1. Summary

The public release engineering report for SilSuit covers the conceptualization, the engineering analysis and design, and manufacturing of the SilSuit. Future follow-on work is also summarized.

2. Conceptualization

Luna Desic, under the SpaceGAMBIT 2013 contract, is seeking to develop a concept for a mechanical pressure space suit. This will be done with the development of an article of a space suit sleeve covering the forearm and elbow of a wearer.

2.1. Goals, Objectives & Strategies

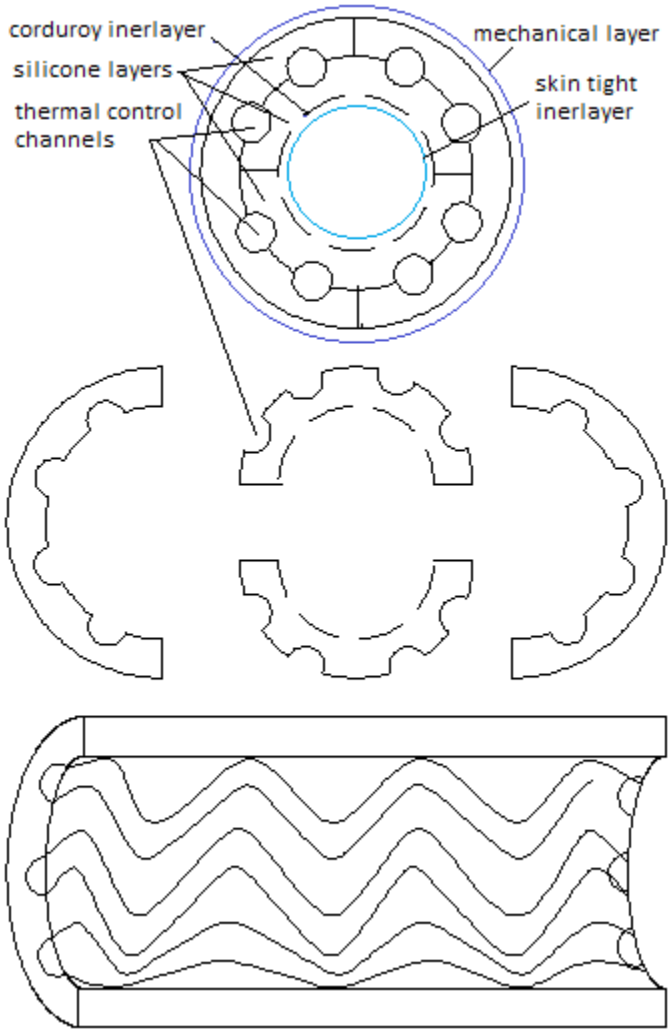
To organize the course of the project, the following goals, objectives and strategies have been plotted for design, qualification and meeting regulations:

- Design
    - Goal: Design a mechanical pressure system that will provide sufficient pressurization to the wearer to allow operation in the vacuum and thermal environment of space.
        - Objectives: It must provide sufficient pressure to the body in vacuum even as the arm flexes and moves at the elbow and rotates and flexes at the wrist. It must also be flexible enough to allow for the natural movement of the arm.
            - Strategy: Research mechanical pressure space suit designs. Examples of such include MIT's BioSuit.[a]
    - Goal: Design a thermal control system that will be able to maintain a reasonable internal temperature in the extremes of the thermal environment of space.
        - Objectives: It must provide a comfortable internal temperature when exposed to external temperatures equal to those in the space environment.
            - Strategy: Research space suit thermal control system designs. There is a history of cooling garments and insulative suits used in space that can be researched for this.

2.2. Conceptual Design

A conceptual design was conceived based on the above goals, objectives and strategies. It was split into the design of the forearm bracer and the elbow flex sleeve sections.

- Forearm Bracer



The design of the forearm bracer is divided into a mechanical pressure layer and a thermal control layer. The mechanical layer is a rigid composite shell and the thermal control layers are channeled silicone to allow the circulation of thermal control fluid. The channeling pattern is convoluted to promote heat transfer. There will be an inner layer of corduroy and skin-tight fabric to allow for comfort when the article is donned.

A rigid composite shell was selected as its rigid form will enable it to exert sufficient mechanical pressure on the body and will serve as an outer protective shell on the bracer. The silicone thermal layer is sufficiently elastic to allow the user to rotate their wrist while wearing the article and provide mechanical pressure as the wearer's forearm flexes with movement.

Fig 1: (top-bottom) Cross-section diagram showing forearm bracer layers and assembly, exploded cross-section diagram of thermal layer to show assembly, lengthwise cutaway view of thermal layer to show channeling convolutions.

The mechanical pressure layer will be a one-piece bracer that will slide over the silicone thermal layers. The thermal layer is divided into four pieces; two inner halves that have half-channels on the outside, and two outer halves that have half-channels on the inside. The halve splits of the inner and outer halves are arranged 90 degrees from each other. The half-channels on each layer are aligned to form whole channels when the entire layer is assembled.

- Flex Sleeve

The design of the flex sleeve is similar to the thermal layer of the forearm bracer. The difference is that there will be a flexible composite sleeve piece that will provide mechanical pressure. It will be donned over the thermal layer.

3. Engineering

Engineering analysis and design has been applied to the conceptual design to determine part materials, sizes and orientations to meet design and qualification objectives.

3.1. Analysis & Design

- Forearm Bracer
    - Mechanical Pressure Layer

For the mechanical pressure layer to provide sufficient pressure to the body, it must be engineered to be able to withstand such pressures. This can be done by applying engineering analysis to the mechanical pressure layer using the required dimensions to fit a user's forearm.

    - Thermal Control Layer

For the thermal control layer to provide a comfortable internal temperature with external temperatures the same as those of the space environment, we must research the thermal characteristics of the materials proposed and select a thermal control fluid that can best perform thermally as needed and is compatible with the material used. This research will be performed as SilSuit development progresses.

- Elbow Flex Sleeve
    - Mechanical Pressure Layer

The engineering analysis and design for the mechanical pressure layer for the elbow flex sleeve is similar to that of the forearm bracer. The difference is that we must make special considerations for the flexibility of the sleeve.

    - Thermal Control Layer

The analysis and design of this element will be the same as that for the forearm bracer's thermal control layer.

4. Manufacturing

- Manufacturing of Composite Parts
    - Molding

By taking molds of one's arm, one is able to lay up composites in the appropriate shape to form mechanical pressure layers.

- Casting Silicone Parts
    - 3-D Printing

3-D scans were taken of the body. The scans were put into CAD to make 3-D models of the different layers. These models would be used to form casts and molds. A 3-D printer would then print these casts and molds to make the various layers of the suit.

    - Manual Casting

By taking molds of one's arm, one is able to form casts and molds of the appropriate shape to form silicone parts.

5. Future Work

Several projects have been proposed as future work for the SilSuit project.

5.1. Derivative Projects

- Design and construction of more of the SilSuit.
    - This project focused on the construction of a sleeve of a forearm bracer and elbow flex sleeve. The project seeks to progress to a more extensive suit design and construction with the ultimate goal of a complete and functional space suit.

6. References

a. 'Extra-Vehicular Activity (EVA) Research @ MVL, BioSuit - Overview', Web Reference: http://mvl.mit.edu/EVA/biosuit/index.html.