109/AERO.2013.6496842 (accessed 10/30/14). Alternate URL: http://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=6490096 and search for authors. , Mar-2013
Significant Media Coverage	Online International Media Coverage. "MIT and Dainese now working on astronaut protection garment." Market Press info website, July 2013., Jul-2013
Significant Media Coverage	Online International Media Coverage. "MIT e Dainese per la protezione degli astronauti (MIT and Dainese working on astronaut protection.)" MEGAMODO online, July 15, 2013., Jul-2013
Significant Media Coverage	Passarello M. "The High-Tech Fabrics that Protect Us. (I tessuti hi-tech che ci difendono.)" Newspaper entitled, 24 Ore Nova: Material Science Section, July 14, 2013., Jul-2013
Significant Media Coverage	Sofge E. "The Deep-Space Suit." Popular Science, Cover Story, p. 54-59, November 2012. PI quoted in article. Posted online 11/19/2012. http://www.popsci.com/technology/article/2012-10/deep-space-suit?dom=PSC&loc=recent&lnk=1&con=read-full-story ; accessed 9/30/13., Nov-2012