Phase I Project Summary

Firm: David Clark Company Incorporated
Contract Number: NNX13CJ27P
Project Title: Morphing Upper Torso: A Resizable and Adjustable EVA Torso Assembly

Identification and Significance of Innovation:
The Morphing Upper Torso is an innovative pressure suit design that incorporates adjustable linkages to enable a spacesuit that is: resizable, highly mobile and easy to don/doff.
The upper torso is integrated as a system of interconnected pressure constrained planes, with adjustable linkages that enable the dimensions of the suit to be reconfigured to match the wearer.
This architecture can be implemented into a wearable, pressurizeable prototype suit in the near term.
This technology has the potential to simplify suit sizing logistics, improve upper body suited mobility, reduce don/doff times, and reduce the number of discrete suit sizes needed to outfit the astronaut population.
This also has the potential to reduce risk of crewmember shoulder injury, and greatly improve logistics for ground training and sizing exercises.
Finally, this technology enables torso designs compatible with the entire anthropometric range, including the smallest female crewmembers.

Technical Objectives and Work Plan:
David Clark Company ultimately proposes to develop and design a Morphing Upper Torso for future EVA astronauts. To work towards this ultimate goal, the objective of this SBIR project (Phase I and II) is to demonstrate the technology in a working, useable, wearable, pressurizeable prototype (TRL 6). This project includes the program objectives and tasks to take the next steps towards the ultimate goal to develop a complete EVA Torso Assembly that can be resized to closely fit a wide range of anthropometries.
The top-level goals of the project are to develop and mature designs, fabricate prototype hardware, and establish subsystem architectures for actual demonstrations of the MUT architecture. A focus of this project is to design a system that can easily be integrated into a spacesuit and work with the suit itself, the human within the suit, and all the other necessary subsystems. Ultimately these advanced prototypes will serve as practical testbeds, which will enable evaluation and incorporation of new EVA suit capabilities in support of future NASA missions.
The objective of the Phase I, a six-month effort, was to perform the necessary groundwork to enable fabrication and delivery in Phase II of a functional prototype. This included maturing the concept through a combination of design efforts, requirements determination, analytical modeling and mockup fabrication and testing.
The Phase II objective is to fabricate, test and deliver a wearable, pressurizeable prototype Morphing Upper Torso. Results from the Phase II will provide the experience, technical data and understanding necessary to develop a fully operational MUT, capable of qualification for use in NASA's next generation EVA spacesuit.

Technical Accomplishments:
This Phase I project furthered the MUT concept, focusing on development of higher fidelity mockups and updated analytical tools and models. These necessary steps were performed to progress towards the ultimate goal of developing a useable, wearable, pressurizable prototype.
New higher fidelity mockups were designed and fabricated, incorporating Link-net as the restraint layer. Link-net is a unique “netting” material created and manufactured exclusively by David Clark. Link-net has been used in numerous high-altitude pressure suits and space suits. In this application, Link-net may provide advantages in the MUT architecture, due to its ability to self stow. When the MUT is reconfigured and resized to smaller dimensions than the restraint is designed, ideally the restraint material will stow underneath the resizable linkages, and will not buckle, dive in, or create hot spots, as is potentially the case with traditional woven fabrics utilized as a pressure garment restraint.
Additionally, various sizing mechanisms were considered and design trades performed to choose a design that allows quick, reliable, mechanical adjustments of the linkages. Ideally the crewmember must be able to quickly make adjustments to the torso size after donning the suit. If it is a suitport-compatible

suit, these adjustments must be made with the suit pressurized. Concepts that are optimal for both unpressurized resizing and pressurized resizing were designed.
Finally, the analytical models have been updated in this project to reflect the current baseline exploration suit geometry. Using these updated analytical models and the higher fidelity mockups, analysis was performed to quantify a reasonable range of sizing adjustments for a wearable prototype, as well as outlining the sizing architecture to outfit the entire future crewmember population.

NASA Application(s):
A Morphing Upper Torso would be beneficial for any future EVA suit. The ability to resize the torso will minimize the number of sizes needed yet allow for some "customization" among individual wearers. Additional mobility provided by such a close fitting suit for all crewmembers will be extremely beneficial for exploration of the Moon, Mars, NEOs, or future ISS construction and maintenance. Furthermore, the ability to resize the suit torso during long duration missions also provides a means to address body dimensional changes associate to long duration exposure to microgravity and thereby enhance the overall performance and efficiency of the suited crewmember. NASA will benefit by ultimately implementing this technology into future suit designs, and hence improving suit logistics (through reduction in the number of discrete torso sizes), minimizing costs and maximizing crewmember productivity.

Non-NASA Commercial Application(s):
The work performed in this project can be leveraged for military applications through the development of systems to evenly and efficiently distribute soldier borne equipment weight. Additionally, the design of components capable of quick adjustment can be leveraged for other protective equipment utilized in extreme environments, such as hazmat suits and firefighters turnout gear.

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