Fiscal Year:	FY 2014	**Task Last Updated:**	FY 03/16/2015
PI Name:	Norcross, Jason M.S.		
Project Title:	OCT High Performance EVA Glove (HPEG) Project Support		
Division Name:	Human Research		
Program/Discipline:	HUMAN RESEARCH		
Program/Discipline--Element/Subdiscipline:	HUMAN RESEARCH--Biomedical countermeasures		
Joint Agency Name:		**TechPort:**	No
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		
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Zip Code:	77058-3711	**Congressional District:**	36
Comments:			
Project Type:	Ground	**Solicitation / Funding Source:**	Directed Research
Start Date:	07/02/2013	**End Date:**	09/15/2014
No. of Post Docs:	0	**No. of PhD Degrees:**	0
No. of PhD Candidates:	1	**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:**	NASA JSC
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Flight Program:			
Flight Assignment:	NOTE: Extended to 9/15/2014 (original end date was 3/31/2014) per HRP (Ed., 6/2/14)		
Key Personnel Changes/Previous PI:			
COI Name (Institution):	Reid, Christopher Ph.D. (Lockheed Martin/NASA Johnson Space Center) Benson, Elizabeth (MEI Technologies/NASA Johnson Space Center) Charvat, Jacqueline (Wyle/NASA Johnson Space Center) McFarland, Shane M.S. (MEI Technologies/NASA Johnson Space Center)		
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Task Description:	Extravehicular activity (EVA) glove-related injuries are a known problem that some crewmembers experience and others do not. There have been various efforts to evaluate a specific EVA glove, document injuries over a limited time window, or look into a possible mechanism of glove related injury. To date, there is no comprehensive documentation of all EVA glove related injuries and possible injury mechanisms. The specific aims of this task will be twofold: First, to develop the best current understanding of what glove-related injuries have occurred to date, and when possible, identify the specific mechanisms that caused those injuries. Second, to create a standardized method for comparison of glove injury potential from one glove to another. The type and format of the standard will largely be a function of the results of the injury incident analysis and determination of leading factors causing said injury. The specific intent of this standard would be to assess the injury potential of gloves delivered as part of the larger High Performance EVA Glove project. This will facilitate direct comparison of these and future gloves against each other and against the current Phase VI glove.
Rationale for HRP Directed Research:	Expertise native to the EVA discipline within HRP has been requested by the Engineering Directorate to augment an existing task (OCT/Space Technology Mission Directorate award for the HPEG Project). Early information from this data mining task can impact the glove designs used for the OCT/Space Technology Mission Directorate funded portion of the task creating a need to do this task concurrently. This task appropriately aligns with EVA gap closure and integrates with the advanced space suit development team at JSC. Due to the involvement of operational practices and research specific to NASA this research should be considered highly constrained.
Research Impact/Earth Benefits:	Although a major goal of this research was to define an injury mitigation standard, the quality of the injury data prevented this objective from being reached. A major benefit to NASA and the EVA community will be a gap analysis from this research effort that is informing a new project seeking to standardize how suited exposures and injury records are recorded.
	This literature review and data mining study was conducted between 2012 and 2014. The study was bound by events occurring between 1981 and 2010, crossing both the Shuttle and International Space Station (ISS) eras. Only US NASA crew were investigated regarding 4000 Series and Phase VI glove models utilized during Extravehicular Mobility Unit (EMU) spacesuit EVA training and flight. Utilizing both literature and anecdotal causation comments recorded in crewmember injury data, investigators were able to identify several types of risks associated to the 23 types of injuries indicated in the study. These risks can be generalized to force based, task based, environment based, and individually based. A large majority of the risks identified point to force against the body (such as axial or shear loading, sustained and/or constricting forces). Task related risks include those that require exposure to repetitive motions and/or overexertion. Environmental variables also could be causational factors, such as fluid shifting due to microgravity or inverted work, moisture accumulation, or extreme temperatures. Lastly, individual factors such as allergic reactions to chemicals or material can act as an injury factor. As force related and task related variables were not assessed by this study, further future work assessing and quantifying these risks will need to be performed. With that, there were many significant findings as a result of this study. These key findings were divided into three primary categories: • Glove Injury Descriptive Statistics • Glove Injury Reporting Methods • Glove Injury Risk Causation Analysis Glove Injury Descriptive Statistics: 1. EVAs were performed by 96 crewmembers during the 322 EVAs that occurred through the investigation period of 1981 to 2010. There was a report of at least one injury during 96 (29.8%) of these 322 EVAs. Further, 50 of the 96 crewmembers (52.1%) who participated in an EVA reported at least one injury. 2. Most reported injuries were from only 1-2 individual incidents. This may indicate that most reported injuries were not chronic or cumulative problems with frequent recurrence, but due to injury data recording inconsistencies over time; there is not enough evidence available to support that chronic/cumulative injury is or is not a considerable risk. Future follow-up correlation studies will need to be performed to confirm this. 3. Injury types reported differed between training and flight exposures. This could be due to actual differences between the exposure events, but more likely indicates a need for standard injury type nomenclature and reporting timeframes. 4. Training injury locations were most commonly reported at the fingernail, metacarpophalangeal (MCP) joint, or finger crotch with pain, erythema (redness), and onycholysis the most common reported injuries. 5. EVA flight injury locations were most commonly reported at the hand, MCP joint, or finger with fatigue, abrasion, and paresthesia the most commonly reported injuries. Glove Injury Reporting Methods 1. Injuries were tracked with different methods over time. Moving forward, there needs to be one standard approach to reporting all suit related injuries regardless of exposure type (EVA flight or training) or suit/glove model. 2. Terms used to describe the injury types were not standardized. Investigators had to group injuries into one large category, and other than onycholysis, no other injury type was investigated separately. Future work should look to investigate other specific injury types. 3. Body part locations were inconsistently labeled, and oftentimes reports were too general citing only the hand or finger as the injury location. Standardized locations including specific finger, joint, or crotch should be used for glove related injuries. 4. There was no use of an injury severity scale for recorded injuries. Without severity information, all injuries had to be treated with equal severity. Also, there was limited information on the duration or persistence of an injury, therefore, investigators could not estimate a severity scale.

	5. Suit sizing information was not available consistently per exposure. If engineering design solutions are to be used to mitigate glove related injury, then a record of relevant suit and glove sizing metrics needs to be included with every EVA training or flight event. 6. Injury data were stored in multiple databases and had to be consolidated. If it is to be studied as an occupational exposure, suit related injury data should be clearly identified from other medical data in a crewmember's medical record. In addition to currently implemented countermeasures, suit related injuries should be mitigated using engineering and operational controls wherever possible.
Task Progress:	Glove Injury Risk Causation Analysis 1. Likelihood of reporting an injury during training was related to handedness, glove model, duration of the training event, and whether the training occurred in the years 2002-2004. Ergonomic task analysis including an evaluation of handedness bias in EVA training classes should be considered. Also, since many of the training event durations were estimated, this should be rectified with an exact recording of suited exposure duration. While this is specific to training, EVA flight recording should also be treated the same. 2. Likelihood of reporting an injury during inflight EVA was related only to the Anthropometric Principal Component 1 (hand size). This indicates that crew with smaller hand anthropometry were at higher risk for reporting an injury. While there are no clear recommendations from this finding, it supports general recommendations for optimizing fit and possibly controlling for and reducing hand intensive tasks and EVA durations for crew with smaller hand anthropometry. 3. Likelihood of reporting an injury earlier in career during training increased with Anthropometric Principal Component 1 (hand size), duration of the training event, and the delta between glove size and anthropometry for middle finger length and decreased with higher age and total number of prior events. Of all of these factors, the most striking finding was how the delta between glove size and middle finger length increased the risk early in a career. This indicates the need to optimize glove sizing as soon as possible in a crewmember's career and to not substitute a poorly fitted glove. 4. Likelihood of reporting an injury earlier in career during inflight EVA increased with exposure event duration and the delta between glove size and middle finger length. Again, this points towards shorter exposures decreasing risk and the need to optimize glove sizing early in a crewmember's career. 5. Likelihood of reporting an onycholysis (fingernail delamination) injury increased with age, duration of the training or EVA event, delta between glove size and middle finger length, and being female. This again points to the need for shorter exposures and optimal glove sizing. 6. Likelihood of reporting a onycholysis injury earlier in one’s career increased with Anthropometric Principal Component 1 (hand size), duration of training or EVA event, and the delta between glove size and middle finger length. In this case, it was the larger handed crewmembers who reported injury earlier, but it still points to shorter exposure and optimal glove fit as important controls. 7. Another interesting find was specific to glove model, indicating that Phase VI gloves could possibly influence the likelihood of developing onycholysis specific injuries versus wearing the 4000 Series glove. To note, there were changes made to the design of the EMU vent tube length where the vent tube was reduced from the wrist to the upper arm around the same time period as the Phase VI implementation. This may contribute in some way to glove related environmental changes in the EVA glove. Additionally, a separate unpublished NASA 2014 Glove Sensor Feasibility study noted that there may be a possible difference between the glove models in how much force is transmitted to the fingertips and fingernails (with the 4000 Series showing lower levels). Further investigation is needed to confirm these results though. 8. A previous study by Opperman et al. (2010) found an increased risk of onycholysis injury with greater hand circumference. Substituting hand circumference for Anthropometric Principal Component 1 in any of the statistical analyses found hand circumference to be a non-significant factor. Future Work 1. NASA should implement a suited injury data collection standard across all EVA training and flight to allow for future causation analysis studies. This data collection standard should clearly define injury, assess severity, and elucidate recurrence/chronicity. A prospective pilot phase of this project would allow for validation of the findings of this current research. Specific follow-up studies can refine the risk quantities to allow for more specific risk thresholds for glove size, age, event exposure time, and event exposure frequency. Additionally, this will also allow for investigators to better assess the acute versus cumulative risk towards these injuries. 2. Additional quantification of the cause-effect risk factors outside of this data mining study, such as those specific to the environment in the glove (forces on the body, moisture, temperature, etc.), should be examined to determine how they contribute to injury. These studies will help understand the glove environment as it relates to injury; this understanding could help provide better operational controls and lead to improved designs for the EVA glove. 3. Approximately 3,000 pages of suit fit and glove fit comments were received. Due to the enormity of the data received, the team was unable to assess these thoroughly in the timeframe allowed by the project. Potentially, additional risk factor data and injury information may be derived from these comments. As these records were mainly provided in a non-queriable format, these comments should be digitized and assessed towards injury risk in a follow-up study. Reference: Opperman, R., Waldie, J., Natapoff, A., Newman, D., & Jones, J. (2010). Probability of spacesuit-induced fingernail trauma is associated with hand. Aviation, Space, and Environmental Medicine, 81:907-913.
Bibliography Type:	Description: (Last Updated: 02/12/2025)

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