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Raven Report No. R0184-002

SPACE SHUTTLE INFLATABLE TRAINING ARTICLES

Final Report for Contract NAS 9-16854

Submitted to:
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas

20 February 1984

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Applied Technology Division

Approved by:
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Vice President
Applied Technology Division
Raven Report No. R0184-002

NASA FINAL REPORT

Table of Contents

1.0 Design Summary 1
   1.1 LDEFI 1
   1.2 STTA 2

2.0 Object Utilization 3

3.0 Appendices
   A - LDEFI Proposal
   B - RBADS 1161
   C - Material Test Results
   D - LDEFI Drawing Package
   E - Torus Construction
   F - STTA Proposal
   G - STTA Alternate Sizing Analysis
   H - STTA Alternate Configuration Analysis
   I - STTA Drawing Package
   J - LDEFI and STTA Service Manual
Final Report for NASA Contract 9-16854

SPACE SHUTTLE INFLATABLE TRAINING ARTICLES

This report concludes contract NAS 9-16854 which included the design, development, construction and testing of the Long Duration Experimental Facility Inflatable (LDEFI) and the Space Telescope Training Article (STTA). Both articles are similar in nature, materials and construction techniques but vary widely in shape and have unique problems affecting size, shape, gross/net lift and balancing.

1.0 DESIGN SUMMARY

1.1 Long Duration Experimental Facility Inflatable

The final design of the LDEFI varied little from the design submitted in the original proposal (Appendix A). The basic variations were in the following areas: Material, end fittings and inflation port construction.

The material used was a 70-denier polyester with a count of 103 x 103 and a weight of 2.0 oz. per yard. This material was coated with .15 oz. of adhesive followed by .25 oz. of aluminized urethane on the outer surface and .25 oz. of adhesive followed by 2.0 oz. of white urethane which served as a helium barrier. This material was designed to meet the specifications set forth in RBADS 1161 (Appendix B). The test reports (Appendix C) show the results as tested to this specification.

The skirts and end panels were made of a nylon material similar in weight and strength to Dacron. The outer surface had .15 oz. of adhesive covered with .35 oz. of silver. No coating was placed on the reverse side.

The end fittings were redesigned to a larger diameter to allow the material to be tucked less as it was secured to the spool. The actual end fitting can be seen in drawing C-51621 in Appendix D.

The torus was originally to be connected to the main envelope by a series of three inch tabs glued to the torus and the main envelope where they intersected. This proved impossible, and a system of Velcro straps was devised instead. Details of this may be found in drawing D-51642 in Appendix D.

To define size, several prototypes were constructed to determine elongation under biaxial pressure. Uniaxial stress/strain and creep proved invalid due to the mechanics of elongation of the woven fabric. The torus lay-flats were
not reduced in size in the warp direction but were reduced by 6.5% in the fill direction. The envelope size was increased in the warp direction by 2.0% and decreased in the fill direction by 3.7%.

The apparatus was constructed in accordance with the drawings in Appendix D. Very few problems occurred during the construction, and most were remedied by adjusting the assembly method or technique. The technique for fabricating the tori is detailed in Appendix E.

1.2 Space Telescope Training Article

The final design of the STTA varied greatly from the original design submitted in the proposal (Appendix F). There were several reasons for this.

First, the original weight distribution in the RFP called for two pounds at each hard mount. As a result, 39 pounds were placed within 41 inches of the forward end of the aft section. A study was conducted to determine whether other shapes could compensate or whether the dimensions of the forward and aft section should be changed (Appendix G).

It was determined that, by shortening the forward section by 5.5 feet and adding that amount to the aft section, the hard mounts were shifted closer to the center of buoyancy of the aft section. The object now could be balanced and buoyant.

Second, several potential problems were discovered in the fabrication of the LDEFI, and it was decided that the unsupported outer skin was not practical for reasons of appearance and sealability. Also, weight distribution for the actual configuration NASA would use varied significantly from the original requirement, increasing from 50 to 78 pounds. To accommodate NASA's needs and optimize our design, the configuration was changed to one of several shown in Appendix H.

Third, the method of attaching the forward and aft sections to each other was changed from the original angles and latching devices. Instead, a hasp latch was mounted to each torus and the two were hooked together using turn-buckles. This allows a limited degree of adjustment to ensure that the centerlines of the two halves line up.

The materials used were identical to those in the LDEFI. The end fittings were like the original design because less material was present with the 10-foot diameter for the inverted end. The changes in torus connection described for the LDEFI were also incorporated into this design.

Sizing of the tori was identical to that of the LDEFI, but minor problems were encountered which required removal of a five- to eight-inch section from the two larger tori.
Expected but unusual changes in elongation resulted when sizing the main envelope. With conical sections to increase and reduce diameter, the biaxial stress was not uniform throughout the body, and each section acted independently. The large diameter section was 14 feet in diameter and about 14 feet from end to end of the conical sections (see Figure 1 below). This meant the torus circumferences had to be corrected for proper skirt fit. Sizing in the fill direction remained the same, and elongation in the warp direction was compensated for by shortening the center cable slightly.

![Figure 1](image)

The apparatus was constructed according to the drawings in Appendix I. One fabricating difficulty occurred while manufacturing the two large tori that was not encountered on the LDEFI. The tube diameter of these tori was large enough that two widths of material were required to form the tube. Thus, a butt seam now ran down the middle of the tucks, making heat sealing very difficult. To resolve this, the area had to be glued, activated and then heat sealed to provide sufficient adhesion.

2.0 OBJECT UTILIZATION

Appendix J, LDEFI and SSTA Service Manual, contains information on assembly, inflation, servicing, maintenance, leak detection, repair and storage.

The articles were designed with gross ballast points located to compensate for the hardware weights as specified in the RFP or by NASA. These gross ballast points bring the objects into approximate balance about the three axes. Small lead weights should be placed in pockets located on the tori to neutralize any remaining rotational forces. Weights should then be evenly distributed in these pockets to bring the inflatable to neutral buoyancy.
APPENDIX A
LDEFI Proposal
RAVEN INDUSTRIES, INC.
PROPOSAL NO. ATD1182111
TECHNICAL SECTION

DESIGN AND FABRICATION OF
LONG DURATION EXPOSURE FACILITY INFLATABLE

Submitted to:
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas
R.F.P. No. 9BB6-10-2-055P

15 November, 1982

Prepared By:
R. M. Enderson
Sales Engineer
Applied Technology Div.

Mark West
Project Engineer
Applied Technology Div.

Approved By:
J. A. Winker
Vice-President
Applied Technology Div.
1.1 INTRODUCTION

Raven Industries, Inc. is pleased to submit this proposal in response to NASA's Request For Proposal No. 9-BB6-10-2-055P.

The proposed basic configuration is a cylinder with inverted and restrained ends. Tori are utilized at the ends to facilitate generating flat ends. The fifteen hard mounting points will be attached to the skin at the required locations. The proposed configuration will be capable of being made neutrally buoyant with and without all government furnished hardware attached.

The proposed material is a polyurethane coated polyester fabric. The polyester base fabric is selected for its dimensional stability and the polyurethane coating for its abrasion resistance, helium retention and durability. The outer surface will incorporate an aluminized coating. The nominal material weight is 7.2 ounces per square yard.

Raven is a leading manufacturer of inflatables involving a wide range of materials. The proposed configuration will involve established and standard fabrication techniques. As a previous supplier of inflatable simulated payloads to NASA, Raven has a solid understanding of the requirement and is completely confident of our ability to meet the requirements for the LDEFI.

2.0 TECHNICAL DISCUSSION

The following detailed discussion of Raven's proposed design and fabrication objectives is presented with a plan for task accomplishment.

2.1 INFLATABLE CONFIGURATION

The proposed configuration of the LDEFI and associated sub-assemblies are shown in Figures 1 through 10.

2.1.1 MAIN ENVELOPE

The primary structure, shown in Figure 1, is a 13.7 ft. diameter cylinder with inverted and restrained ends with an overall length of 29 ft. A critical feature of the LDEFI is the limited volume for buoyancy to support required hardware. The inverted end design optimizes available volume while continuing to provide sufficient skin tension for stiffness and hardware support.

Additionally, the inverted end configuration is more compatible than a hemispherical end in generating a flat
FIGURE 1: CROSS-SECTION SIDE VIEW
end shape. The resulting torus radius at the end is only approximately 7 inches as shown on Figure 1.

The cylinder will be formed from longitudinal gores with shaped ends to yield the inverted end shape. The material at each end will be banded to a standard spool type balloon end filling. An adequate minimum gore width will be maintained to provide the necessary strength. The fittings at either end will be connected with a steel restraining cable. Details of the end fitting are shown on Figure 2.

2.1.2 TORUS END SECTIONS

Flat ends are generated by using a torus with a 7 inch radius around each end of the cylinder (see Figure 1). Each torus will be constructed independently and attached to the cylinder.

The skirts and end panels will be attached to the inflatable with hook and pile fastener (see Figure 3). The primary function of both sections is the generation of the desired shape and will carry no structural loads. Hard mounting points on the ends will be, as discussed in a following section, attached to the main inflatable surface. These will be available through holes in the end panels. The ability to remove the end panels facilitates the location of inflation servicing hardware and will be a distinct advantage in case of leak checking or repairs.

2.1.3 DIMENSIONAL PARAMETERS

The following tabularized information lists the final dimensions and resulting surface area and volume of the LDEF. The structure is subdivided as shown in Figure 4 for ease of understanding.

| TORUS | END | CENTER CYLINDER | END | TORUS |

FIGURE 4
The tabulated lift is based on standard conditions (ISA) at sea level with a free lift of helium of .06589 pounds per cubic feet. The total gross lift would be reduced to 269.4 lbs with an increased ambient temperature of 85°F (helium free lift of .06275). This gross lift value will be used for all subsequent buoyancy calculations.

2.2 MATERIAL

The proposed material is a polyurethane coated polyester fabric.

The base fabric is a 220 denier polyester with a thread count of 52 x 52. The nominal weight is 3.2 ounces per square yard. The tensile strength is 198 lbs x 215 lbs, tongue tear strength is 15.2 lbs.

The total nominal weight of the coating will be 4.0 ounces per square yard. The coating will be distributed with 3.0 ounces per square yard on the inside surface and 1.0 ounce per square yard on the outer surface. The outer coating will be pigmented to give the appearance of aluminum.

The measured helium permeability of a similar material is less than one liter per square meter per 24 hours. The only difference in this material and that proposed for the LDEF1 is that the base fabric weighs 4.2 ounces per square yard. The helium permeability of the proposed material, based on this comparison and Raven's extensive experience with coated fabrics, will also be less than one liter per square meter per 24 hours, well within the requirement of the statement of work.

A polyester base fabric is proposed because of its low elongation characteristics at low stress as compared to that of nylon. The polyurethane coating provides good abrasion resistance, helium retention and overall durability. The coating is compatible with both adhesive bonding and heat sealing techniques.

A sample of material representative of that proposed except for weight is enclosed.
POLYURETHANE COATED POLYESTER
2.3 STIFFNESS

Three types of stiffness must be considered for the LDEFI; skin, bending, and torsional. The following paragraphs will discuss each.

2.3.1 SKIN STIFFNESS

FIGURE 5

Skin stiffness is a factor of skin stress in an inflatable. Longitudinal stress for a cylinder with hemispherical ends is given by:

\[
S_1 = \frac{\Delta P R}{2}
\]

In the proposed configuration with inverted ends, the above relationship must be modified to the following:

\[
S_1 = \frac{\Delta P (R^2 - r^2)}{2R}
\]

From Figure 1 \(R=82.25\) in, \(r=41.125\) and for an operating pressure of 3 inches of water:

\[
S_1 = \frac{(.108)(82.25^2 - 41.125^2)}{2(82.25)}
\]

\[= 3.33 \text{ lbs/in}\]

Lateral skin stress is represented by the following equation:

\[
S_2 = \Delta P R
\]

For an operating pressure of 3 inches of water and radius of 82.25 inches:

\[
S_2 = (.108 \text{ lb/in}^2)(82.25 \text{ in})
\]

\[= 8.88 \text{ lbs/in}\]
The skin stress tangential to the end plane of the inverted ends of the main envelope will be governed by the following equations:

\[ S_1 = \Delta P r \]
\[ S_2 = \frac{\Delta P r}{2} \]

Again, for three inches of water pressure:

\[ S_1 = 0.108(41.125) = 4.44 \text{ lbs/in} \]
\[ S_2 = \frac{0.108(41.125)}{2} = 2.22 \text{ lbs/in} \]

The end tori will be inflated to the same operating pressure as the main envelope. To determine the maximum skin stresses in each direction, the following equations apply:

\[ S_1 = \frac{\Delta P r'(2R-3r')}{2R - 4r'} \]
\[ S_2 = \frac{\Delta P r'}{2} \]

Where \( R = 87.25 \) and \( r' = 7.06 \):

\[ S_1 = \frac{0.108(7.06)(164.5-21.18)}{(164.5-28.24)} = 0.80 \text{ lbs/in} \]
\[ S_2 = \frac{0.108(7.06)}{2} = 0.38 \text{ lbs/in} \]

2.3.2 BENDING STIFFNESS

Bending stress is related directly to longitudinal stress for a cylinder. The first wrinkle in the skin of the cylinder will occur when bending stress equals longitudinal stress. For the proposed configuration, this can be represented as follows:

\[ M = S \pi R^2 \]
For the stress determined in 2.1.4.1 of 3.33 lbs/in for the 82.25 inch radius:

\[ M = (3.33 \text{ lbs/in}) \times \pi \times (82.25 \text{ inches})^2 \]
\[ = 70,773 \text{ in lbs} \]
\[ = 5898 \text{ ft lbs force} \]

Increasing internal pressure yielding higher longitudinal skin stress will increase the bending force required to cause wrinkling.

2.3.3 TORSIONAL STIFFNESS

Thin, flexible fabrics vary wide in their reaction to shear in the plane of the material with thread denier, weave and coating material. Torsional loading also causes a reduction in lateral stress in the material and thus reduces skin tension. As the fabric is displaced in torsion and lateral stress is reduced, the material becomes susceptible to flexural displacement where lateral loads rapidly diminish.

Torsional stiffness of a rigid cylinder is proportional to the shear modulus of the material and is usually represented by the following equation:

\[ \text{Torsional Stiffness} \quad \frac{M_T}{\Theta} = \frac{\pi(D^4-d^4)G}{32L} \]

Where \( \Theta \) = angular displacement, \( M \) = torsional moment applied, \( G \) = shear modulus, \( D \) = outer diameter, \( d \) = inner diameter, \( L \) = length.

RFP 055P requires a torsional stiffness of:

\[ M_T = 3000 \text{ ft lb/radian} \]

Assuming a material thickness of 10 mils and shear modulus \( G = 3000 \text{ PSI} \)

\[ M_T = \frac{\pi[(164.5)^4-(164.48)^4]}{32(360)} 3,000 = \frac{[(\text{in})^4-(\text{in})^4]1\text{b/in}^2=\text{in/lbs}}{\Theta} \]
\[ = 291,290 \text{ in lbs/RAD} \]
\[ = 24,274 \text{ ft lbs/RAD} \]

*The shear modulus of 3000 PSI was derived from test data determined from model testing of pressurized cylinders under torsion constructed of coated fabric (NASA TN D-755 Aug 61). This material is somewhat heavier than the proposed LDEFI material but should yield a shear modulus on the same order of magnitude.
The shear modulus required by the statement of work would be 30.9 PSI. Synthetic rubber has a shear modulus of 5-20 PSI and when combined with a fabric, this modulus increases by two orders of magnitude or more.

The actual value for torsional stiffness of the LDEFI structure would fall well above the requirement set in the statement of work, but precise determination would only be possible through the collection of empirical data.

2.4 BOUYANCY

The bouyancy of the LDEFI as determined in section 2.1.3 is a gross lift of 269.4 lbs. A gross loading computation must first be made to place the center of gravity at the volumetric center of the LDEFI. The following table shows 17 required hardware mounts, their respective weights, and their x, y, and z locations (see Figure 8) with respect to the volumetric center. Points 1-15 are the required 15 hard points. Point 16 is the main inflation port and point 17 is the gross ballast point. The summation of moments in each axis is equal to zero.

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Cable and Spools 6.5 lbs
Total Hardware Wt. 167.15 lbs
Trim Weights 10.00 lbs
Fabric Weight 85.75 lbs

269.4 lbs

ORIGINAL PAGE IS OF POOR QUALITY
MAIN RETENTION/GRAPPLING INTERFACE

FLAT HEAD SCREW

MOUNTING RING

GASKET

REINFORCED FABRIC

GASKET

INSIDE RING

SEALANT

SECTION A-A

SPLINE NUT
2.5 FABRICATION AND CONSTRUCTION

The techniques which will be used to fabricate and construct the LDEFI are well proven and reliable. Quality control is built into each step of the process, i.e.; random samples of the materials will be tested to ensure the material meets desired specifications, seam samples will be tested for strength.

2.5.1 MAIN CYLINDER CONSTRUCTION

The main cylinder will be constructed of twelve gores. The end of each gore will split to form two gores for a more uniform construction of the inverted end (see engineering drawing C-51510). The seams will be bonded using high strength adhesives final assembly and checkout will be accomplished for the LDEFI with helium.

2.5.2 TORUS CONSTRUCTION

Several methods exist for the fabrication and construction of a torus. With the large difference between the outside torus radius 81.5 ± .75 inches and the tubular torus radius 7.0 ± .06 inches, the torus may be formed of gores, tucked tubular, or a modified gore tubular method. The latitude provided by these options allows for the selection of the design which would afford best distribution of skin stresses with other considerations of porosity, esthetics, maintainability and repairability.

2.6 ATTACHMENTS

Along with the fifteen required hard point attachments, several other types of attachments are required. Each will be discussed in the following sections.

2.6.1 HARD POINT ATTACHMENTS

The fifteen hardware attachment mounting points will be mounted on the skin of the LDEFI in the manner shown in Figure 9. The mounting ring will be constructed of 1/2" 60-64 aluminum with a matting inside ring constructed of 1/4" aluminum. Gaskets will be placed between each ring and the fabric which will be reinforced in the area of the interface.

2.6.2 BALLAST AND TRIM WEIGHTS

Ballast and trim weights will be contained in four pockets at each end of the LDEFI construction.
2.6.5 INFLATION SYSTEM

The LDEFI will consist of three distinct air chambers. The two tori will require only a single Schrader valve for both filling and top off due to the relatively low volume of helium contained in each. A second Schrader valve will be installed in each air chamber to allow pressure monitoring during servicing.

The main cylinder will have a rapid fill inflation tube (shown in Figure 10) which will be used for initial servicing. The inflatable will be taken up to just prior to skin stretch using this inflation port. The cover plate will then be installed and either of two Schrader valves located in the ends of the LDEFI main envelope will be used to reach operating pressure.

The rapid inflation port will be located as shown on Figure 8 so as to reduce the total amount of weight required to reach the coarse balance of the LDEFI.

2.6.4 TIE DOWN LINES

Tie down lines will be attached to each end of the main envelope on a "D" ring at the crossing point of three load webbings which will be adhered to the inverted end. The "D" ring will protrude through the end panel.

2.7 SAFETY

Safety is paramount in the design of any pressurized structure. Even with the low operating pressures of the LDEFI, an examination of the most serious failure must be made.

The restraining cable and end fittings have been determined as representing the greatest safety hazard if a failure were to occur. The restraining cable supporting the inverted ends will be constructed of steel aircraft cable. The tension is governed by the following relationship:

\[ \sigma_t = \Delta P \pi r^2 \]

For a working pressure of 3 inches of water pressure and a radius of 41.125 inches:

\[ \sigma_t = 0.108 \pi (41.125)^2 \]

\[ = 574 \text{ lbs} \]

Using a safety factor of 10, 7/32 inch 7x19 aircraft cable will be used. A proportionally larger cable will be used if it is determined that higher operating pressures are required.
2.8 MAINTENANCE

Maintenance and servicing are minimal as the LDEFI will only require helium servicing periodically. It is recommended that prior to beginning an operational day the internal pressure be checked and brought up to working pressure. This will insure a minimum of 8 hours service free operation.

Tears, holes or leaks must be repaired with adhesive patches. A detailed discussion of this procedure will be accompanying the LDEFI with a field repair kit.

3.0 MANAGEMENT

3.1 GENERAL

The proposed program will be conducted within the Applied Technology Division of Raven Industries. Mr. James A. Winker is a Vice-President of Raven Industries and manager of the Applied Technology Division.

3.2 PROGRAM MANAGEMENT

The primary program management will be assigned to the engineering group. Mr. Patrick J. Cannon is the Engineering Group Manager. The program will be conducted on a project basis with an assigned project engineer from within the engineering group. Assignment of the project engineer will be made at the time of contract award and would be dependent upon existing requirements at that time. The engineering group will have the total technical responsibility as well as data management, documentation and conference requirements.

Fabrication will be coordinated with Mr. K. L. Tekrony, Production Manager for the Applied Technology Division.

3.3 PROGRAM SCHEDULE/PLAN

A program schedule outlining the major tasks with manpower loading is enclosed as Figure 11.
PROGRAM PLAN

TASKS AND MANPOWER LOADING

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FIGURE 11
PROPOSAL CLARIFICATION

RAVEN PROPOSAL NO. ATD118211

1.0 SKIRTS AND END PANELS

Question being addressed: Calculate and state surface area and material of the skirts and end panels.

The end panels and skirts will be constructed of a 2.16 ounce dacron polyester base fabric with either a .5 ounce pigmented polyurethane coating or a .5 mil aluminized mylar laminate on the outer surface. The end panels will be circular in shape with a diameter of 152.5". The skirt will fit circumferentially around the main envelope and end torus. The flat panel will have approximate dimensions of 516.8" x 36". The total surface area of the skirts (129.2 ft² each) and end panels (126.8 ft² each) is 512 ft² or 56.9 yds².

2.0 GROSS BALLAST POINT

Question being addressed: What is meant by "gross ballast point?"

The gross ballast point is the position (point 17 on Figure 8 of Ref. B) at which the absolute minimum amount of ballast can be placed to bring the center of mass concentric with the volumetric center of the LDEF. This point is not intended to be used to reach neutral buoyancy. Only to balance cut rotational moments about each axis. Some fine trimming with weights in the end pockets may be required to "fine tune" the rotational moments. A tubular 1.25" diameter webbing filled with lead shot in one foot sections will be used to comprise the weights for the gross ballast as well as trim weights. Each one foot section will weigh approximately 3.25 lbs. and will require seven such bags for gross ballast.

An area of reinforced material will be located about the gross ballast point to which the weights will be attached by means of elastic straps (see Figure 1). The skirt will cover the mounting area of the gross ballast point and is easily removable by means of the hook and pile fastener. This will allow some or all of the weights to be removed to compensate for any government provided equipment which may be removed and maintain rotational balance.
3.0 TRIM POCKETS

Question being addressed: Specify the location and orientation of weight pockets and total weight each can hold.

Once the LDEF I has been brought into gross balance by means of the gross ballast point, trim weights may now be placed in eight locations as necessary to trim out imbalances and bring the LDEF I to neutral buoyancy. On each end, there will be four locations on the main envelope which weights may be attached as described in 2.0 and Figure 1. This will facilitate balancing out any large amount of buoyant force which must be overcome to reach neutral. Adjacent to each of these locations will be a pocket located on the end panel and will provide a secure location for small amount of trim weights. The pocket will be closed by a strip of hook and pile fastener on the open end flap.

Each inner location on the main envelope ends will be designed to accomodate 25 lbs. of weight while the trim pockets will hold up to 5 lbs. This will enable the LDEF I to be brought to equilibrium with all government equipment removed and a best lift condition of 282.9 lbs.
4.0 BUOYANCY

Question being addressed: Is the LDPII capable of being neutrally buoyant as described in the proposal? Show calculations to that effect.

While answering the aforesaid questions, it was realized that the weight of the end panels and skirts were left off of the buoyancy calculations. To compensate, a slightly lighter weight material is being proposed for use in the LDPII.

The base material remains a dacron polyester fabric of 70 denier thread and a thread count of 107 x 105. The nominal weight of the fabric is 2.2 ounces per square yard with tensile strengths of 111 x 110.5 lbs. and trapezoidal tear strength of 20 lbs. This yields a minimum safety factor of 12.5.

The fabric will be coated on the inside with 2.5 ounces per square yard of polyurethane. The outside will either be coated with a pigmented urethane to produce a polished aluminum appearance (see material sample in Ref. B) or a .5 mil layer of aluminized mylar will be laminated to the surface producing a highly polished appearance. The final nominal fabric weight is 5.2 ounces per square yard. Final material selection will be made during preliminary design reviews with NASA.
Enclosed is a stress-strain curve of the material showing a linear elongation rate which would result in a 1.25% elongation at a maximum operating load of 0.8 lbs./in. This graph also shows a grab tensile strength of 235 lbs./in.

The following is a tabulation of buoyancy based on worst case lift of 269.4 lbs. as would be generated at 85 F (helium free lift of 0.06275):

- Cable and Spools: 6.5 lbs.
- Government Hardware: 125.0 lbs.
- Mounting Hardware/Gross Ballast: 42.15 lbs.
- Trim Weights: 14.04 lbs.
- Main Fabric + 10%: 69.53 lbs.
- Skirts and End Panels: 11.30 lbs.
- Total Gross Life: 269.4 lbs.

*194.5 square yards @ 5.2 oz./yd² plus 10%
** 56.9 square yards @ 3.2 oz./yd²

5.0 LIFETIME

Question being addressed: What is the service life of the LDEFI?

The service life of the 5.2 ounce coated fabric used to construct the main envelope and end tori is a minimum of 5 years. All other components have a virtually limitless life expectancy if maintained within the design criteria. The actual life of the LDEFI will be determined by the degree of use, stress, and abuse which it undergoes. No means of estimating these effects on the lifetime exists.
APPENDIX B
RBADS 1161
COATED FABRIC, NASA INFLATABLES

Applied Technology Division
RBADS 1161

Prepared by:

M. L. West
Project Engineer
Applied Technology Division

Raven Industries, Inc.
P. O. Box 1007
Sioux Falls, SD 57117
1.0 Base Fabric

The base fabric shall be a Dacron polyester made of 70 denier yarns having a base weight of approximately 2.0 oz/yd².

2.0 Coating

Side one shall be a heat and solvent sealable polyurethane which will constitute a helium barrier with permeability rates as established in paragraph 5.3 of this specification. Side two shall have a base coating or adhesive with approximately .5 oz/yd² of a bright aluminized polyurethane.

3.0 Construction

The construction shall be as specified above with a total weight not to exceed 5.0 oz/yd².

4.0 Width

The minimum trimmed width shall be 43 inches.

5.0 Physical Properties

The finished fabric must meet the minimum values of the following listed physical properties.

5.1 Tensile Strength (one-inch strip method)

Machine direction - 50 lbs. (minimum)
Transverse direction - 50 lbs. (minimum)

5.2 Tear Strength (tongue tear)

Machine direction - 1.5 lbs. (minimum)
Transverse direction - 1.5 lbs. (minimum)

5.3 Permeability (helium)

Maximum acceptable - 1 liter/meter²/24 hours

5.4 Seam Strength

The peel strength of a one-inch heat sealed lap seam (side one to side one) shall be a minimum of 7 lbs. The peel strength of a one-inch heat sealed lap seam (side two to side two) shall be a minimum of 4 lbs. This test shall be accomplished on a sample prepared using the hot wheel sealing method.

5.5 Acceptance Tests

Failure of the fabric to meet the listed physical properties may constitute ground for rejection.
RAVEN INDUSTRIES, INC.  Page 1 of 2  Date 4-7-83

TESTING DATA SHEET

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<td>MFG.</td>
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TYPE OF TEST: 1" STRIP TENSILE

TEST METHOD: [INCOMPLETE]

MATERIAL TESTED: [INCOMPLETE]

OF POOR QUALITY

Coated Sales Mate White Style 412

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COPIES: RS-238  MARK WEST  CUSTOMER ____________  GRAPH NO.: 1657
Raven Report No. R0184-002

APPENDIX C

Material Test Results
RAVEN INDUSTRIES, INC.

TESTING DATA SHEET

ITEM: NASA-STA/I NDEF  
CONTRACT/P.O.#:  
W.O. #: 3007/03  

LOT #: LOT SIZE: MFG.  
TEST FACILITIES: RAVEN  

TYPE OF TEST: WEIGHT - TONGUE TEAR 
TEST METHOD:  
MATERIAL TESTED: COATED SALES MAT'L WHITE  

WEIGHT  
1.99 
2.0 oz/yd²  

TONGUE TEAR  
WARP FILL  
Initial 43 2.9 Initial 48 2.9  
5.7 3.6 4.6 3.6  
4.5 3.1 4.0 2.9  
3.2 lbs sq yd 2.9 lbs sq yd  

TECHNICIAN: 

COPIES:  
RS-238  MARK WEST  
CUSTOMER:  

ORIGINAL PAGE IS OF POOR QUALITY  

GRAPH NO.: 1657
**RAVEN INDUSTRIES, INC.**

**TESTING DATA SHEET**

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| M.O. | 767.0 |
| MFG. | KELCH'S BROS |
| TEST FACILITIES | RAVEN |
| ROLL No. | 47 |
| LOT SIZE | 32.7 YD. |

**TYPE OF TEST:** Width - Width

**TEST METHOD:** PER ROADS 1181

**MATERIAL, TESTED:** Coverlight, White, 1.0 mil.

| 4.6 | 0.2 |

**WEIGHT:** 5.0 C = 1yd² (Max).

| 4.63 |
| 4.60 |
| 5.00 |
| 4.76 C = 1yd² |

**WIDTH:** 43 inches (Min.)

| 41 1/2 inches |

**TECHNICIAN:**

**COPIES:**

**CUSTOMER:**

**GRAPH NO.:** 1882

**SEE DET. T. 1928**
**TESTING DATA SHEET**

**ITEM:** NASA  
**CONTRACT NO.** 2813  
**M.C. #** 36671-03  
**LOT #:** Roll 4379  
**LOT SIZE:** 187 yd  
**REG. RECEIVED FROM:** Raven  
**TEST FACILITIES:** Raven  

**TYPES OF TEST:** 1" Strip Tensile - Tongue Tear  
**TEST METHOD:** Per B3ADS 118.1  
**MATERIAL TESTED:** Coverlight White I Aluminum  
4.6 oz 4.7"  

### 1" Strip Tensile

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| TEST METHOD: | PER ROAD N.H. |

| MATERIAL TESTED: | COVER LIGHT WHITE | ALUMINUM |
| 4.6 oz. 5/8 INCHES (MM) |

**White To Silver - Heat**

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**White To Silver 7133 + Heat**

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**COPY:** RS-238

**MARK:** WEST

**CUSTOMER:**

**SEE B.R. # 1978**
HELIUM PERMEABILITY TEST

DATE: [blank]  TECHNICIAN: [blank]

MATERIAL: [blank]  ROLL: 43 76 180 yd

MANUFACTURER: [blank]


TEST NO. 1

Start MIC setting: 7240  Start pressure: __________ in

Finish MIC setting: __________  X = ______________

Time of test T = __________ min

\[ \frac{11.75}{X} \times 1.44/ (T) = \text{_________ L/m}^2\text{day} \]

TEST NO. 2

Start MIC setting: 7240  Start pressure: __________ in

Finish MIC setting: __________  X = ______________

Time of test T = __________ min

\[ \frac{27.75}{X} \times 1.44/ (T) = \text{_________ L/m}^2\text{day} \]

TEST NO. 3

Start MIC setting: 7240  Start pressure: __________ in

Finish MIC setting: __________  X = ______________

Time of test T = __________ min

\[ \frac{47}{X} \times 1.44/ (T) = \text{_________ L/m}^2\text{day} \]

AVERAGE = __________ L/m²/day

Copies to: MARK WEST  Q.C. Chart No. 1882

[Signature]  [Date: 1478]
ITEM: NISA - LDF E1  CONTRACT NO.: 2939 R.R. # 160-057
TRF Rec Inc.  V.O.: 70071-13
LOT #: LOT SIZE:
-2 Rolls: 1 Roll Sampled  Mfg. REEFS BAUS
TYPE OF TEST: Weight - Width
TEST METHOD: ZCR R.H.D. 110V
MATERIAL TESTED:
Dacron Good Sales Style 4/2

WEIGHT: 5.2 oz/1yd²

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<th>4.70</th>
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<td>4.67 oz/1yd²</td>
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WIDTH: 4.3" wide

42 inches

FOR WEST
arc Mar 11-83

TECHNICIAN:  

COPIES:  RS-238 MARK WEST  CUSTOMER:  R. GOO.

GRAPH NO.: 1920
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<td>RAVEN</td>
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<td>TYPE OF TEST:</td>
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| Tongue Tear: 15 lbs. Min. Warp & Fill |
|------------------|----------------|----------------|
| WARP             |                |                |
| 18.3             | 2.2            |
| 21               | 2.2            |
| 20               | 1.9            |
| 20               | 2.2            |
| 20 / 165 deg     | 27 / 165 deg  |

TECHNICIAN: [Signature]

COPIES: RS-230

CUSTOMER: [Signature]

GRAPH NO.: 1980

NOTE: PAGE 19 OF POOR QUALITY
**TESTING DATA SHEET**

**ITEM:** NASA E DE F 1  
**CONTRACT U. C.:** J 373 3 R.R. 1 400 037

**LOT #:**  
**LOT SIZE:**  
**M.Q.:** 1 308 71 13  
**FOG:** ELLIS PORS

**TYPE OF TEST:** PEEL Tests  
**TEST FACILITIES:** RAVEN

**MATERIAL TESTED:** Dacron Control Sales Style 412

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**TECHNICIAN:**  
**DATE:** 10.17.83

**COPY:** RS-238  
**MARK WEST**  
**CUSTMER:**  
**GRAPH NO.:** 7720

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CUSTOMER: [Signature]

GRAPH NO.: 1920
Silver to Silver 7133 + Heat 450°

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10.16
6.9
10.2
10.5 hrs. Avg.

Silver to Silver 7133 + The

18.2
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20.6
15.3
15.4
13.2 hrs. Avg.

Technician: [Signature]

Copies: RS-238

Mark West
Roy Wood

Customer:

Graph No.: 1920.
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**Test Method:**

**Material Tested:** Dacon Coated Sales Style 412

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**Technician:**  

**Copies:** RS-238 Mark West  
**Customer:**  
**Graph No.:** 1520
### HELIC: PERMEABILITY TEST

**DATE:** 10-31-83  
**TECHNICIAN:** JMG  
**MANUFACTURER:** Reeves Bros.  
**JOB NO.:** 300 71-13  
**MATERIAL:** NASA-2 DE-1  
**ROLL #:**  
**P.O.:** 273 13  
**R.R.:** 400 337

### TEST NO. 1
- **Start MIC setting:** 72.0  
- **Start pressure:** 5.39 in  
- **Finish MIC setting:** 27.0  
- **X:** 10.1  
- **Time of test:** **T = 10 min**

\[
10.1 \times 1.44 \times 10 \times (T) = 1.45 \quad \text{L/m}^2\text{day}
\]

### TEST NO. 2
- **Start MIC setting:** 72.0  
- **Start pressure:** 4.96 in  
- **Finish MIC setting:** 27.4  
- **X:** 9.6  
- **Time of test:** **T = 10 min**

\[
9.6 \times 1.44 \times 10 \times (T) = 1.38 \quad \text{L/m}^2\text{day}
\]

### TEST NO. 3
- **Start MIC setting:** 74.0  
- **Start pressure:** 5.14 in  
- **Finish MIC setting:** 26.0  
- **X:** 11.5  
- **Time of test:** **T = 10 min**

\[
11.5 \times 1.44 \times 10 \times (T) = 1.66 \quad \text{L/m}^2\text{day}
\]

### AVERAGE
- **AVERAGE = 1.497 L/m²/day**

**Copies to:**  
- **MARK TEST**  
- **REQUIRED Q.C. Chart No.: 1620**

**ORIGINAL PAGE IS OF POOR QUALITY**
NOTE: Because of its bulk, this drawing package is included as a separate package with this report.
APPENDIX E

Torus Construction
TORUS CONSTRUCTION
LDEPl and STTA

1.0 BASIC DESIGN

The tori were constructed using 36 gores to provide a smooth, non-lobed shape. Because the silver side of the material was difficult to seal, a butt seam would have been required with the sealing strip for each gore pattern. This would have produced three times the number of seams in the material compared to using only the radial seam. To prevent this, tucks were made in the material in the same gore shape as would have been cut.

2.0 FABRICATION

The torus lay-flat was marked with the 36 gore patterns, and glue was placed on the silver side of the material. After allowing the glue to dry, a hot iron was used to tack the tuck in place. The tuck was then run through a heat sealer to fuse the three layers of material. Several passes were required, depending on the width of the tuck.

The ends of the tucks tended to pull loose due to a concentration of stress. To eliminate this problem, a 1 x 2 inch patch was sealed over this point on the white side. This reinforcement removed any tendency to separate.

The two ends of the lay-flat were sealed together with a butt seam. A radial butt seam formed the tubular shape.

3.0 CONSTRUCTION DIFFICULTIES

The only major difficulties which occurred were in construction of the two large tori for the STTA. Two pieces of material were required to form the lay-flat. The material was sealed together with a glued butt seam to prevent heat shrinkage. The tuck now included six thicknesses of material, and heat would not adequately penetrate all layers. This problem was alleviated first by activating the glue with solvent and then running the material through the heat sealer. Test samples using this procedure produced extremely strong seals.
RAVEN INDUSTRIES, INC.
PROPOSAL NO. ATD0882092

TECHNICAL SECTION

DESIGN AND FABRICATION
OF
SPACE TELESCOPE TRAINING
ARTICLE

Submitted to:
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas
R.F.P. No. 9-BC72-93-2-66P

6 August, 1982

Prepared By:

R. M. Enderson
Sales Engineer
Applied Technology Div.

Approved By:

J. A. Winker
Vice President
Applied Technology Div.
1.0 INTRODUCTION

Raven is pleased to submit this proposal in response to NASA's Request For Proposal No. 9-BC72-93-2-66P.

Raven's proposed basic configuration for meeting the requirements of the Space Telescope Training Article (STTA) is a 10 ft. diameter cylinder with inverted and restrained ends. Tori are used to generate flat ends on the 10 ft. diameter sections. Tori and/or a rigid structural ring are proposed for generating the 14 ft. diameter section of the AFT article.

Two different materials are being considered. One is a lamination of polyester film and polyester fabric. The other is a urethane coated polyester fabric. The polyester fabric is the same in both configurations.

The requirement presents an interesting challenge. Raven is completely confident, though, of its ability to successfully accomplish the requirements of the statement of work. Developed fabrication techniques will be utilized regardless of the material configuration selected.

A detailed discussion of Raven's proposed configuration is presented in the following sections as well as a plan for accomplishing the task.

2.0 PROPOSED DESIGN

2.1 STRUCTURAL CONFIGURATION

The proposed configurations for the Forward and Aft sections of the STTA are shown on figures 1 and 2.

2.1.1 FORWARD SECTION

The basic structure, as shown on figure 1, is a 10 ft. diameter cylinder with inverted and restrained end sections. The inverted end configuration was selected primarily because this shape is more compatible than hemispherical ends in constructing flat ends.

The cylinder will be formed from longitudinal gores with shaped ends to yield the inverted end shape. The material at each end will be banded to a standard spool type balloon end fitting. An adequate minimum gore width will be maintained to provide the necessary
strength. The fittings at either end will be connected with a steel restraining cable. Details of the end fitting are shown on figure 3.

The structure incorporates two tori which facilitate affecting flat ends and connecting the two sections together. This second factor will be discussed in detail in a following paragraph.

The exterior surface is completed with the two skirt sections and circular panels at either end.

The cylinder and two tori will be fabricated as separate items and then joined together with the skirts and end panels. Adhesive bonding techniques will be used in the fabrication. It is not determined at this time if the skirts will employ a laced section to establish skin tension or if this will be dependent upon stress developed by inflation.

Critical parameters of the Forward section as proposed are as follows:

* Inflated Volume 1633 Ft.\(^3\)
* Gross Lift 107 Lb.
* Total Surface Area 140 Yd.\(^2\)

These parameters will be referenced and considered in the discussion on buoyancy.

2.1.2. AFT SECTION

The proposed configuration is shown on figure 2.

The basic structure is the 10 ft. diameter cylindrical section as used in the Forward section. The 14 ft. diameter section will be formed by either two tori or one torus and a structural ring. The configuration of the end if the structural ring is used will be essentially the same as the ends of the simulated payloads previously supplied to NASA by Raven.

Fabrication and assembly of the Aft section will be similar to that of the Forward section.

Critical parameters of the Aft section are as follows:

* Inflated Volume 3000 Ft.\(^3\)
* Gross Lift 197 Lb.
* Total Surface Area 260 Yd.\(^2\)
The surface area is based on using two tori in configuring the 14 ft. diameter section. The volume between the 10 ft. and 14 ft. diameter surfaces will be only slightly pressurized.

2.1.3. STIFFNESS

The basic stiffness of a pressurized cylindrical shape is directly related to the longitudinal stress in the material. In a cylinder with hemispherical ends the longitudinal stress is given by:

$$ S = \Delta p \frac{PR}{2} $$

In the proposed configuration with inverted ends the above relationship has to be modified to the following:

$$ S = \Delta p \frac{P(R^2 - r^2)}{2R} $$

$R$ and $r$ are as shown on figure 1 and the values are 5 ft. and 2.5 ft. respectively.

The stress in a 10 ft. diameter cylinder with hemispherical ends and pressurized to 3 inches of water pressure is computed to be 3.25 lb./in. The longitudinal stress with the ends inverted is computed, at the same pressure, to be 2.43 lb./in. To generate a skin stress of 3.25 lb./in., the proposed configuration will have to be pressurized to 4.0 inches of water pressure.

The stress in the restraining cable is given by the following relationship:

$$ S = \Delta P \pi R^2 $$

At 4.0 inches of water pressure this stress is computed to be 408 lb.

The first wrinkle will occur in a cylinder when the bending stress equals the longitudinal stress. For the proposed configuration this can be represented as follows:

$$ M = 12 S \pi R^2 $$

With a skin stress of 3.25 lb./in., $M$ computes to be 3063 ft./lb.

The basic stiffness of the STTA will be related to the minimum or 10 ft. diameter. If a maximum bending
stress of 3063 ft./lb. is not adequate a higher degree of pressurization will have to be considered. The computed material stresses are nominal and a higher degree of pressurization can be easily tolerated. The tori will be inflated to a pressure that will yield a skin stress equivalent to that of the cylinders.

The other factor that will directly effect the stiffness of the assembled STTA is the configuration of the interface connection. Raven's proposed method involves attaching rigid supports to the mating tori of the Aft and Forward sections and utilizing latching clamps to secure the connection. A sketch of a typical connection point is shown of figure 4.

The interface connection will impact directly also on the longitudinal alignment. A misalignment of one degree on the interface plane will cause an offset of approximately 4 inches at the end of the STTA. The rigid supports will provide a means of shimming as necessary to obtain proper alignment. The latches will be installed after correct permanent shimming has been accomplished. This task of final assembly and checkout will be done with the STTA inflated with helium.

The number of connection locations and the material for the rigid supports is to be determined. There is a significant degree of latitude in configuring the supports as well as available latch mechanisms. The latch protrusions will be limited to less than one inch from the surface of the STTA units.

2.1.4. ATTACHMENT HARDWARE

2.1.4.1. HARD MOUNTING POINTS

The proposed method for attaching the hard mounting points vary depending upon location and are discussed accordingly.

a. Aft Section - Station 3.0

Rigid supports similar to the interface supports are proposed to be used since the radius of the torus tube is approximately six inches and the center of the hard mounting is only three inches from the end of the inflatable. The hard point will be bolted to the rigid support stations. See figure 5.

b. Aft Section - Stations 28.0, 41.0, and 121.0
Forward Section - Station 81.75
Aft Section - 14 ft. Diameter End
At these locations the hard mounting points will be bolted to a clamp ring located on the inside surface, see figure 5. The surface at station 121.0 of Aft section is not a pressurized surface as such. Additional support at this stations, normal to the surface in direction, may have to be obtained with an auxiliary support attached to the pressurized 10 ft. diameter surface.

2.1.4.2. VELCRO PILE

The velcro pile patches will simply be adhesively bonded to the surface at the required locations. Rigid supports will again be utilized at station 6.00 of the Forward section and the end of the Aft section if the locations cannot be located on the curved surface of the tori.

2.1.5. MISCELLANEOUS ATTACHMENTS

2.1.5.1. BALLAST AND TRIM

A suitable number of pockets and weights will be provided to effect neutral and balanced buoyancy with or without the government furnished hardware attached.

2.1.5.2. TIE DOWN LINES

A fitting will be provided at the geometric center of both ends of both sections to which a tie down line can be attached.

2.1.6. INFLATION SYSTEM

Inflation ports will be provided in accordance with the statement of work. Two Shrader type valves will be provided at each end of a unit. This will provide a means of "topping off" the inflatable while monitoring pressure. Separate inflation means will be provided for inflating the tori. The large bore filling port for the cylindrical sections will be similar to those provided on previous SSSP's supplies by Raven.

2.1.7. FABRICATION & CONSTRUCTION

Adhesive bonding techniques will be utilized in fabricating the inflatable articles.
The tori will be fabricated from tubular elements. Each tori will consist of 24 elements. The elements are connected with a circumferential seam. The procedure is standard and used successfully numerous times in making gas tight structures.

The cylinders will be fabricated from straight longitudinal gores with shaped ends to form the inverted ends. Eighteen gores will be used for each cylinder. The proposed procedures are, again, standard.

Final assembly and checkout will be accomplished with the STTA inflated with helium.

2.2 BUOYANCY

In analyzing the buoyancy of the STTA an estimate of material weight has to be made. This estimated material weight is initially selected as 4.0 oz. per square yard. The weight and buoyancy of each section of the STTA and the assembled system is estimated as follows:

Forward Section

1. Volume - 1633 Ft.³
2. Gross Lift - 107 Lb.
3. Weight
   a) Two hard mounting points at 1.5 lb. each 3.0 Lb.
   b) Attached government hardware 12.0 Lb.
   c) Fitting and miscellaneous 15.0 Lb.
   d) Material - 140 Yd.² at 4.0 oz./yd.² 35.0 Lb.
      (includes 10% overage allowance)

   Total Weight 65.0 Lb.
4. Net buoyancy (107-65) 42.0 Lb.

Aft Section

1. Volume - 3000 Ft.³
2. Gross Lift - 197 Lb.
3. Weight
   a) 18 hard mounting points at 1.5 lb. each  27.0 Lb.
   b) Attached government hardware  38.0 Lb.
   c) Fittings and miscellaneous  25.0 Lb.
   d) Material - 260 Yd.²  65.0 Lb.
      4.0 oz./yd.² (includes 10% overage allowance)

   Total Weight  155.0 Lb.

4. Net Buoyancy (197-155)  42.0 Lb.

Obtaining balanced and neutral buoyancy, with the net buoyancy available for trim weights, will not be a problem for either the assembled or the individual sections. The existing net buoyancy will also allow consideration of alternate materials. Using a 5.2 oz./yd.² would increase the weight of the Forward section approximately 10 lb., the Aft section 20 lb. Sufficient buoyancy would remain for trimming.

The Aft section buoyancy and weight is based on using a torus to obtain a flat end on the 14 ft. diameter. This torus would weigh approximately 8 lb. The buoyancy is adequate if this torus is eliminated to consider the alternate configuration of using a structural ring to obtain a flat end as shown on figure 2.

### MATERIAL

Two different material configurations, a lamination and a coated fabric, will be considered for fabricating the STTA. A description of each is as follows:

**Lamination**

This proposed material is a lamination of polyester film and a type 68 dacron polyester fabric. The film on the outer surface would be a 0.5 mil aluminized polyester film. The inner surface would be a 0.75 mil clear polyester film. The ultimate tensile strength is approximately 110 lb./in. The maximum weight will be 4.0 oz./yd.². A computed factor of safety at a pressure of 4.0 inches of water is 12.7.

**Coated Fabric**

This proposed material would consist of the same base fabric as used in the lamination. The fabric would be coated with 3 oz./yd.² of polyurethane. The coating on the outer surface would have a polished aluminum
appearance. The strength would, with the same base fabric being used, be the same as the lamination. Total weight would be approximately 5.2 oz./yd.².

Either of the proposed material configurations will meet all of the requirements of the statement of work. There are advantages and disadvantages to be considered with both with respect to ease of fabrication. Functionally they will be very similar. A Kevlar base fabric was considered but discounted on the basis of reported field experience.

Samples of similar material configurations are enclosed as figures 6 and 7.

The decision on the material will be made at the time of the preliminary design review. NASA's preference will be a factor in the decision.

3.0 MANAGEMENT

3.1 GENERAL

The proposed program will be conducted within the Applied Technology Division of Raven Industries. Mr. James A. Winker is a Vice-President of Raven Industries and manager of the Applied Technology Division. The latest annual report of Raven Industries is enclosed with this proposal.

3.2 PROGRAM MANAGEMENT

The primary program management will be assigned to the engineering group. Mr. Patrick J. Cannon is the Engineering Group Manager. The program will be conducted on a project basis with an assigned project engineer from within the engineering group. Assignment of the project engineer will be made at the time of contract award and would be dependent upon existing requirements at that time. The engineering group will have the total technical responsibility as well as data management, documentation and conference requirements.

Fabrication will be coordinated with Mr. K. L. Tekrony, Production Manager for the Applied Technology Division.

Resumes of key personnel that may be assigned to the program are enclosed in Appendix A.
3.3 PROGRAM SCHEDULE/PLAN

A program schedule outlining the major tasks to be accomplished is enclosed as figure 3. A discussion of the tasks is presented in the following paragraphs of this section.

3.3.1 INITIAL INTERFACE MEETING

A primary objective of this meeting will be to critique Raven's proposed configuration with respect to the requirements of the statement of work and resolve any deficiencies or questions in the proposed program and/or interpretations of the statement of work. This meeting is proposed to be held at Raven's facility in Sioux Falls.

3.3.2 SYSTEM DEFINITION

The proposed configuration will be modified in accordance with the determinations of the initial interface meeting. Detail design of components will be initiated.

3.3.3 PRELIMINARY DESIGN REVIEW

The system as defined and design accomplished under task 3.3.2. will be reviewed. A major objective will be to finalize the material configuration.

3.3.4 MATERIALS PROCUREMENT

The proposed polyester base fabric is a long lead time item. It is proposed that this material be ordered upon receipt of contract since it will be used regardless of the final material configuration. The decision as to whether the fabric will be coated or laminated will be made at the time of the preliminary design review.

3.3.5 DETAILED DESIGN AND TESTING

The detailed design will be completed under this task. Tests will be accomplished as necessary to verify designed configurations are functional.
3.3.6. CRITICAL DESIGN REVIEW

The final detailed design and results of tests will be presented as well as the status of purchased material.

3.3.7. DESIGN MODIFICATION

Any design modifications that may result from 3.3.6. will be accomplished.

3.3.8. FABRICATION

3.3.9. FINAL ASSEMBLY AND CHECKOUT

3.3.10. DELIVERY

3.3.11. INSTALLATION

3.3.12. SUBMIT FINAL REPORT & PROGRAM END

4.0 BACKGROUND

The Applied Technology Division of Raven is a major designer and fabricator of inflatables. The products range from polyethylene zero pressure balloons to heavy lift balloons utilized in the logging industry.

More different configurations of materials are utilized by Raven than probably any other single balloon manufacturer. The materials range from 0.5 mil polyester films to coated fabrics weighing approximately 16 oz./yd².

Raven is very familiar with the requirements of NASA for simulated payloads. Raven has previously worked with NASA in the design and fabrication of two previous simulated payloads. We are confident of our proposed approach to this requirement.
FIGURE 3
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TYPICAL LATCH, FORWARD/AST INTERFACE

FIGURE 4
# Tasks and Manpower Loading

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## Labor Categories & Hours

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<td>120</td>
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<td>5. MACHINE SHOP</td>
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<td></td>
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<td></td>
<td></td>
<td>80</td>
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</tbody>
</table>

MONTHLY TOTALS

| MONTHLY TOTALS          | 210 | 250 | 250 | 120 | 180 | 310 | 180 | 352 | 120 |     |    |    | 1972         |

**FIGURE 8**
APPENDIX G

STTA Alternate Sizing Analysis
# ORIGINAL FORWARD SECTION

<table>
<thead>
<tr>
<th>SECTION</th>
<th>SURFACE AREA</th>
<th>VOLUME</th>
<th>C/L (FROM FREE END)</th>
<th>LAYOUT DIMENSIONS</th>
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</thead>
<tbody>
<tr>
<td>END TORUS</td>
<td>77.44 ft²</td>
<td>16.62 ft³</td>
<td>5.15&quot;</td>
<td>1.04</td>
</tr>
<tr>
<td>END % TORUS</td>
<td>123.77 ft²</td>
<td>29.27 ft³</td>
<td>17.28&quot;</td>
<td>9.68</td>
</tr>
<tr>
<td>8&quot; DIA TUBE</td>
<td>572.47 ft²</td>
<td>117.11 ft³</td>
<td>127.81&quot;</td>
<td>100.11</td>
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<tr>
<td>END % TORUS</td>
<td>123.77 ft²</td>
<td>29.27 ft³</td>
<td>17.28&quot;</td>
<td>9.68</td>
</tr>
<tr>
<td>END TORUS</td>
<td>77.44 ft²</td>
<td>16.62 ft³</td>
<td>5.15&quot;</td>
<td>1.04</td>
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<tr>
<td>END PANEL</td>
<td>68.42 ft³</td>
<td>-</td>
<td>-</td>
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</tr>
<tr>
<td>SKIRT</td>
<td>65.45 ft²</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SKIRT</td>
<td>65.45 ft²</td>
<td>-</td>
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</tr>
<tr>
<td>END PANEL</td>
<td>68.42 ft³</td>
<td>-</td>
<td>-</td>
<td>-</td>
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</table>

*1181.83 ft², 1422.84 ft³
+ 5% SCANS...
1240.52 ft²

= 127.88"

<table>
<thead>
<tr>
<th>OBJECT WT</th>
<th></th>
<th>MOUNTING HARDWARE</th>
<th>HELIUM LIST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cable and Spools</td>
<td>6.4</td>
<td>12 x 12 Velcro = 0.025 lbs</td>
<td>0.0275 lbs/ft³</td>
</tr>
<tr>
<td>Total Hardware</td>
<td>23.25</td>
<td>Hard ps rings = 1.25 lbs</td>
<td>@ 5L, 85°F</td>
</tr>
<tr>
<td>Trim WT</td>
<td>10.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fabric WT @ 520/yo</td>
<td>44.31</td>
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<tr>
<td></td>
<td>84.96 lbs</td>
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ORIGINAL PAGE IS OF POOR QUALITY
**ORIGINAŁ FORWARD SECTION**

<table>
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<tr>
<th>POINT</th>
<th>WEIGHT</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
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The moments in the x axis equal -800.432
The moments in the y axis equal 91
The moments in the z axis equal 0
**ORiGInAL AFT SECTiON**

<table>
<thead>
<tr>
<th>SECTION</th>
<th>SURFACE AREA (ft²)</th>
<th>VOLUME (ft³)</th>
<th>C/L (FROM SM ENDO)</th>
<th>LIFT</th>
<th>MOMENT</th>
<th>DIMENS.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM END TOR.</td>
<td>78.80</td>
<td>17.24</td>
<td>5.25</td>
<td>1.08</td>
<td>5.67</td>
<td>R=505 R=52</td>
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<tr>
<td>10' SM. 1/2 TOR</td>
<td>123.37</td>
<td>154.21</td>
<td>17.28</td>
<td>9.68</td>
<td>16.727</td>
<td>R=60 R=2075</td>
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<tr>
<td>10' TUBE</td>
<td>526.22</td>
<td>1320.45</td>
<td>130.50</td>
<td>82.86</td>
<td>1083.23</td>
<td>R=72 R=12</td>
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<tr>
<td>MID TURNTS</td>
<td>236.87</td>
<td>114.43</td>
<td>73.25</td>
<td>7.43</td>
<td>544.25</td>
<td>R=72 R=1015</td>
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<tr>
<td>14' OUTER CYL.</td>
<td>641.41</td>
<td>981.12</td>
<td>161.12</td>
<td>61.56</td>
<td>9918.55</td>
<td>R=72 R=1015</td>
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<tr>
<td>10' LG 1/2 TOR</td>
<td>133.37</td>
<td>164.21</td>
<td>243.72</td>
<td>9.68</td>
<td>2359.21</td>
<td>R=70 R=12</td>
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<tr>
<td>LG ENOTOR</td>
<td>268.67</td>
<td>156.73</td>
<td>297.0</td>
<td>9.83</td>
<td>2928.01</td>
<td>R=70 R=12</td>
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**C/L = MOMENTS/LIFT**

= 2623.11/182.12

= 144.06

**OBJECT WT.**

- CABLE AND SPOOLS: 6.4
- TOTAL HARDWARE: 106.0
- TAIM WT: 10.0
- FABRIC WT @ 52°: 85.90

**MOUNTING HARDWARE**

- 12 x 12 VELCRO: 0.0625 lbs
- HARD PR ANGS: 1.25 lbs
- INTERFACE MATS: 2.25 lbs

**HELIUM LIFT**

- 0.6275 lb/5°F
- @ 5°F 85°F

**ORIGINAL PAGE 19**

OF POOR QUALITY
## ORIGINAL AFT SECTION

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The moments in the X axis equal -4611.87
The moments in the Y axis equal 203.1
The moments in the Z axis equal 6.10352E-05

ORIGINAL PAGE IS
OF POOR QUALITY
THE MOMENTS IN THE X AXIS EQUAL 1531.18
THE MOMENTS IN THE Y AXIS EQUAL 294.1
THE MOMENTS IN THE Z AXIS EQUAL 6.10352E-05

C/L = 302.29

: GROSS BALANCE 7/14/85
LEN:\N CHANGES 5' INC.

FOR AN ADDED LENGTH OF 0 FT:
SURFACE AREA = 1998.71 SQUARE FEET
VOLUME = 2902.39 CUBIC FEET
LIFT = 182.125 LBS
C/L IS LOCATED AT 144.062 INCHES FROM THE SMALL END

FOR AN ADDED LENGTH OF .5 FT:
SURFACE AREA = 2024.41 SQUARE FEET
VOLUME = 2911.68 CUBIC FEET
LIFT = 184.597 LBS
C/L IS LOCATED AT 145.144 INCHES FROM THE SMALL END

FOR AN ADDED LENGTH OF 1 FT:
SURFACE AREA = 2051.08 SQUARE FEET
VOLUME = 3020.1 CUBIC FEET
LIFT = 187.053 LBS
C/L IS LOCATED AT 152.198 INCHES FROM THE SMALL END

FOR AN ADDED LENGTH OF 1.5 FT:
SURFACE AREA = 2077.1 SQUARE FEET
VOLUME = 3130.01 CUBIC FEET
LIFT = 191.982 LBS
C/L IS LOCATED AT 160.225 INCHES FROM THE SMALL END

FOR AN ADDED LENGTH OF 2 FT:
SURFACE AREA = 2061.51 SQUARE FEET
VOLUME = 3059.47 CUBIC FEET
LIFT = 191.982 LBS
C/L IS LOCATED AT 168.151 INCHES FROM THE SMALL END

FOR AN ADDED LENGTH OF 2.5 FT:
SURFACE AREA = 2077.21 SQUARE FEET
VOLUME = 3169.74 CUBIC FEET
LIFT = 194.446 LBS
C/L IS LOCATED AT 164.91 INCHES FROM THE SMALL END

FOR AN ADDED LENGTH OF 3 FT:
SURFACE AREA = 2091.91 SQUARE FEET
VOLUME = 3130.01 CUBIC FEET
LIFT = 196.911 LBS
C/L IS LOCATED AT 168.151 INCHES FROM THE SMALL END

FOR AN ADDED LENGTH OF 3.5 FT:
SURFACE AREA = 2107.8 SQUARE FEET
VOLUME = 3177.28 CUBIC FEET
LIFT = 199.374 LBS
C/L IS LOCATED AT 172.078 INCHES FROM THE SMALL END

FOR AN ADDED LENGTH OF 4 FT:
SURFACE AREA = 2124.31 SQUARE FEET
VOLUME = 3216.55 CUBIC FEET
LIFT = 201.839 LBS
C/L IS LOCATED AT 175.982 INCHES FROM THE SMALL END

FOR AN ADDED LENGTH OF 4.5 FT:
SURFACE AREA = 2140.01 SQUARE FEET
VOLUME = 3255.82 CUBIC FEET
LIFT = 204.303 LBS
C/L IS LOCATED AT 179.665 INCHES FROM THE SMALL END

FOR AN ADDED LENGTH OF 5 FT:
SURFACE AREA = 2155.71 SQUARE FEET
VOLUME = 3295.09 CUBIC FEET
LIFT = 206.767 LBS
C/L IS LOCATED AT 183.726 INCHES FROM THE SMALL END

FOR A C/L LOCATED 144.062 INCHES FROM THE SMALL END:
THE MOMENTS IN THE X AXIS EQUAL-5923.89 50.22 LBS
THE MOMENTS IN THE Y AXIS EQUAL 471.5
THE MOMENTS IN THE Z AXIS EQUAL-1750.2

FOR A C/L LOCATED 145.144 INCHES FROM THE SMALL END:
THE MOMENTS IN THE X AXIS EQUAL-5835.93 47.17 LBS
THE MOMENTS IN THE Y AXIS EQUAL 471.5
THE MOMENTS IN THE Z AXIS EQUAL-1750.2

FOR A C/L LOCATED 152.198 INCHES FROM THE SMALL END:
THE MOMENTS IN THE X AXIS EQUAL-5746.17 47.17 LBS
THE MOMENTS IN THE Y AXIS EQUAL 471.5
THE MOMENTS IN THE Z AXIS EQUAL-1750.2

FOR A C/L LOCATED 155.255 INCHES FROM THE SMALL END:
THE MOMENTS IN THE X AXIS EQUAL-5654.67 47.17 LBS
THE MOMENTS IN THE Y AXIS EQUAL 471.5
THE MOMENTS IN THE Z AXIS EQUAL-1750.2

FOR A C/L LOCATED 160.225 INCHES FROM THE SMALL END:
THE MOMENTS IN THE X AXIS EQUAL-5561.42 47.17 LBS
THE MOMENTS IN THE Y AXIS EQUAL 471.5
THE MOMENTS IN THE Z AXIS EQUAL-1750.2

FOR A C/L LOCATED 164.91 INCHES FROM THE SMALL END:
THE MOMENTS IN THE X AXIS EQUAL-5466.55 47.17 LBS
THE MOMENTS IN THE Y AXIS EQUAL 471.5
THE MOMENTS IN THE Z AXIS EQUAL-1750.2

FOR A C/L LOCATED 168.151 INCHES FROM THE SMALL END:
THE MOMENTS IN THE X AXIS EQUAL-5370.14 47.17 LBS
THE MOMENTS IN THE Y AXIS EQUAL 471.5
THE MOMENTS IN THE Z AXIS EQUAL-1750.2

FOR A C/L LOCATED 172.078 INCHES FROM THE SMALL END:
THE MOMENTS IN THE X AXIS EQUAL-5272.17 47.17 LBS
THE MOMENTS IN THE Y AXIS EQUAL 471.5
THE MOMENTS IN THE Z AXIS EQUAL-1750.2

FOR A C/L LOCATED 175.982 INCHES FROM THE SMALL END:
THE MOMENTS IN THE X AXIS EQUAL-5172.71 38.91 LBS
THE MOMENTS IN THE Y AXIS EQUAL 471.5
THE MOMENTS IN THE Z AXIS EQUAL-1750.2

FOR A C/L LOCATED 179.865 INCHES FROM THE SMALL END:
THE MOMENTS IN THE X AXIS EQUAL-5071.9 37.95 LBS
THE MOMENTS IN THE Y AXIS EQUAL 471.5
THE MOMENTS IN THE Z AXIS EQUAL-1750.2

FOR A C/L LOCATED 183.726 INCHES FROM THE SMALL END:
THE MOMENTS IN THE X AXIS EQUAL-4969.67 37.95 LBS
THE MOMENTS IN THE Y AXIS EQUAL 471.5
THE MOMENTS IN THE Z AXIS EQUAL-1750.2
FOR AN ADDED LENGTH OF 5.5 FT:
SURFACE AREA = 2171.41 SQUARE FEET
VOLUME = 3334.56 CUBIC FEET
LIFT = 209.24 LBS
C/L IS LOCATED AT 187.568 INCHES FROM THE SMALL END
FOR AN ADDED LENGTH OF 6 FT:
SURFACE AREA = 2187.11 SQUARE FEET
VOLUME = 3373.63 CUBIC FEET
LIFT = 211.695 LBS
C/L IS LOCATED AT 191.385 INCHES FROM THE SMALL END
FOR AN ADDED LENGTH OF 6.5 FT:
SURFACE AREA = 2202.81 SQUARE FEET
VOLUME = 3412.9 CUBIC FEET
LIFT = 214.159 LBS
C/L IS LOCATED AT 195.192 INCHES FROM THE SMALL END
FOR AN ADDED LENGTH OF 7 FT:
SURFACE AREA = 2218.51 SQUARE FEET
VOLUME = 3452.17 CUBIC FEET
LIFT = 216.624 LBS
C/L IS LOCATED AT 198.976 INCHES FROM THE SMALL END
FOR AN ADDED LENGTH OF 7.5 FT:
SURFACE AREA = 2234.21 SQUARE FEET
VOLUME = 3491.44 CUBIC FEET
LIFT = 219.088 LBS
C/L IS LOCATED AT 202.743 INCHES FROM THE SMALL END
FOR AN ADDED LENGTH OF 8 FT:
SURFACE AREA = 2249.91 SQUARE FEET
VOLUME = 3530.71 CUBIC FEET
LIFT = 221.552 LBS
C/L IS LOCATED AT 206.493 INCHES FROM THE SMALL END
FOR AN ADDED LENGTH OF 8.5 FT:
SURFACE AREA = 2265.61 SQUARE FEET
VOLUME = 3569.98 CUBIC FEET
LIFT = 224.016 LBS
C/L IS LOCATED AT 210.226 INCHES FROM THE SMALL END
FOR AN ADDED LENGTH OF 9 FT:
SURFACE AREA = 2281.31 SQUARE FEET
VOLUME = 3609.25 CUBIC FEET
LIFT = 226.48 LBS
C/L IS LOCATED AT 213.944 INCHES FROM THE SMALL END
FOR AN ADDED LENGTH OF 9.5 FT:
SURFACE AREA = 2297.01 SQUARE FEET
VOLUME = 3648.52 CUBIC FEET
LIFT = 228.945 LBS
C/L IS LOCATED AT 217.646 INCHES FROM THE SMALL END
FOR AN ADDED LENGTH OF 10 FT:
SURFACE AREA = 2312.71 SQUARE FEET
VOLUME = 3687.79 CUBIC FEET
LIFT = 231.409 LBS
C/L IS LOCATED AT 221.333 INCHES FROM THE SMALL END

FOR A C/L LOCATED 187.568 INCHES FROM THE SMALL END:
THE MOMENTS IN THE X AXIS EQUAL -4866.21
THE MOMENTS IN THE Y AXIS EQUAL 471.5
THE MOMENTS IN THE Z AXIS EQUAL 1750.2

FOR A C/L LOCATED 191.385 INCHES FROM THE SMALL END:
THE MOMENTS IN THE X AXIS EQUAL -4716.39
THE MOMENTS IN THE Y AXIS EQUAL 471.5
THE MOMENTS IN THE Z AXIS EQUAL 1750.2

FOR A C/L LOCATED 195.192 INCHES FROM THE SMALL END:
THE MOMENTS IN THE X AXIS EQUAL -4565.41
THE MOMENTS IN THE Y AXIS EQUAL 471.5
THE MOMENTS IN THE Z AXIS EQUAL 1750.2

FOR A C/L LOCATED 198.976 INCHES FROM THE SMALL END:
THE MOMENTS IN THE X AXIS EQUAL -4414.45
THE MOMENTS IN THE Y AXIS EQUAL 471.5
THE MOMENTS IN THE Z AXIS EQUAL 1750.2

FOR A C/L LOCATED 202.743 INCHES FROM THE SMALL END:
THE MOMENTS IN THE X AXIS EQUAL -4263.49
THE MOMENTS IN THE Y AXIS EQUAL 471.5
THE MOMENTS IN THE Z AXIS EQUAL 1750.2

FOR A C/L LOCATED 206.493 INCHES FROM THE SMALL END:
THE MOMENTS IN THE X AXIS EQUAL -4112.52
THE MOMENTS IN THE Y AXIS EQUAL 471.5
THE MOMENTS IN THE Z AXIS EQUAL 1750.2

FOR A C/L LOCATED 210.226 INCHES FROM THE SMALL END:
THE MOMENTS IN THE X AXIS EQUAL -3961.56
THE MOMENTS IN THE Y AXIS EQUAL 471.5
THE MOMENTS IN THE Z AXIS EQUAL 1750.2

FOR A C/L LOCATED 213.944 INCHES FROM THE SMALL END:
THE MOMENTS IN THE X AXIS EQUAL -3810.61
THE MOMENTS IN THE Y AXIS EQUAL 471.5
THE MOMENTS IN THE Z AXIS EQUAL 1750.2

FOR A C/L LOCATED 217.646 INCHES FROM THE SMALL END:
THE MOMENTS IN THE X AXIS EQUAL -3659.66
THE MOMENTS IN THE Y AXIS EQUAL 471.5
THE MOMENTS IN THE Z AXIS EQUAL 1750.2

FOR A C/L LOCATED 221.333 INCHES FROM THE SMALL END:
THE MOMENTS IN THE X AXIS EQUAL -3508.71
THE MOMENTS IN THE Y AXIS EQUAL 471.5
THE MOMENTS IN THE Z AXIS EQUAL 1750.2
AFT SECTION INCREASED BY 5.5 FEET

<table>
<thead>
<tr>
<th>SECTION</th>
<th>SURFACE AREA</th>
<th>VOLUME</th>
<th>C/A (FROM SMALL END)</th>
<th>LIFT</th>
<th>MOMENT</th>
<th>R cref/r max</th>
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<tbody>
<tr>
<td>3M END FORK</td>
<td>79.80 ft²</td>
<td>17.24 ft³</td>
<td>5.25&quot;</td>
<td>1.08</td>
<td>5.67</td>
<td>R: 547° r: 25°</td>
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<tr>
<td>3M END TBE</td>
<td>133.37 ft²</td>
<td>159.21 ft³</td>
<td>17.28&quot;</td>
<td>2.18</td>
<td>167.27</td>
<td>R: 30 r: 30</td>
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<tr>
<td>10' FORK</td>
<td>149.0 ft²</td>
<td>147.51 ft³</td>
<td>163.5&quot;</td>
<td>109.66</td>
<td>1792.80</td>
<td>R: 60 L: 667</td>
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<tr>
<td>M10 FORK</td>
<td>224.87 ft²</td>
<td>117.43 ft³</td>
<td>131.2%</td>
<td>213</td>
<td>1034.63</td>
<td>R: 76 L: 12</td>
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<tr>
<td>M14 O/B</td>
<td>211.41 ft³</td>
<td>98.12 ft³</td>
<td>227.12&quot;</td>
<td>61.56</td>
<td>1391.51</td>
<td>R: 84 L: 115.6</td>
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<tr>
<td>1.0 SIGN</td>
<td>123.37 ft²</td>
<td>154.21 ft³</td>
<td>309.72</td>
<td>768</td>
<td>2590.17</td>
<td>R: 30 r: 30</td>
</tr>
<tr>
<td>1.0 END FORK</td>
<td>249.67 ft²</td>
<td>156.73 ft³</td>
<td>313.0&quot;</td>
<td>9.83</td>
<td>2972.79</td>
<td>R: 70 r: 14</td>
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<tr>
<td>2171.49 ft³</td>
<td>3329.45 ft³</td>
<td>313.0&quot;</td>
<td>9.83</td>
<td>2972.79</td>
<td>R: 70 r: 14</td>
<td></td>
</tr>
</tbody>
</table>

| 3M END SHTT  | 15.48 ft²    |        |                    |      |         | C/A: MOMENTS/LIFT |
| 3M END PNE   | 16.12 ft²    |        |                    |      |         | = 3919.76/209.92 |
| M10 END SHTT | 28.36 ft²    |        |                    |      |         | = 187.6"  |
| 1.0 END PNE  | 106.9 ft²    |        |                    |      |         |                |
| 267.13 ft²   |            |        |                    |      |         |                |

OBJECT WT
- CABLE AND SPANS 6.6 -
- TOTAL HARDWARE 96.03
- TRIM WT 10.0
- MFG WT 86.76
- SLACKLINE WT 2.7 5.55
- 204.44

EXCESS LIFT 4481 ft + 10 lbs trim wts

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**Forward Section Decreased by 5.5 Feet**

<table>
<thead>
<tr>
<th>SECTION</th>
<th>Surface Area</th>
<th>Volume</th>
<th>C/L (from front end)</th>
<th>Lift</th>
<th>Moment</th>
<th>C/L Moment/Lift</th>
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<tbody>
<tr>
<td>(a) End Toon</td>
<td>77.44</td>
<td>16.12</td>
<td>5.15</td>
<td>1.04</td>
<td>5.32</td>
<td>0.515:1.5415</td>
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<tr>
<td>(b) End 1/2 Toon</td>
<td>123.57</td>
<td>154.81</td>
<td>17.38</td>
<td>9.68</td>
<td>167.27</td>
<td>0.604:1.0025</td>
</tr>
<tr>
<td>10' Dia Tube</td>
<td>332.67</td>
<td>281.21</td>
<td>9.60</td>
<td>5.29</td>
<td>595.69</td>
<td>0.306:1.9670</td>
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<tr>
<td>(c) End 1/2 Toon</td>
<td>133.57</td>
<td>154.81</td>
<td>17.38</td>
<td>9.68</td>
<td>167.27</td>
<td>0.604:1.0025</td>
</tr>
<tr>
<td>(d) End Toon</td>
<td>77.44</td>
<td>15.82</td>
<td>12.80</td>
<td>1.04</td>
<td>111.98</td>
<td>0.515:1.5415</td>
</tr>
</tbody>
</table>

\[ C/L = \frac{\text{Moments}}{\text{Lift}} \]

= \frac{7087.81}{79.73}

= 90.21

**Object WT**

- Cable and Spool: 6.7 10
- Total Hardware: 20.8
- Trim WT: 10.0
- Main Fabric: 19.352
- Skin/Cover: 12.012

\[ \text{Excess Lift} = 2.76 \text{ lbs} + 10 \text{lbs Trim WT} \]

**Original Page is of Poor Quality.**
APPENDIX H

STTA Alternate Configuration Analysis
<table>
<thead>
<tr>
<th>SECTION</th>
<th>SURFACE AREA</th>
<th>VOLUME</th>
<th>$CL/(C_{x}=0.1)\text{ in.}^2$</th>
<th>LIFT</th>
<th>MOMENT</th>
<th>DIMENSIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM END TORS 78.70 Fr²</td>
<td>17.24 Fr³</td>
<td>5.25&quot;</td>
<td>1.08</td>
<td>5.67</td>
<td>$R=54.75,\text{ in.}$</td>
<td>$r=5.25$</td>
</tr>
<tr>
<td>SM END 1/2 TORS 123.37 Fr²</td>
<td>154.21 Fr³</td>
<td>17.28&quot;</td>
<td>9.69</td>
<td>167.27</td>
<td>$R=30,\text{ in.}$</td>
<td>$r=30$</td>
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<tr>
<td>10' 6&quot; SECTION 255.91 Fr²</td>
<td>637.77 Fr³</td>
<td>78.18&quot;</td>
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<td>316.18</td>
<td>$R=60,\text{ in.}$</td>
<td>$\tau=97.75$</td>
</tr>
<tr>
<td>SM END Conc 150.3 Fr²</td>
<td>394.94 Fr³</td>
<td>150.8&quot;</td>
<td>24.74</td>
<td>3730.75</td>
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<td>$\tau=97.75$</td>
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<td>14' 6&quot; SECTION 315.78 Fr²</td>
<td>1105.92 Fr³</td>
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<td>63.28</td>
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<td>$\tau=96.21$</td>
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<tr>
<td>LG END Conc 150.8 Fr²</td>
<td>394.94 Fr³</td>
<td>233.95&quot;</td>
<td>24.74</td>
<td>6772.52</td>
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<td>$\tau=96.21$</td>
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<tr>
<td>LG END 1/2 TORS 123.37 Fr²</td>
<td>154.21 Fr³</td>
<td>309.72&quot;</td>
<td>9.69</td>
<td>2913.97</td>
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<td>$\tau=96.21$</td>
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<td>LG END TORS 266.61 Fr²</td>
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<tr>
<td>MID TORS 180.70 Fr²</td>
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<td>4.13</td>
<td>5439</td>
<td>$R=75.24,\text{ in.}$</td>
<td>$\tau=96.21$</td>
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$CL=C_{r}n_{r}+C_{n}n_{n}$

$C_{L}=\text{sums over } L=182.12$

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<th>OBJECT WEIGTH</th>
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<tr>
<td>CABLE AND SPOOLS</td>
<td>10.0</td>
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<tr>
<td>TOTAL HARDWARE</td>
<td>79.73</td>
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<tr>
<td>TRIM WT</td>
<td>10.0</td>
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<tr>
<td>MAIN PANEL + 18@ 5.2</td>
<td>65.48</td>
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<tr>
<td>SKIRT PANEL + 10@ 2.7</td>
<td>11.29</td>
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<tr>
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<td>172.60</td>
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ORIGINAL PAGE IS OF POOR QUALITY
SINGLE WALL INVERTED END
ALTERNATE AFT SECTION

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<th>SECTION</th>
<th>SURFACE AREA (sq ft)</th>
<th>VOLUME (cu ft)</th>
<th>C/L (ft^3/m^3 END)</th>
<th>LIFT</th>
<th>MOMENT</th>
<th>DIMENS</th>
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<tr>
<td>10' END TOR</td>
<td>78.8</td>
<td>17.23</td>
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<td>108</td>
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<td>83.12</td>
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<td>MIO TUBUS</td>
<td>178.29</td>
<td>64.1</td>
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<td>4.02</td>
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<td>150.9</td>
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<td>423.77</td>
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<td>LARGE END</td>
<td>421.8</td>
<td>236.8</td>
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<td>LARGE END TOR</td>
<td>142.34</td>
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<td>254.25</td>
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<td>65.44</td>
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<td>SM END PANEL</td>
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<td>79.3</td>
<td>196.85</td>
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<td>MIO TWO PANEL</td>
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<tr>
<td>LG END SKIRT</td>
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<td>2066.98</td>
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C/L = moment/lift
= 256.94/174.32
= 143.38

ORIGINAL PAGE IS OF POOR QUALITY

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<tr>
<th>OBJECT WT</th>
<th>MOUNTING HARDWARE</th>
<th>HELIUM LIFT</th>
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<tr>
<td>CABLE AND SPOOLS 6.4</td>
<td>12 x 12 VELCRO = 0.0625 lbs</td>
<td>0.0625 lbs/ft^3</td>
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<td>TOTAL HARDWARE 105.45</td>
<td>HARD AT RINGS = 1.25 lbs</td>
<td>@ 5 L. 85°F</td>
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<td>TRIM WEIGHT 10.0</td>
<td>INTERFACE. MTS = 2.25 lbs</td>
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<td>FABRIC WT@529 ft 74.64</td>
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<td>196.49</td>
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<td>POINT</td>
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<tr>
<td>30</td>
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The moments in the X axis equal -4566.57
The moments in the Y axis equal 203.1
The moments in the Z axis equal 6.10352E-05
**SPHERICAL ENDED**

**ALTERNATE ART SECTION**

<table>
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<th>SECTION</th>
<th>SURFACE AREA (sq ft)</th>
<th>VOLUME (cu ft)</th>
<th>CL (from free end)</th>
<th>LIFT</th>
<th>MOMENT</th>
<th>DIMENSIONS</th>
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<tr>
<td>10' TURNS</td>
<td>140.23</td>
<td>60.13</td>
<td>10.29</td>
<td>3.77</td>
<td>38.79</td>
<td>R = 49.34</td>
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<tr>
<td>10' DIA ½ SPHERE</td>
<td>157.78</td>
<td>76.90</td>
<td>34.56</td>
<td>16.43</td>
<td>567.82</td>
<td>R = 75.31</td>
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<td>178.29</td>
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<td>70.38</td>
<td>4.92</td>
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<td>14' EJOTORUS</td>
<td>274.72</td>
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<td>246.59</td>
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<td>2554.67</td>
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<td>150.8</td>
<td>435.42</td>
<td>83.69</td>
<td>24.81</td>
<td>2076.35</td>
<td>R = 84.56</td>
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<td>14' DIA Cyl.</td>
<td>270.65</td>
<td>945.18</td>
<td>175.78</td>
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<td>307.58</td>
<td>718.38</td>
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<td>45.05</td>
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<td>R = 79</td>
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<tr>
<td>14' EWO PAN</td>
<td>106.90</td>
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<td>163.78</td>
<td>2554.77</td>
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<td>10' SKIRT</td>
<td>256.56</td>
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<td>MIDI SKIRT</td>
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<td>10' SKIRT</td>
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<td>10' EWO PANEL</td>
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\[
\text{C/L = MOMENTS/LIFT} = 2554.77/156.28 = 156.28
\]

**OBJECT WT**

- TOTAL HARDWARE WT 118.44
- FRM WEIGHT 10.00
- FABRIC WT @ 5.23 59 84.99 212.92

**MOUNTING HARDWARE**

- 12' x 12 VECRO 0.675 lbs
- HARD PT RINGS 21.25 lbs
- INTERFACE MTS 2.25 lbs

**HELIUM LIFT**

- 0.0225 lbs/ft²
- @ S.L. 85%
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THE MOMENTS IN THE X AXIS EQUAL -5426.03
THE MOMENTS IN THE Y AXIS EQUAL 203.1
THE MOMENTS IN THE Z AXIS EQUAL 6.10352E-05
NOTE: Because of its bulk, this drawing package is included as a separate package with this report.
APPENDIX J
LDEFI and STTA Service Manual
LDEPI and STTA
SERVICE MANUAL

Table of Contents

1.0 List of Special Tools and Equipment Required 1
2.0 Inflation and Assembly of the LDEPI 1
3.0 Inflation and Assembly of the STTA 3
4.0 Daily Servicing 5
5.0 Periodic Maintenance 6
6.0 Leak Detection 6
7.0 Leak and Damage Repair 7
8.0 Storage 7
LDEFI and STTA

SERVICE MANUAL

1.0 LIST OF SPECIAL TOOLS AND EQUIPMENT REQUIRED

The following is a complete list of tools and equipment required to inflate, assemble, attach equipment, repair and maintain these inflatables.

**Tools, Equipment**

- Main inflation port adaptor
- Main inflation hose with regulator
- Servicing hose with dill valve adaptor
- Pressure gauge with range of 0 to 5 inches of H₂O
- Pressure gauge with range of 0 to 3 psi
- 7/16 inch hex socket or open end (for 1/4 inch-20 attaching bolts)
- Scissors
- Acid brushes
- Rubber gloves
- Sponges and pail
- Roller

**Consumable Supplies**

- Bostik 7133 adhesive (patching adhesive)
- Reeves E119-099 adhesive (Velcro adhesive)
- THP activator
- Patching material
- Compressed helium

2.0 INFLATION AND ASSEMBLY OF THE LDEFI

2.1 The LDEFI is composed of the following pieces:

- 1 main envelope
- 2 tori
- 2 end skirts
- 2 round end panels
- 6 gross ballast shot bags

2.2 **Inflation and assembly require a minimum of two (2) people.** Begin by inflating the main envelope and two tori with helium. To inflate the main envelope, attach a large hose to the large port on the main servicing panel and fill to a pressure of **three (3) inches of water pressure**. Fill the tori by attaching a small hose with a dill valve adaptor to the dill valve on the torus. Service the tori to a pressure of **one (1) psi**.
Prior to inflation, remove as much air as possible from the envelopes to ensure maximum lift when inflated.

WARNING

Use great caution. Helium is usually under extremely high pressure, up to 3,000 psi. Pressurized gases contain a great deal of potential energy and can be dangerous.

2.3 Match the torus marked "Forward" with the end of the main envelope marked "Forward." Find the Velcro strap on the torus with the number that matches a convenient attaching patch on the main envelope. Attach the Velcro strap so that the black mark lines up with the end of the Velcro on the main envelope (see Figure 2.1).

Move around the balloon attaching each strap in the same manner. When complete, attach the remaining torus to the opposite end in the same manner.

2.4 Identify the skirt marked "Forward." Locate the black marks on the Velcro of the torus and main envelope of the forward end. Attach approximately 24 inches to the envelope Velcro. Then attach to the torus envelope. Continue around the balloon in the same manner until the skirt is attached.

NOTE

Uneven pressure on the Velcro during installation will cause wrinkling and uneven stretch.
If the ends of the skirt are uneven or do not meet, return to starting point and restretch Velcro on each edge around the balloon. Attach the remaining skirt in the same manner on the opposite end.

2.5 Identify the round end panel marked "Forward." Locate the black mark on the Velcro and the corresponding mark on the Velcro of the forward torus. Move around the circumference of the panel, attaching it to the Velcro. To verify proper orientation, check that access patches are directly in front of servicing ports. Attach remaining panel to opposite end in same manner.

3.0 INFLATION AND ASSEMBLY OF THE STTA

3.1 The STTA is composed of the following pieces:

1 forward end main envelope
1 aft end main envelope
5 tori
5 skirts
4 round end panels
1 mid panel
6 gross ballast shot bags

3.2 Inflation and assembly require a minimum of three (3) people. Begin by inflating the main envelopes and five tori with helium. The main envelopes may be filled by attaching a large hose to the large port on the main servicing panels. The tori may be filled by attaching a small hose with a dill valve adaptor to the dill valve on the torus. The envelopes should be inflated to the following pressures:

<table>
<thead>
<tr>
<th>Envelope</th>
<th>Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward main envelope</td>
<td>4&quot; $\text{H}_2\text{O}$</td>
</tr>
<tr>
<td>Aft main envelope</td>
<td>3&quot; $\text{H}_2\text{O}$</td>
</tr>
<tr>
<td>Large torus (1)</td>
<td>7&quot; $\text{H}_2\text{O}$</td>
</tr>
<tr>
<td>Mid torus (1)</td>
<td>14&quot; $\text{H}_2\text{O}$</td>
</tr>
<tr>
<td>Small tori (3)</td>
<td>35&quot; $\text{H}_2\text{O}$</td>
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</tbody>
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NOTE
Prior to inflation, remove as much air as possible from the envelopes to ensure maximum lift when inflated.

WARNING
Use great caution. Helium is usually under extremely high pressure, up to 3,000 psi. Pressurized gases contain a great deal of potential energy and can be dangerous.

3.3 To begin attaching the tori, select the large torus and match it up with the aft end of the aft envelope. Find the
corresponding mark on the Velcro of the aft end torus. Move around the circumference of the panel attaching it to the Velcro. Verify correct orientation by checking that access panels are directly over servicing ports. In the same manner, attach the remaining end panels and the mid panel. Both Velcro index marks on the mid panel must be matched to ensure that no twist has been induced in the material.

3.6 To hook forward and aft section together, match the two ends so the trunnion mounts are all in line. Then turn both balloons so the top attaching points are accessible. Attach a turn buckle to each point. The balloons are now connected at the top point only (1 of 6). Turn the balloons back to the normal orientation. Adjust the position so that the two halves line up. When a proper alignment is achieved, attach a turn buckle to each side simultaneously. Install the remaining three turn buckles and adjust as necessary to ensure that the center lines are nearly parallel.

4.0 DAILY SERVICING

4.1 The STTA and LDEFI should be serviced daily to prevent total loss of skin tension which could cause bending of the objects and possible misalignment of tori, skirts and end panels. If the objects are not in active use, they need only be serviced to one-half (1/2) of normal operating pressure. This reduces stress and lengthens fabric and coating life.

The following is a summary of operating pressures for each object: (See Figures 4.1 and 4.2 for servicing locations of the LDEFI and STTA, respectively.)

LDEFI

Main envelope - 3" H₂O
Tori - 1 psi (28" H₂O)

Figure 4.1
5.0 PERIODIC MAINTENANCE - None

6.0 LEAK DETECTION

Three types of leaks may be found in helium inflatables: Micro leaks, small pinhole leaks and large leaks.

6.1 Micro leaks are often caused by minute holes. They may not take a direct path through the material but rather find a series of channels by which to escape. It is very difficult to find these leaks. A special apparatus must be used to detect the presence of inner gases. Such leaks do not present a problem for articles such as the STTA and LDEFI because their operating time between servicing is short.

6.2 Higher than usual loss rates for a particular envelope are the first indication of pinhole leaks. Most small pinholes will not allow enough gas to escape to need servicing more often than the required eight-hour operational period, but they should be identified and repaired. If the proximity of the leak is known, Liquid Snoop (provided in the repair kit) may be used to identify its exact location. If the proximity is unknown, the envelope may be leak-checked by going over the balloon section-by-section with a soapy water solution and watching for bubbles.
6.3 Large leaks are those too large to be detected with soapy water. High air flow blows away all the soap solution before bubble films can form. Loss of gas in a relatively short time is evidence of such leaks. The best way to locate these leaks is by sound and touch. The face tends to be more sensitive to the air flow than the hands.

7.0 LEAK AND DAMAGE REPAIR

7.1 Once a leak has been located, or if a tear has occurred, lower the pressure of that envelope to below 0 psid.

CAUTION

If a repair is attempted while the balloon is pressurized, the area to which glue is applied may become completely porous.

CAUTION

The adhesive and activator are hazardous materials. Read the labels on the cans and the enclosed safety data sheet before using.

A hole or damaged area can be repaired by making a fabric patch which, if possible, overlaps the damaged area on all sides by three inches. Apply adhesive with a small paintbrush to both the patch and damaged area. Allow the adhesive to dry completely. Apply a second coat of glue. When the second coat has dried, use a cloth to apply the activator to the adhesive on both the patch and the balloon. This seals the patch to the balloon.

When repairing a long tear, activate the glue on only a portion of the balloon and the patch at one time. The portion which has been activated should then be pressed to the envelope and rolled in place with the roller provided. Continue this process until the entire patch has been secured to the balloon.

NOTE

The adhesive provided, Bostik 7133, has a shelf life of six (6) months. Once the shelf life has been passed, the adhesive may not dry properly, and this may enlarge the damage area.

8.0 STORAGE

8.1 If the envelope is stored inflated or partially inflated, the pressure should be kept near or below 0 psid to provide longest service life.
CAUTION

Changes in atmospheric pressure may cause overpressurization of some or all of the envelopes.

8.2 If the balloon is deflated and packed in a crate, use extreme care to ensure that hardware does not damage the fabric. The envelope should be folded and stored in a low or normal humidity area at temperatures between 50°F and 80°F.