1990-91 PROJECT SUMMARIES

GEORGIA INSTITUTE OF TECHNOLOGY

Georgia Tech's School of Textile & Fiber Engineering and School of Mechanical Engineering participated in four cooperative design efforts this year. One group designed a thermal shield for a lunar telescope. The second group designed a selenotextile habitat shielding structure. The third group designed a pneumatically assisted elbow joint for the NASA zero-prebreathe suit (ZPS). The final group designed an electromechanical system to power an astronaut's finger joints. Following are summaries of these projects.

DESIGN OF A THERMAL SHIELD FOR A LUNAR TELESCOPE

The goal of this project was to design a shield to provide thermal protection for a lunar telescope. This design was required to meet specific objectives, including the ability to (1) retract during nighttime viewing; (2) close during lunar day; (3) reflect infrared radiation; (4) minimize temperature fluctuations; (5) cover the entire telescope; and (6) last 30 years.

In addition, the design was subject to a number of constraints related to lunar conditions and shuttle cargo space; some of these include (1) 50-man-hour assembly time; (2) launch mass $\leq$ 4000 kg; (3) transport length $\leq$ 27 m; (4) transport diameter $\leq$ 7 m; (5) efficacy within lunar temperature range; (6) tolerance of vacuum; and (7) tolerance of severe solar radiation (β and UV).

The final design has been dubbed "The Rising Cylinder." The proposed structure will consist of two concentric cylinders 9.75 m high and a 10-m-high third cylinder that will carry the cover. Figures 1 and 2 are schematics of the structure in the open and closed positions, respectively. The top two cylinders will be lifted into place using a bootstrap reeving system located in the support members of the cylinders. The cover will consist of two disk halves that open and close using a rack and motor system.

The primary thermal protection system will be gold-coated fiberglass woven fabric attached to the support frame. Specifications of this fabric are as follows: (1) 5.5 tex continuous filament fiberglass yarn; (2) 22 ends/cm; (3) 22 picks/cm; (4) plain weave; and (5) coated weight 194 g/m^2.

Gold will be vacuum deposited onto a polyester film that will then be adhesively bonded to both sides of the fiberglass substrate. The purpose of this double-sided coating is to prevent "curling" caused by the differential between thermal properties of the coating and substrate. Gold was selected because of its reflectivity and because it does not oxidize.

This design has many advantages. The rigid structure will prevent folding and abrasion of the fabric. The structure will completely enclose the telescope, and the lifting mechanism technology already exists. There are, however, some disadvantages to this design. Opening and closing of the cover will be clumsy, and supporting the open cover will be difficult.

When the shield is closed, the telescope will be vertically positioned. When the shield is opened, the telescope can move away from the vertical position by a maximum of 15° (see Fig. 2). The proposed shield is designed to have a lifetime of 30 years with a two-year maintenance schedule.

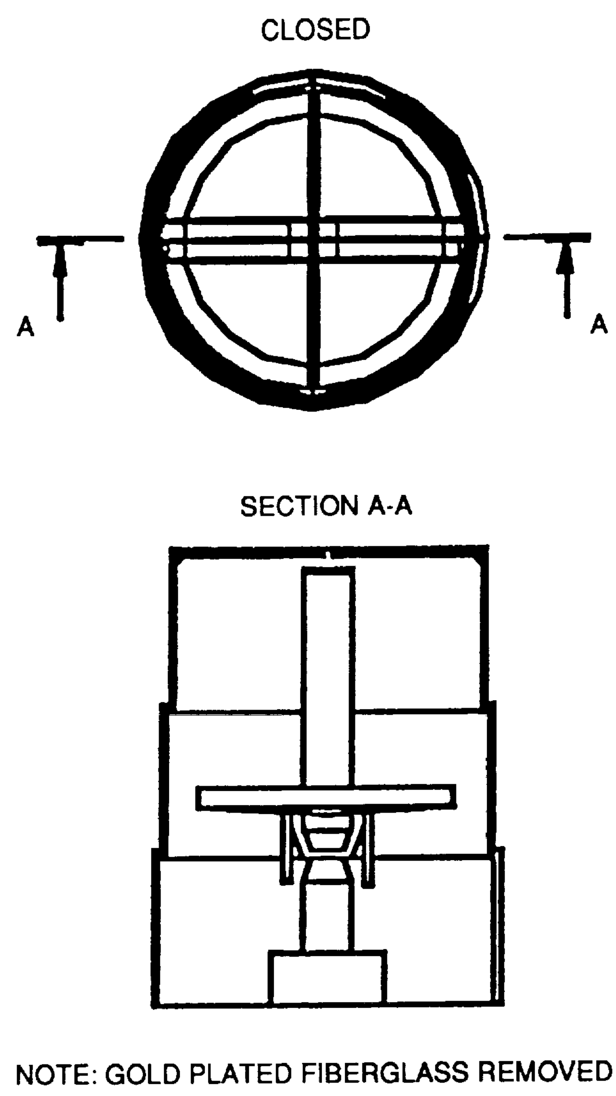

Fig. 1. Schematic of Closed Lunar Telescope Shield.

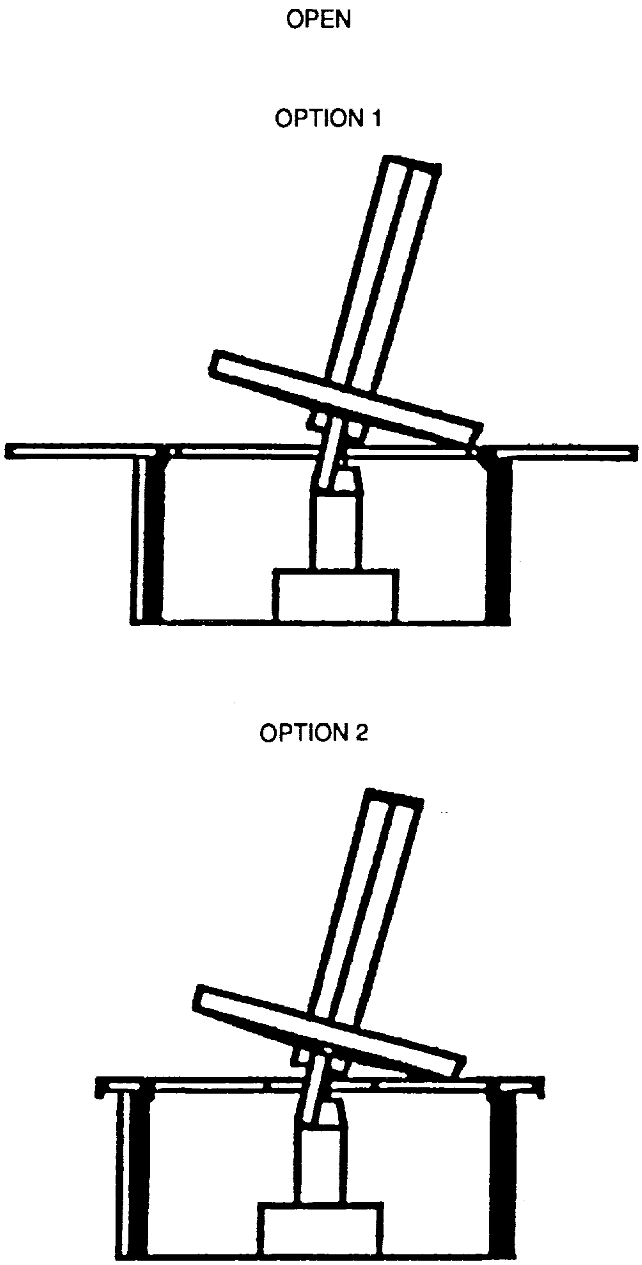

Fig. 2. Schematic of Open Lunar Telescope Shield.

Selenotextile Shielding Structure

The objective of this study was to design a structure to protect a lunar habitat from intense solar radiation. Included in the design is equipment for construction of the structure. The proposed protective structure is designed to withstand the extreme conditions of the lunar environment and to provide a 2-m maintenance space around the habitat. The construction equipment is designed to operate on less then 13 hp. Packaged, the structure and construction equipment will fit into a space shuttle cargo bay.

The shielding structure will be 26 m in length, 12 m in width, and 9.5 m in height. The structure will consist of 26 tubes, rectangular in cross section (1.5 m × 1.0 m), leaned like horseshoes at a 45° angle against a bank of regolith (see Fig. 3).

The individual tubes will be made of woven polytetrafluoroethylene (PTFE)-coated fiberglass fabric. Fabric specifications include (1) plain weave; (2) 22 ends/cm; (3) 25 picks/cm; and a (4) coated weight 240 g/m^2.

Fabric sections (from which the tubes will be made) will be heat-sealed together to form airtight seams and thus prevent escape of regolith from the filled tubes. Each tube will have a top opening supported by a fiberglass hoop. Individual tubes will also be connected with an airtight joint to form the final structure.

The textile structure will be held in shape prior to and during filling by an interior cavity filled with compressed gas. Regolith will be supplied to the structure via the fiberglass hoops and a conveyor system. The primary conveyor system will be supported by a series of telescoping legs and will be fed regolith by a second conveyor resting on the support mound. The conveyors are shown in Fig. 4.

Pneumatically Assisted Elbow Joint Design for the NASA Zero-Prebreathe Suit

In the near future it is expected that NASA will establish a lunar colony. To assemble and operate this lunar base it will be necessary for astronauts to spend a significant amount of time working outside the base. The existing procedure for adjustment from cabin pressure to suit pressure takes 13 hours and 30 minutes. The proposed suit design will allow astronauts to make the transition from a high-pressure internal environment to a lower-pressure suit without spending time in an air lock. This suit, the Zero-Prebreathe Suit (ZPS), is pressurized to 57

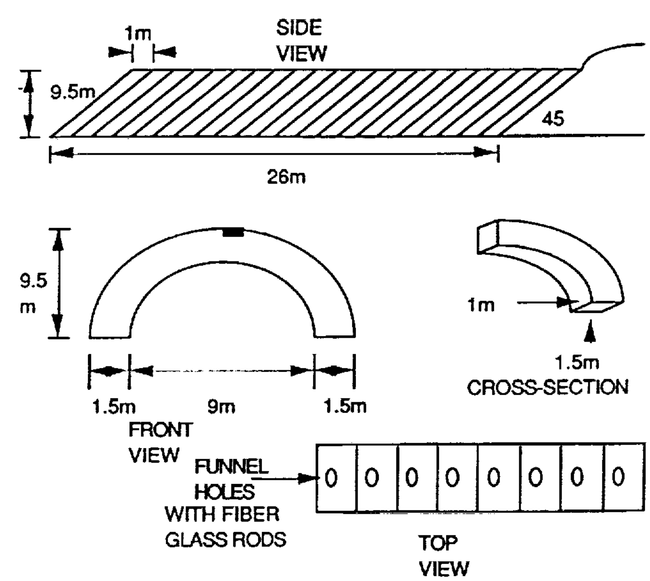

Fig. 3. Structure Schematic.

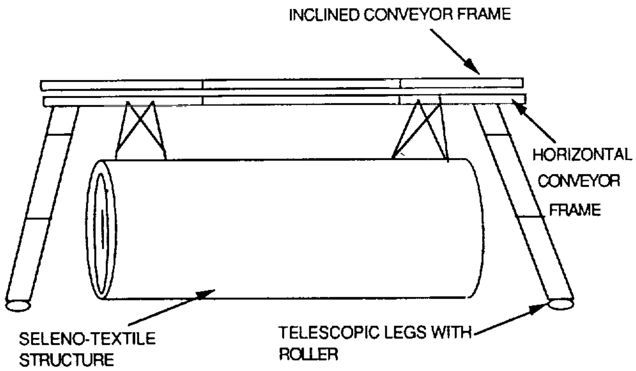

Fig. 4. Conveyor Structure.

kPa, compared to the current shuttle suit, which is pressurized to 29 kPa, and the shuttle's atmosphere, which is pressurized to 101 kPa.

The current ZPS design uses a toroidal joint to provide flexibility and has a bending resistance of 3.0 Nm. When used with a micrometeoroid shield, the resistance to bending increases to 5.4 Nm. This resistance, in conjunction with deconditioning caused by prolonged exposure to low gravity or weightless conditions, accelerates the onset of fatigue and can artificially limit the amount of work that an astronaut can do. The proposed design will counteract the resistant forces to regain some lost work time and to help optimize the astronauts' performance.

The assist mechanism to overcome the resistance of the elbow joint uses an inflatable structure that deforms asymmetrically to match the path that the elbow travels through. A rendering of the proposed solution to the problem of overcoming the resistance of the ZPS suit is shown in Fig. 5. Figure 6 shows sectional views of the design. The components of the assist mechanism are shown in Fig. 6. The expansion pattern is shown in Fig. 7. The outer edge is exposed to a very high deformation, with approximately a 120% change in length. The inner edge expansion is relatively smaller, with a total elongation of approximately 70%. Note that the total angular rotation is 130°, as specified by NASA requirements. The upper sealing joint must be able to accommodate 15° of angular rotation. The proposed design meets this requirement by being compatible with the existing joint. Note that a 0.635-cm ring thickness has been included in the sealing joint design to accommodate any later adaptation of the design. Similarly, the lower sealing joint must accommodate 180° of rotation.

The total cross-sectional area of the structure is approximately 7.9 cm^2. The area is approximate because the segmented form has an area that varies slightly between the large and small diameters. The torque exerted by the structure is constant at 5.4 N because the ends of the structure occur at the large diameter.

The assist mechanism is made from a plain woven polyester fabric cut with a saw-tooth pattern. In order to make the chamber deform, as shown in Fig. 7, filling yarns of varying linear densities should be used to weave the fabric. Fine filling yarn should

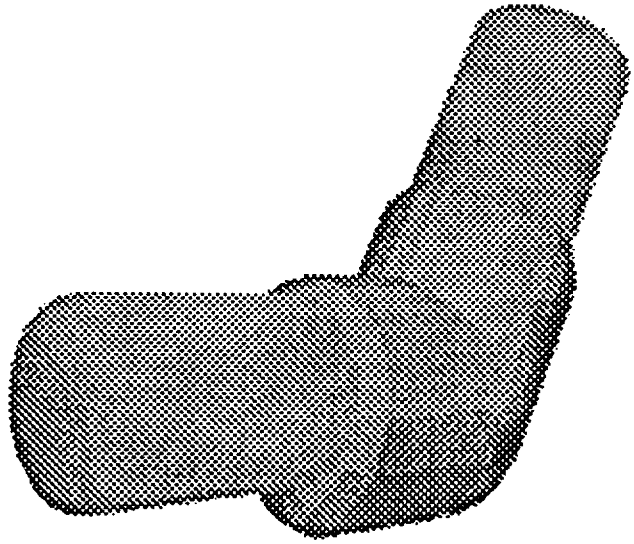

Fig. 5. Rendering of Elbow.

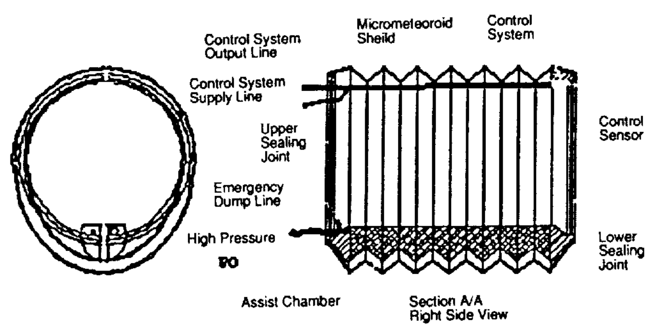

Fig. 6. Cross-Sectional View.

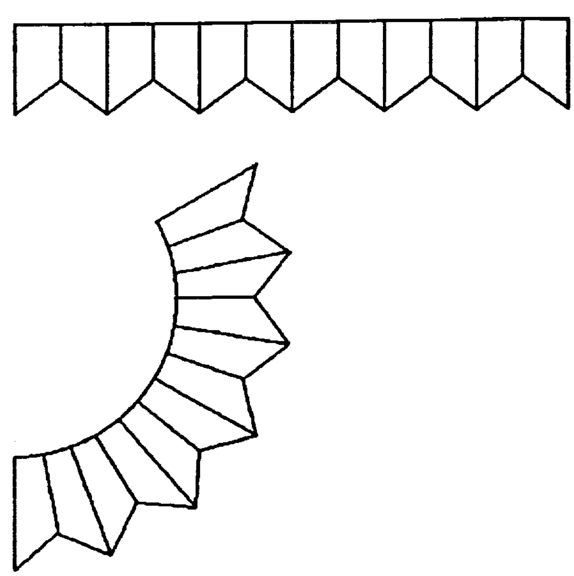

Fig. 7. Deformation Pattern.

be inserted for flexibility (and chamber elongation) along the outer side of the fabric pattern, and coarser filling yarn is used to weave stiffer fabric along the inner axis of the fabric pattern. When the fabric is folded and assembled, the fine yarns meet at the saw-tooth seam, where greater elongation takes place. The chamber should be assembled to achieve the necessary response of the chamber upon inflation.

Fabric specifications are (1) plain weave; (2) 14 ends/cm; (3) approximately 14 picks/cm; and a (4) nominal yarn diameter of 0.013 cm.

The finished, cut fabric should be impregnated with urethane before assembly of the structure.

This joint is designed to be incorporated with the NASA ZPS and to have a lifetime equal to that of the ZPS.

Electromechanical System to Power Assist in Astronaut's Finger Joints

The proposed design is an electromechanical system to power-assist the movement of an astronaut's distal and proximal interphalangeal finger joints. Figure 8 shows these joints and their desired range of motion. The objectives of this project were to reduce astronaut fatigue and provide greater ease of movement.

The design was subject to a number of constraints, including the need to (1) allow 90° range of motion at proximal interphalangeal joint; (2) allow 45° range of motion at distal interphalangeal joint; (3) compensate for 75% of suit's bending resistance; (4) integrate with current suit; (5) weigh ≤ 5 lbs/arm; (6) not generate excessive heat; (7) require little or no maintenance; (8) have a lifetime comparable to that of a suit; and (9) not hinder hand operation in event of failure.

The approach taken is called the "Stacked Triangle" method. It includes design and selection of a force sensing system, electromechanical actuator, glove finger bending mechanism, actuator controls, and materials for the bending mechanism and motor mount construction. Figure 9 is a rendering of the design. The force sensing system will consist of a polyvinylidine fluoride (PVDF) piezoelectric pressure-sensing grid, which will relay electrical voltage to an amplifier per unit of force. The proposed electromechanical actuator is an advanced linear electric motor with a rare-earth magnetic core. The linear motor will move the finger apparatus by displacing a Kevlar cable. This cable will force the aluminum structure to actuate due to off-center force-derived moments about the distal and proximal interphalangeal joints. The automatic controls for the system will consist of sensor, amplifier, and motor transfer functions. The feedback loop will consist of an adjustable feedback gain. The entire system will be incorporated into the spacesuit between two Teflon-coated textile layers. All components will be integrated into the suit with appropriate textile materials.

The electromechanical system will overcome the suit's bending resistance and provide force to achieve a range of motion of 45° for the distal interphalangeal joint and 90° for the proximal interphalangeal joint. Required operations will be power assisted as necessary. The system is designed to have a lifetime comparable to that of the spacesuit.

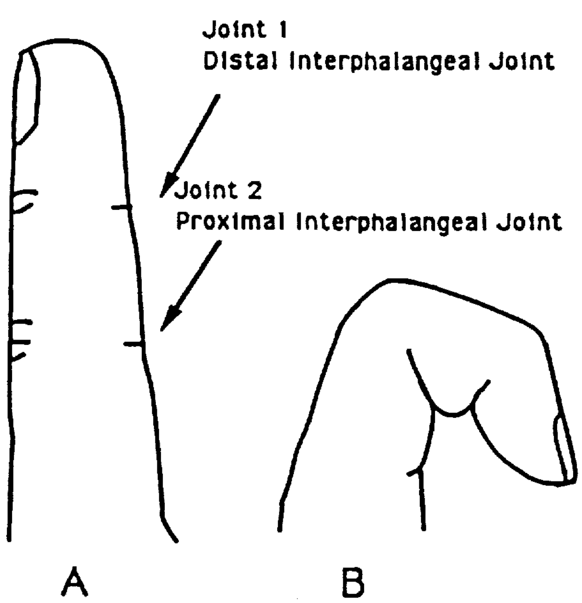

Fig. 8. Range of Motion Desired in Electromechanical System.

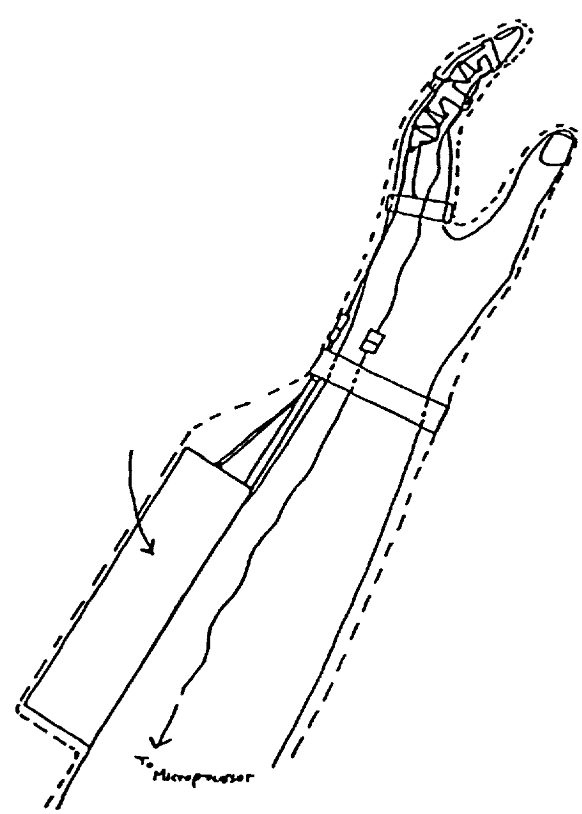

Fig. 9. Artist's Rendering of Electromechanical System.