LOW SIGNATURE TENT STRUCTURES

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ABSTRACT

. Tension Systems has developed structures for lightweight tents that can provide the enclosure of very large volumes with low structural mass, and exhibiting low multispectral signatures. We believe these are the first tent designs in which low signature is derived from fundamental design rather than pigments and camouflage nets. The design is basically a double skinned aspensional structure in which the inner and outer skins contribute integrally to the rigidity of the whole. Additionally, the design is a clear-span tent—requiring no interior support poles. The design is not inflatable—requiring no compressed air source to erect or maintain. Modeling shows that visual, near infrared, thermal, and radar signatures should be reduced when compared to other current tent designs. A brief treatise on the role of tent signatures and their results is included

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1.0 INTRODUCTION

Tension Systems L.L.C. is a small company, based in Madison, Alabama, that researches and designs innovative structures and their application to military and transportation infrastructures As part of an independent R & D Program, they are developing the design of a stealthy, energy-efficient portable enclosures for personnel and equipment. In short, they are low-signature tents.

This work is an outgrowth of the author's previous work with tent manufacture and design at Teledyne Brown Engineering. Teledyne recently decided to divest itself of its Fabricated Products Division—which provided the manufacturing base to support any research and development of new tent designs. It turns out that the R & D personnel familiar with tents were also the personnel most familiar with CCD research and development—probably owing to the textile engineering common to both subjects. Regardless, the two areas became intertwined in the minds of those individuals, and concepts for low-signature tents evolved.

Unfortunately, the loss of the manufacturing base meant the loss of corporate interest in further developing any of the low-signature tent concepts. So, with Teledyne's blessing (or, at least, complete disinterest) some of those individuals formed Tension Systems LLC with the idea of further developing some of their concepts into designs and prototypes.

It turns out that the same technology used for these tents can be applied for a variety of other structural problems, such as: portable blast shielding, lightweight crash barriers, environmental sequestration, and agricultural containment. We have secured government SBIR funding for some of these developments.

2.0 ASPENSIONAL DESIGN

"Aspensional" is a word coined by R. Buckminster Fuller around 1961[1] (USPTO Patent #) to describe a method of inverting the structural principles of suspension bridges to create structures that use gravity to arch up and over, rather than down and under. It is closely related to tensile integrity, or tensegrity, as exemplified in the sculptures and patents of Kenneth Snelson. Many consider it, in fact, to be a subset of the structural principles encompassing tensegrity. It bears no relationship at all to Carlos Casteneda. Shortly thereafter, Fuller got busy with geodesic domes, and practical uses of his aspensional principles languished.

Tensegritic structures are the most efficient, in terms of strength to weight ratios, than any structural principle known. The truth of this claim is implied by the fact that nature uses tensegrity to build the cells of living plants and animals[2]. Therefore, one might also claim that tesegritic structure is also the most pervasive structural principle on earth.

The basic principle of aspension is the use of multiple tension elements to raise and support compressional members. This is shown in figure 1. Multiple tension-only elements (strings) stabilize compressional elements (sticks or tubes) in three-dimensions. The structure must be anchored to some load sink (usually the ground, or some other rigid body). These elements are stackable, so that large structures can be made. The tensile elements on the outside and inside of the surfaces so made can be fabric – thus creating an enclosure with a space in between. This space creates a lot of dead-air volume that greatly reduces the amount of heat transfer between the inside and outside surfaces.

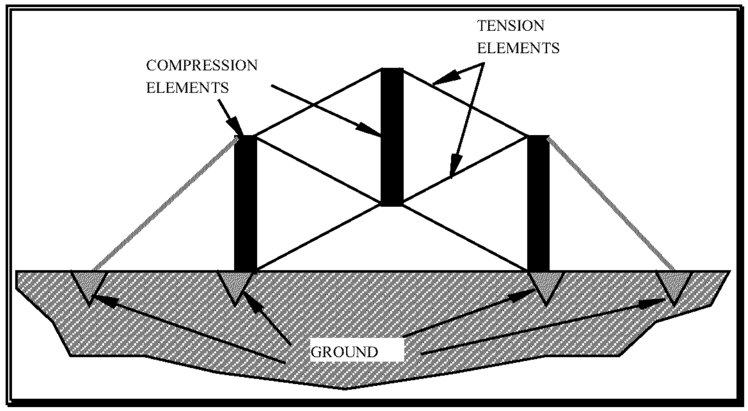

Figure 1. Basic Aspensionl Element Cell

Figure 2 shows a rendered image just such an aspensional structure . This is a prototype tent design that we have built and tested as proof of principle that the structure works – it's hard to believe it could stand up if you just look at computer drawings. The outer tension elements form the white skin on the outside, while the inner tension elements form the yellow skin on the inside surface. The compression elements are magenta, while the remaining lifting and stabilizing tension elements appear as white strings stretching from top to bottom of adjacent compressional elements.

Since the structural cells repeat, there are only a few different lengths of string, tubing, and fabric triangles that make up the complete structure. Therefore, there is no need for lots of non-repeatable operations to create the whole thing.

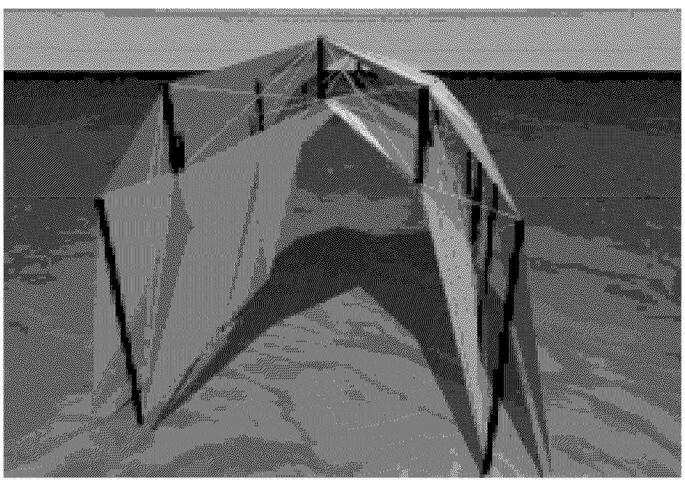

Figure 2. Rendered Aspensional Structure

It turns out that the air space between the inner and outer layers can be manipulated to provide a very energy efficient tent. We have determined that, by using low-emissivity fabric coatings on the inside surfaces of the air space, coupled with some very rudimentary insulation in the inner liner, we can produce tents requiring very little energy to heat or cool – a 2-ton heat pump providing livable conditions inside (10 to 35 C) for extreme outside temperatures (-40 to 60 C).

We show in figures 3 and 4 the cross section and half-cross section of a tent designed along these lines for the Air Force Medium Tent Program. This was not proposed for that program – we merely used the requirements for that program for the design to see just how well aspensional tents might fulfill typical military tent requirements. The floor area of the tent is approximately 30' x 50'. This tent weighs just over 89 pounds. It supports a 10 lb/ft^2 snow load.

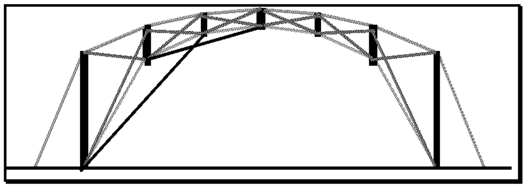

Fig. 4. AF Medium Tent Structure
Cross-Section

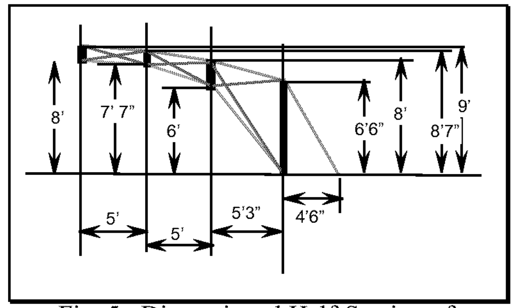

Fig. 5. Dimensioned Half-Section of
AF Medium Tent

4.0 SIGNATURE ASPECTS OF THE DESIGN

First we rendered an image of our medium tent design, as shown in figure 6. As one can see, it looks pretty conventional from the outside, except for the faceted top. The facets of the tent are all one of 16 angles, and no facet forms a right angle with any other facet or with the ground.

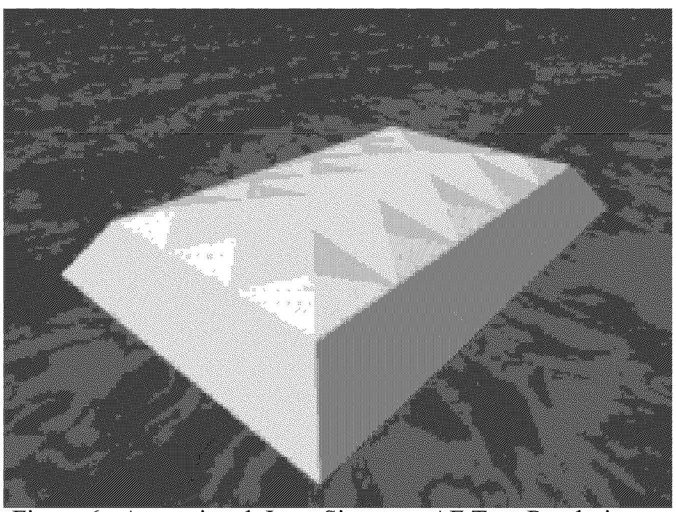

Figure 6. Aspensional, Low-Signature AF Tent Rendering

The compression elements of the structure are fiberglass tubing. The lifting and stabilizing elements are made of Vectran liquid crystal cordage. The outside skin is ripstop nylon. The inner liner is a sandwich of aluminum foil, foamed polyethylene, and vinyl so arranged that the white, diffuse vinyl serves as the inside surface of the tent. All seams are heat sealed.

Radar signature is controlled by the a combination of facet geometry and aluminum skin on the inside liner. The outside liner is radar transparent, but can be made to be slightly radar scattering.

Thermal signature is controlled by using a lightweight, partially transparent outer skin. Such a skin remains very near ambient air temperature even during solar loading. Through this outer liner, the aluminum skin of the inner liner is just visible (20-40%). The inner lining skin, then, appears as a low emissivity surface radiating very little and reflecting the background radiation (outer skin and sky). The effect is to give the tent an apparent temperature somewhere between ambient air temperature and background sky temperature. Figure 7 shows the radiant signatures making up the tent's apparent temperature.

The tent's signature in the near infrared and visible is governed simply the dyes and/or pigments used for the outer skin.

The outer skin is assembled from each individual facet, so that each piece going into the skin is small enough to be easily handled by one person. Therefore, printing the unassembled pieces is easy accomplished, and a disruptive camouflage pattern can be included in the final assembly.

The double-skin construction allows doorways to be configured in each layer. Therefore light security can be provided by allowing only one of the two doors to be opened at a time. Heat sealing of seams also reduces pinholes allowing light escape.

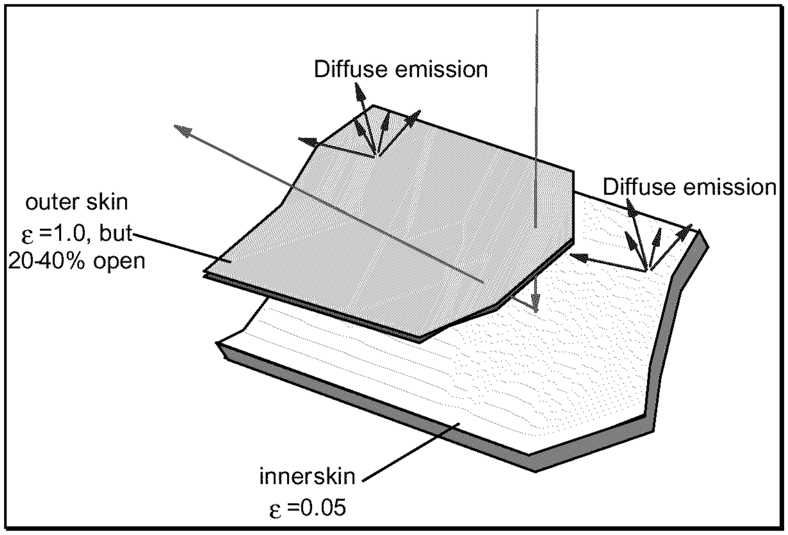

Figure 7. Radiant Processes Through Tent Skins

Well, when we put all this together, we hopefully get a tent like that shown in Figure 8. Actually, since this is a rendered image, we kind of cheated. We used the same texture as the background in this figure, but we just scaled it differently. Notice, however, that the biggest signature cue is the shadow of the long wall of the tent. This area of the tent is dead space – not occupied – so, we could actually extend the bottom of the side wall out at a more shallow angle to reduce this shadow cue.

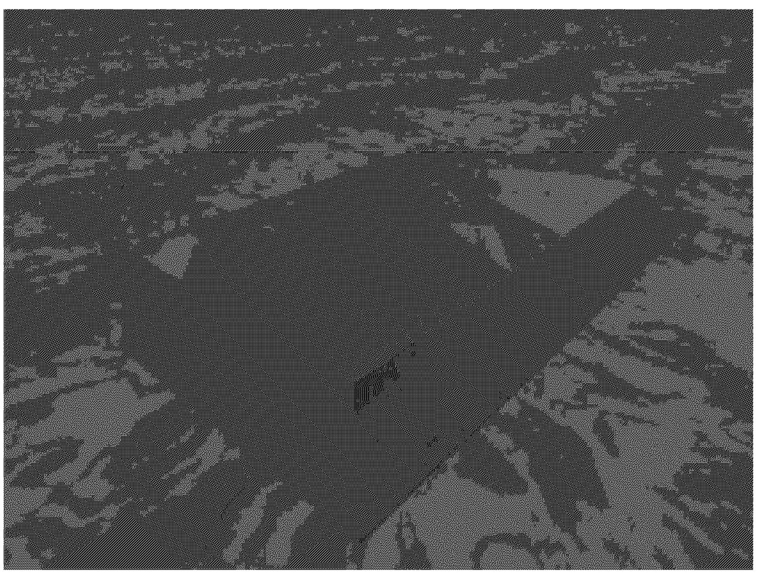

Figure 8. Total Camouflage Treatment

5.0 FUTURE EFFORTS

In FY '99, we intend to build and demonstrate the medium tent discussed above. We will be able to test it against low-light, image intensified, and thermal imagers during the year. We are currently looking for a partner, possibly under a CRADA, for radar testing of the prototype at some future date.

[1] Fuller, R. Buckminster, "Aspension (Geodesic Structures)", USPTO Patent #3,139,957, July 7, 1964

[2] Ingber, Donald E., " The Architecture of Life", *Scientific American*, January, 1998.