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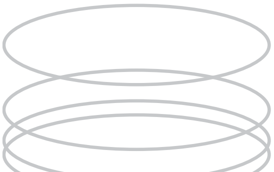

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Inflatable Structures Technology Development Overview

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Abstract

This paper gives a brief overview of the development of Precision Inflatable Space Structures during the last three decades or so. The authors cover the highlights of the work that has been done mainly in the U.S. during this time interval. This includes some of the characteristics of Space Inflatables, lessons learned in both DOD and NASA programs, current development efforts, and future outlook for this promising structures technology.

1. Introduction

There has been a lot of attention recently on the subject of Space Inflatable Structures. With space program budgets shrinking due to the tightening of the U.S. fiscal policies, NASA's motto "faster, better, and cheaper", is being heard with continuously increasing intensity. Thus, it is natural in this climate to turn one's attention to the promise that Inflatables hold. In their many configurations they are lighter, package in much smaller volumes and are much less expensive than their mechanical counterparts. Good dimensional accuracies have been attained in ground test systems and what remains is to prove they have adequate long-term strength and survivability in the space environment. Recent developments in thin film research and manufacturing techniques are helping substantially towards this end.

In the discussion that follows we describe some of the most important characteristics of Space Inflatable Structures, followed by a short historical perspective of their development, mainly at L'Garde, Inc, where significant activity in this technology has been occurring for almost 25 years. We then focus on some of the advances that have been made in the last 15 years or so, the lessons learned from the numerous suborbital space flights and sophisticated ground test systems of the much larger structures contemplated and being worked on today. We will then give a short description of some of the programs that are planned for the foreseeable future and finish with a short discussion on the needs of the Space Inflatables Technology so that the proof of their viability in space can be completed.

2. Advantages

The primary attraction of inflatable space structures has been their low weight and ease of packaging. The Department of Defense has investigated the use of inflatable space decoys for a variety of systems, and some have become operational. The inflatables in most cases were found to be optimum when compared to competing methods of deployment. The primary reasons for this were the following:

(a). The typical weight advantage of an inflatable over the best competing mechanical system was a 50% reduction. The inflatables use very thin (typically from 0.25 to 10 mil) materials which obtain their strength from the inflation gas pressure. On a different scale this was the technique that made the Atlas missile possible; it is "inflated" by its propellant to give the strength needed to survive launch.

(b). An inflatable can be packaged in a small volume typically less than 25% of that for a mechanical erectable structure. Not only is the amount of volume significantly less, but the ability to package in nearly any shape is also advantageous. In many of the DoD systems, the desired decoys were retrofit to operational systems, and the ability to use available volume nearly independently of their shape was very important.

(c). The inflatable structure is inherently strong. Much of this results from the inflatable being able to absorb loads over a large surface area. Mechanical systems typically have loads concentrated in a few points which must then be made extra heavy.

(d). The inflatable has low production cost. Inflatables normally require inexpensive tooling, and flat tables in a semi-clean environment. Because of their low weight they are easy to manipulate during manufacturing. The materials used are not exotic. For large antenna structures, the production cost is estimated to be at least a factor of ten less than competing structures.

(e). Inflatables have a high reliability of deployment. In the past 20 years of flying inflatable space structures, we have seen very few surprises in deployment behavior. Inflatables deploy very repeatably. If properly designed, they have only one point of failure— the initiation of the gas release. It is the nature of the inflatable deployed from a high pressure source, that if a system starts to hang up for some reason the deployment force continues to build up as pressure increases; the system is inherently self correcting.

(f). The engineering is less complex. Once the technology has been developed, a new application is inexpensive. This is because of the simplicity of the elements of the inflatable: flat gores of the material, seams and adhesives, some sort of package to hold it, and an inflation system. None of these elements are exotic. However, inflatables are not easily analyzed using programs like NASTRAN which were designed for systems with small deflections. When the proper tools are used, the engineering of new systems is perhaps 50% cheaper than for other deployables.

(g). Easily adapted to symmetric shapes and curved surfaces. Inflatables can be designed to closely approximate a large variety of concave shapes with no special ties and very few constraints. In zero gravity, the desired shape becomes the equilibrium shape in response to the inflation pressure.

(h). Favorable dynamics. A surface distortion in an inflatable typically must act against a nearly constant restoring force - the inflation pressure. Thus the resulting motion is not that of a simple harmonic oscillator (SHO). These modes of motion will not couple into a system attitude control because the frequency of motion depends on the amplitude of distortion. Some SHO modes of motion do exist, for instance in rigidized support structure for the inflatable. However, the effect is minimized because of the nonlinearity of the modulus and the high damping coefficients of the typical materials used.

(i). Favorable thermal response. Because of the large opposing continuous surfaces inherent in inflatables, radiation exchange can efficiently reduce temperature gradients. With the proper choice of external and internal optical properties, temperature differences of 10 K or less between a sunlit and shadowed surface element are possible, In addition, there are some new polymers being developed that have very low coefficients of thermal expansion.

Thus inflatables in many important ways are the ideal deployable structure for use in space. They have therefore been the focus of an increasing amount of R&D and interest.

3. In the Beginning

At the start of space exploration, inflatables were strong candidates for large structures. Fig. 1 shows 5 NASA inflatable satellites that were orbited in the 1960's. These devices were flown in spite of the immaturity of the technology because there was no choice; if the missions were to be done, inflatables were the only way given the capabilities of launch vehicles of that day. In general, all of these satellites were very successful. Why then did the community turn from the inflatables for their mainline efforts?

SYSTEM	WT (LB)	DIA (FT)	LAUNCH DATE	LIFE (YRS)	PURPOSE	FILM/METAL THICKNESS (MIL)
ECHO I	135	100	AUG 1960	5	COMM.	0.5 FILM/VDA
EXPLORER IX	34	12	FEB 1961	3	HI-ALT. DENSITY	0.5 FILM (2) 0.5 AL (2)
EXPLORER XIX	34	12	DEC 1963	2	HI-ALT. DENSITY	0.5 FILM (2) 0.5 AL (2)
ECHO II	580	135	JAN 1964	-	COMM.	0.35 FILM 0.18 AL (2)
PAGEOS I	149	100	JUN 1966	5	EARTH SURVEY	0.5 FILM VDA (2000 Å)

Fig. 1 NASA Inflated Thin-Film Satellites

The most probable reason for this turn to mechanically-deployed structures was the familiarity of the industry to such systems. The tools to analyze large mechanical deployables existed and there were many engineers skilled in developing even complex mechanical structures. When larger boosters became available, and recognizing that we were in a race for space, the most viable approach was to go with what could be most easily done; not necessarily the optimum.

In addition, there was some concern about how inflatables could function in space. The meteoroid threat was not well defined, and very conservative estimates were used in those days. As a result, the industry concentrated what effort it could on the inflate-then-rigidize systems. These would rigidize after inflation so that there was little concern about losing gas pressure through a meteoroid puncture over the system's life. Pioneering work on such methods was done by Avco (Ref. 1), Sheldahl (Ref. 2), Goodyear (Ref. 3), Sundstrand (Ref. 4) and others in the 60's. Contraves has developed a fully-rigidizable space antenna (Ref. 5) which however has not yet flown. Work continues on the rigidizing concepts to the present day.

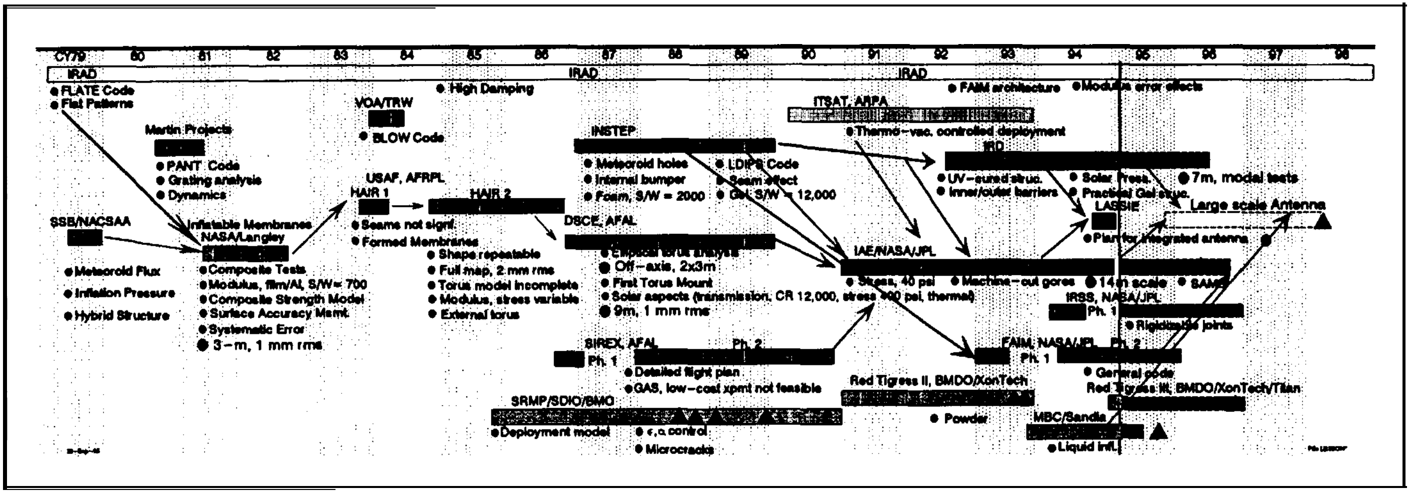

Fig. 2 Lessons Learned for Inflatable Space Antennas

However, to apply the rigidizing concept to very large precise inflatables was both very difficult and also heavy. The weight and volume advantage of the inflatables became much less significant under these constraints. Only in the last ten years, has it become obvious that the meteoroid threat was greatly over estimated. Even with the increased debris in orbit that we see today, inflatables can have long productive lives without rigidization of the primary structure; makeup gas can be economically carried for lifetimes on the order of ten years.

With this new information, and the increased emphasis on cost-effectiveness now that the "space race" has apparently ended, the industry is re-examining the inflatables for use on large deployable space structures. There have been many lessons learned during the past 15 years that apply to inflatable systems design. The next section deals with these.

4. Lessons Learned

Fig. 2 shows programs applicable to inflatable space antennas carried out by L'Garde over the past 15 years. Some of these were company funded, but most were sponsored by the government. Many lessons were learned and much experience gained during the pursuit of this technology, and these are indicated by the brief bullets under each of the programs shown. A very brief summary of each is presented in the following:

- FLATE code: showed that a solution existed for building an inflatable structure that would when inflated be accurate

- Flat Patterns: developed the method to prepare precision inflated curved surfaces from flat, seamed material

- Meteoroid flux: the discovery that the early investigators of inflatables had used fluxes three orders of magnitude too high.

- Inflation pressure: the need to reduce the pressure of large space structures to very low values near vacuum (conditions).

- Hybrid structure: the fact that hybrid structures for defining the edge of the antenna were lighter than a fully inflatable form.

- PANT code: the need to include the partial transparency of typical inflatable materials in modeling thermal effects.

- Grating analysis: the fact that the regular distortion of an inflatable antenna produced less gain **loss** than a random distortion with the same rms deviation.

- Dynamics: the non-SHO motion of the inflatable structure.

- Composite tests: **first** systematic tests to provide a data base for strength determination of **inflate/rigidize** struts.

- Modulus: the **first** indication of the difficulty of accurate modulus measurement in thin films.

- Composite strength models: **first** correlation of the strength of the aluminum-mylar composite structures.

- Surface accuracy measurement: attainment of less than 1 mm rms deviation along any chord on the very **first** inflatable antenna (3 m diameter)

- Systematic error: discovery that the primary error in inflatable antennas is systematic, gradually varying with distance.

- BLOW code: discovery that radiation pressure can cause significant penalties in the system weight of large inflatables.

- Seams not **significant:** proof that the surface error in inflatables is not due to seams.

- Formed membranes: discovery that forming membranes, rather than seaming from flat patterns, did not improve accuracy

- Shape repeatable: remounting a membrane if done carefully reproduces the same distortion pattern.

- Full map: **first** mapping of full area of **3-m** system showed surface error was actually near 3 mm rms.

- Torus model incomplete: pure compression model of torus was not adequate for even symmetric antennas

- Modulus dependency on stress: **quantified** the nonlinearity of the modulus of thin **films.**

- External torus: showed that the antenna needed to be supported by an external torus to allow for torus rigidization, thermal control of torus, and adjustment of the antenna reflector.

- High damping: measurement in a vacuum of the damping **coefficients** of typical films; 3X that of typical metals.

- Deployment model: first computer model of actual inflation event used to guarantee that the inflatable would survive the deployment.

- Meteoroid holes: tests showed that crater diameter exceeded meteoroid diameter by factor of 3.

- Internal bumper: damage on back side of inflatable is magnified by meteoroid fragmentation, requiring bumpers internal to structure.

- Foam rigidization: tests on foam showed a improved strength to weight ratio over the aluminum-mylar laminate (from 700 to 2000).

- **LDIPS** code: first finite element code designed for large deflection and precision structures.

- Seam effect: application of **LDIPS** to verify that the seams produce a minimal distortion of a precision reflector

- Water-based resin composites: use of gel-rigidized composites to get strength to weight ratios of space rigidized structures from 2000 to 12000, using special formulations.

- Elliptical torus analysis: completed the analytic description of the deformations of the load-carrying elliptical torus due to an inflatable off-axis reflector.

- First torus mount: showed that the accuracy of an inflatable antenna is not degraded when removed from a hard mount and mounted on the deployable torus. (2x3 **off-**axis reflector).

- Solar aspects: a variety of lessons concerning required surface stress, obtainable concentration ratios, film transmission, and thermal distortion for an inflatable solar concentrator

- Detailed flight plan: showed the impracticability of a small-scale demonstration flight of an inflatable precision system.

- Emissivity and absorptivity control: developed a series of methods for applying special coatings/processes to tailor the optical properties of thin **films** used for inflatables.

- Microcracks: discovered the complete loss of surface conductivity when microcracks, invisible except to an electron microscope, are allowed to form in certain metal coatings.

- Thermo-vacuum deployment: proved that sufficiently-controlled deployment of an inflatable is possible at extreme cold temperatures. No system damage.

- Stress level for antennas: discovered that **film** stress could be reduced to 40 psi (allowing wrinkles to remain) and still provide sufficient surface accuracy for MMW antennas

- **UV-cured** structure: identified some packageable and storeable candidates through testing for **inflatable-rigidizable** by ***W*** exposure, structures.

- Inner-outer barriers: for gel-type rigidized structures, both inner and outer bladders are needed to control inflation and rigidization.

- Machine-cut gores: pioneered the machine cutting of large flat gores for large reflectors.

- Solar pressure: discovered what combination of optical properties minimizes the effect of solar pressure on a inflatable space system.

- Practical Gel structure: Many techniques to obtain good quality of the gel composite structure applied to struts.

- Plan for integrated antenna: the complete picture for the development of a fully-functional inflatable space antenna.

- FAIM: extension of LDIPS to nonsymmetric cases. Ability to predict the best accuracy obtainable using various flat gores.

- Powder inflatants: extension of the Echo technology to provide inflation by powder sublimation at high pressures.

- Liquid Inflatants: extension of old decoy technology to provide inflation by liquids at very high pressure (for high deployment velocities). Learned how to package and maintain such.

- Modulus error effects: determined that the primary cause of surface error from modulus errors is the uncertainty in the ratio between transverse and longitudinal moduli.

- Rigidizable joints: discovered practical method for joining struts to form complex large inflatable structures.

- SAMS: extended the McDonnell Douglas DIR surface accuracy system to a space qualified flight unit.

Each of these items listed above is a story in itself and shows the large advancement of the development over the past 15 years.

5. The State Of the Art

In this section we describe the major areas of Space Inflatables Research and Development at L'Garde. Four classes of structures comprise the major activity areas.

Reflectors: These are usually parabolic, although the FLATE and LDIPS codes can handle a variety of conical sections. Figure 3 shows all the structural elements of a working reflector assembly: the lenticular structure is comprised of the reflecting parabolic surface and a (usually) symmetric canopy which must be transparent in the working frequency range of the reflector. They are joined together at the aperture with a strong flexible ring, thus forming a closed surface that can be inflated to shape. The number and shape of the gores are determined using the FLATE. The structural torus surrounding the aperture is attached to the it by means of adjustable ties and gives it shape stability. The torus and lens assembly is attached to the spacecraft with three inflatable cylindrical struts made of the same materials as the torus. The inflation of the system proceeds controllably from the inflation system plenum to the struts followed by inflation of the torus. The lenticular structure is inflated last at a pressure many orders of magnitude lower than the structural components.

There are two classes of reflectors that L'Garde has studied and tested: Antennas and Solar Concentrators. The structural and fabrication aspects of these reflectors are almost identical with one significant exception being the canopy. The latter requires highly transparent materials in the visible and infrared range of the spectrum to achieve the (usually) high concentration ratios required in such applications, where as antenna applications require only RF transparency, which is easily attainable with a variety of currently available films such as Kapton® or other appropriate polyimids. There are current efforts, particularly at NASA Langley Research center that are successfully addressing the subject of highly transparent polyimids (Ref. 6.). In addition to this, a conical canopy design with the focal spot of the concentrator contained inside the apex of the canopy cuts the transmissivity loss by a factor of 2 as the solar rays have to traverse the canopy only once.

With these general design guidelines in mind

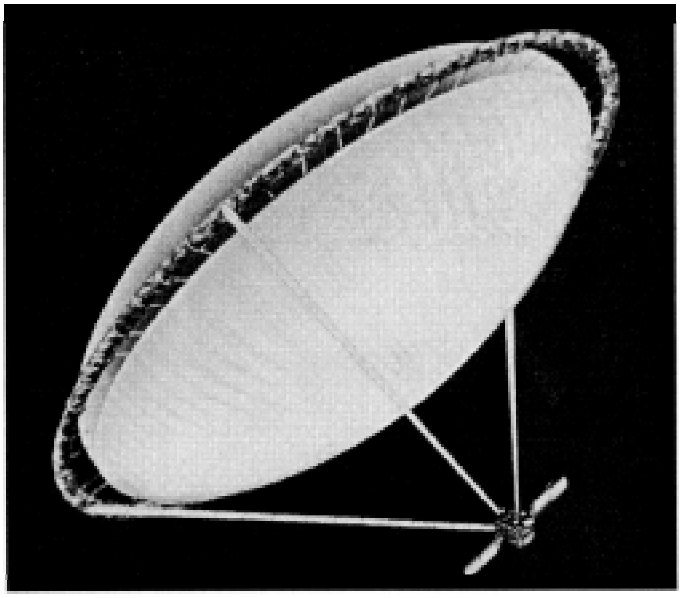

Fig. 3 Reflector Assembly

L'Garde has built and tested ground systems that exhibit lmm rms, or better, surface accuracy, This feature permits these devices to be used as high gain communications antennas in the frequency range of up to 20 or 30 GHz. In the case of concentrators, slope errors in the neighborhood of 2 mrad and concentration ratios of about 10,000 to 11,000 can be obtained with this surface accuracy figure. The high gain and excellent slope errors are obtained because the inaccuracy of these reflectors is not surface roughness, but rather, a slowly varying function of position on the surface of the reflector (Ref. 7.).

Deployment/Support Structures: These structures are mainly straight cylindrical sections of varying lengths that can be inflated to high pressures, resulting in strong, stiff beams. This class of structures has been the focus of much R&D at L'Garde during the last 10 years. They can be classed as strictly inflatable, or inflatable-rigidizable. The former are built with strong fiber materials, such as Kevlar® cloth, covered or impregnated with an elastomer that acts mainly as a pressure barrier. The purely inflatable deployment/support structures are of little interest at present as they can be used only in short-lived space flights or missions. In a matter of days or weeks the finite permeability of these membranes causes the high pressure to drop and for long term missions a large amount of make-up inflatant gas is required to sustain the structural strength and stiffness. Nevertheless, their characteristics are very well understood, and their design, fabrication and testing techniques are enough of a routine, so as to consider them off-the-shelf. It is for this reason that the short STS mission of the Inflatable Antenna Experiment (Reference 3) uses purely inflatable struts and torus (See Figure 4).

Of much more interest in this class of structures are the inflatable-rigidizable ones. In-space rigidization for these structures can occur in a variety of ways: foam injection, mechanical rigidization or chemical rigidization. Foam rigidization was studied very early at L'Garde. but uncontrollable non-uniformities in the remote foaming-in process and the superior strength-to-weight ratios exhibited by chemically rigidized structures led us to abandon this rigidization technique.

Mechanical rigidization is an improvement of the Echo satellite series rigidization. Thin aluminum foil is sandwitched between two layers of fiber re-enforced polyimid film and the resulting material is fashioned into cylindrical struts. These can be flattened and folded into successive folds occupying very limited space. A controlled, usually long inflation pulse deploys them to their original cylindrical shape and a second, overpressure pulse strains the aluminum foil. The result is a monocoque, thin walled cylinder that can take considerable compression without buckling. Figure 5 shows the L'Garde Inflatable Solar Array deployed by the inflation of, and supported by the mechanical rigidization of two 10 cm-diameter, 4 m-long tubes on either side of the solar array blanket. These tubes can take about 60lbs of compressive loading before the first sign of buckling due to cylinder surface imperfections is observed. This 275 W (Beginning Of Life) Engineering Prototype solar array was successfully tested at the Naval Research Laboratory. It deployed at a temperature of -90° C without damage to the array. and exhibited a natural frequency of 1.04 Hz. Although this rigidization method does not offer a very high strength to weight ratio, it is well developed and can accommodate a variety of space applications, such as instrument deployment and support, or solar arrays up to about 1kW total power output (and considerably more, if gallium arsenide or advanced band-gap solar cells are used) with impressive power densities. What remains to be shown for this technology is controlled deployment in space.

As mentioned above, the highest strength-to-weight ratio are the **chemically rigidized inflatable-**rigidizeable structures. Just like their purely inflatable cousins, these are also manufactured from high-strength matrix fiber cloth, but the matrix is a material that under terrestrial storage is very pliable, but when exposed to space environments it rigidizes to its predictable configuration within the desired tolerances. In L'Garde's current Inflatable Reflector Development Program, water-based resins are being researched extensively as the matrix for a variety of structural fibers. The cylindrical struts are impregnated with the resin and folded as the mechanically rigidized cylinders above, occupying a small amount of space. Upon inflation in vacuum the entrained water is allowed to evaporate at a controlled rate, leaving behind a very strong and stiff structure. Although this class of inflatable rigidizeable structures still faces some design challenges, it is a very desirable technology to develop because of the reversibility of the rigidization process: when a rigidized water-based resin is subjected to a high humidity environment it regains its original flexibility. This is very advantageous for repeated ground testing of these structures.

Much attention has also been paid to the UV-rigidized structures. The process for fabricating them is almost identical to that used in the water-based resin case, but rigidization occurs by UV ray action upon inflation. This presents some problems as UV penetrates only the outer few monolayers of the matrix material leaving the rest in the soft "prepreg" state, so the structure could fail. In addition, once deployed, the structure must be placed in a "rotisserie" mode so that all its outer surfaces may be exposed to UV rays uniformly, thus imposing undesirable constraints to the spacecraft.

Complex structures: We define as a complex structure one that has a much more complex configuration than a straight cylindrical strut or a torus fabricated of straight sylindrical segments. A truss, on the other hand, is considered to be a complex structure. There is an intensive effort underway at L'Garde to perfect the design of such inflatable-rigidizable structures, and again, a variety of high strength fibers are being investigated in this connection, including graphite and Kevlar®. Moduli of over 1 million psi have been measured using the apparent thickness of these thin resin-impregnated cloths. With more work, these numbers can increase further making the pay-off of this technology enormous: Large and complex space structures can be deployed quickly and reliably with minimal involvement of either flight or ground crew. This can turn substantial space construction projects into reachable goals in the not too distant future.

Space Targets and Decoys: Last. but still first at L'Garde, this class of structures continues to employ much of our attention. There is still much DOD activity in this area and these precursors of the Space Inflatable Structures Technology are still launched, from the simplest to the most sophisticated and instrumented configurations. The data from these flights continue to provide us with much information on the behavior of Inflatable Structures in Space.

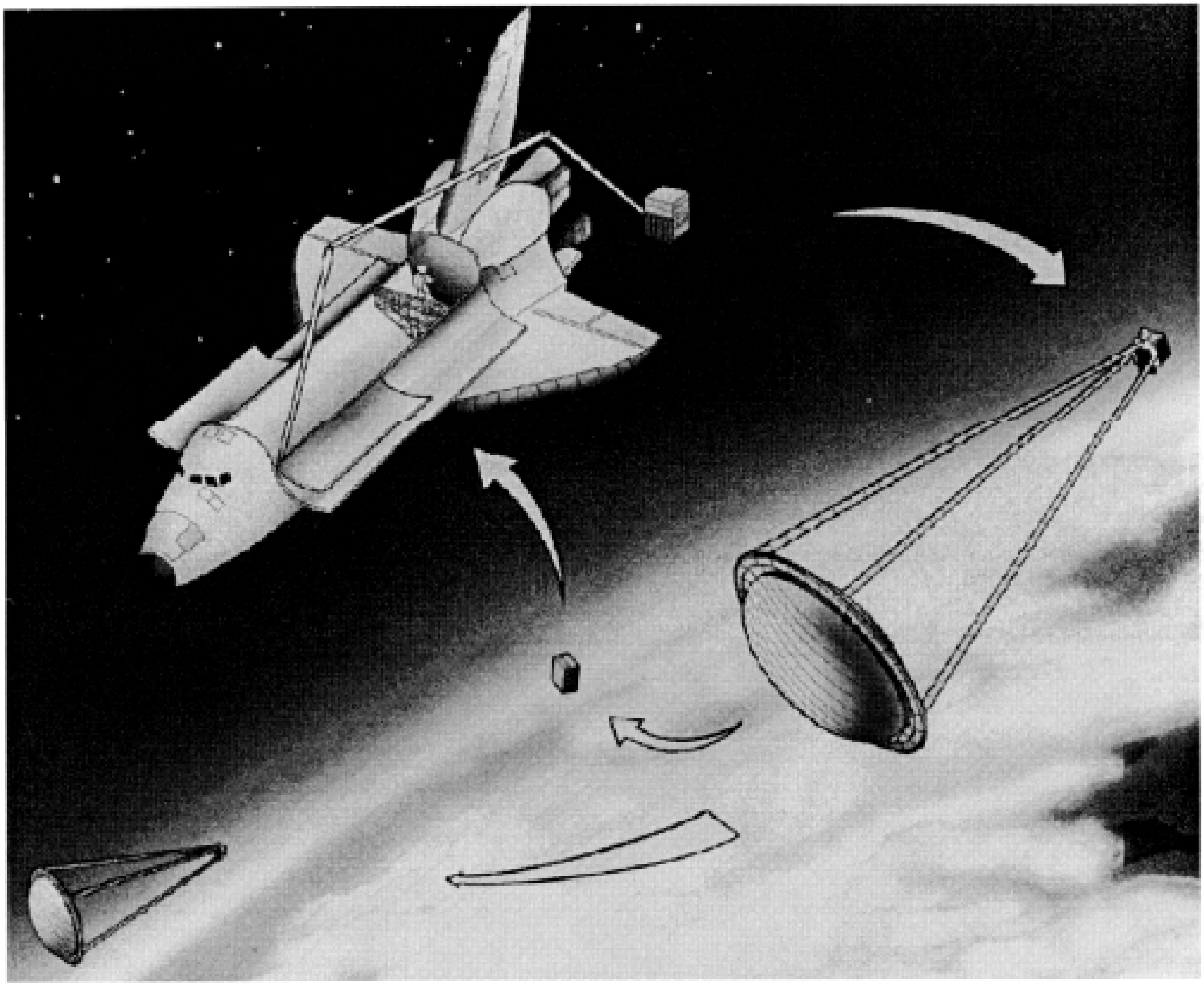

Fig. 4 Inflatable Antenna Experiment

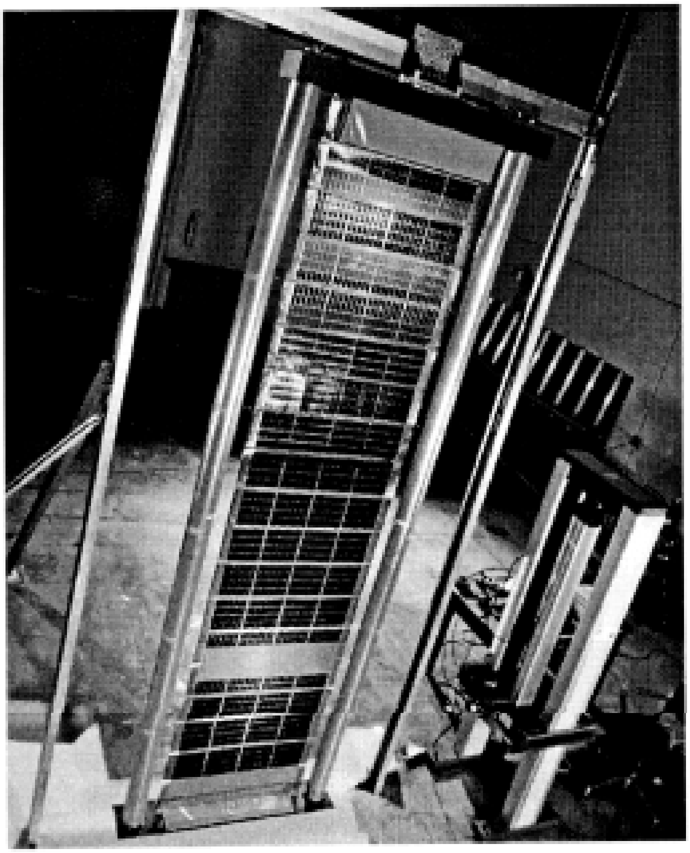

Fig. 5 Inflatable Solar Array

6. The Next Five Years

There is a Technology Roadmap that is being adhered to at L'Garde. In this section we discuss some of the programs that are already under way and those that are planned for the next five years. All of these have one objective: To bring the development of the Inflatable Space Structures to the point they will be flown with confidence, yield the expected results, while at the some time fulfill the promise of the Technology: Smaller, Better, Faster and above all, Cheaper. These programs are:

(a). A 3 m ground test system will be measured for both surface accuracy mapping and near-field beam patterns. Far-Field beam patterns will be determined from these measurements, which will be made over a large range of frequencies (Few MHZ to a few ten GHz). These measurements should be completed by early 1996.

(b). A technology program is underway to address testability and manufacturability of large reflectors in a 1 g environment. This should be completed in the 1997-98 time frame.

(c). A 2 to 3 m aperture off-axis antenna for the New Millennium Program has been proposed to fly in NMP mission one to a near earth asteroid. It will utilize new reflector materials with samll coefficients of thermal expansion and its structure will be inflatable-rigidizable. Even though precision inflatables demonstrate most of their advantages in the much larger aperture ranges, this reflector will be a very powerful demonstration of the technology, in so far as inflatably deployed of a rigidized structure antenna is concerned. Also, it will be the first demonstration of an actual working infaltable antenna in space.

(d). The Power Antenna is a large aperture inflatable reflector that doubles both as an antenna and a solar concentrator for outer planetary missions. The concept has arisen from a collaboration between JPL and L'Garde. The near term involves ground tests for direct measurements of concentration ratios and beam patterns with the help of a heliostat and a vacuum chamber. The goal is to achieve high concentration ratios with minimal pressure.

It should be noted, that the Power Antenna concept that the inflatables technology offers, can in the not too distant future alleviate the need for radioisotopes as the only power source of choice for deep space missions. With proper funding a power antenna flight can be achieved by 2000 AD.

(e). An inflatable solar array flight has been proposed to prove that controlled solar array deployment using inflatable-rigidizable booms will produce no significant dynamics for either spacecraft or array. And furthermore, should any dynamics be generated, they will damp out promptly. This flight is expected to occur within the 1996-97 time frame.

(f). Also within the context of the New Millemmium Program we expect to demonstrate the large Power Densities attainable with advanced rigidizable methods, such as cold or chemical rigidization, and the developing high efficiency solar cell technologies (band-gap and thin-film amorphous solar cells). For some of these combinations, power densities in the neighborhood of 300 to 350 W/kg are expected to be attainable utilizing the Inflatable Solar Array concept .

7. Technology Needs

Space inflatables have worked in the past and could be effectively used now, by using current state of the art knowledge. However, improvements in certain areas are desirable. These are discussed below:

(a). Materials: Many of the thin films used in ground tests and analysis are space proven (Kapton, teflon) but others are not. As new materials are developed to meet certain desired features, there will be a continuing need to space qualify them. Of concern is the atomic oxygen environment at low earth orbit, response to meteoroid impact, and aging in the vacuum of space while bombarded with UV and cosmic radiation.

For solar concentrators there is the need for development of better clear polymers. For control of both thermal and EM characteristics, special coatings and treatments are needed to provide the necessary properties. Current optical coatings of interest are nearly as heavy as the film on which they are applied. Ideally, optical properties could be introduced into the manufacturing process for the film (such as the currently-available black Kapton). Some degradation in physical strength is acceptable if the correct optical properties can be obtained.

(b). Analysis: Analysis tools to handle space inflatables are being developed. However, there is no systematic attempt to apply them to the systems that they were designed for. A parametric study is needed to determine the effect of various design parameters on system performance. For instance, methods of correcting the surface error on inflatables by adjusting mounting, changing pressure, design variations, or manufacturing tolerances should be examined analytically. This will guide future developments of precision space inflatables

(c). Manufacturing: As mentioned above, manufacturing reflectors in the RF frequency range entails cutting flat film gores in the right shape and properly joining them. Both of these processes must be done accurately to preserve surface accuracy. Additionally, to preserve the cost effectiveness of this method of building large apertures, at least the cutting of the gores must become automated. Later, as we gain more experience in the joining of large thin films segments, this could also be automated. Note that both cutting and joining of thin films are automated at present in certain industries, but not with the accuracies required by Precision Inflatable Space Structures. Figure 6 shows the 14 meter IAE lenticular reflector joined to its torus. A detailed look at this picture gives a perspective on the magnitude of this challenge.

(d). Testing: In 1 g we know how to map the surfaces of reflectors apertures up to about 30 meters. For larger apertures the gravitational effects will interfer with the inflation pressure effects. This needs to be further examined.

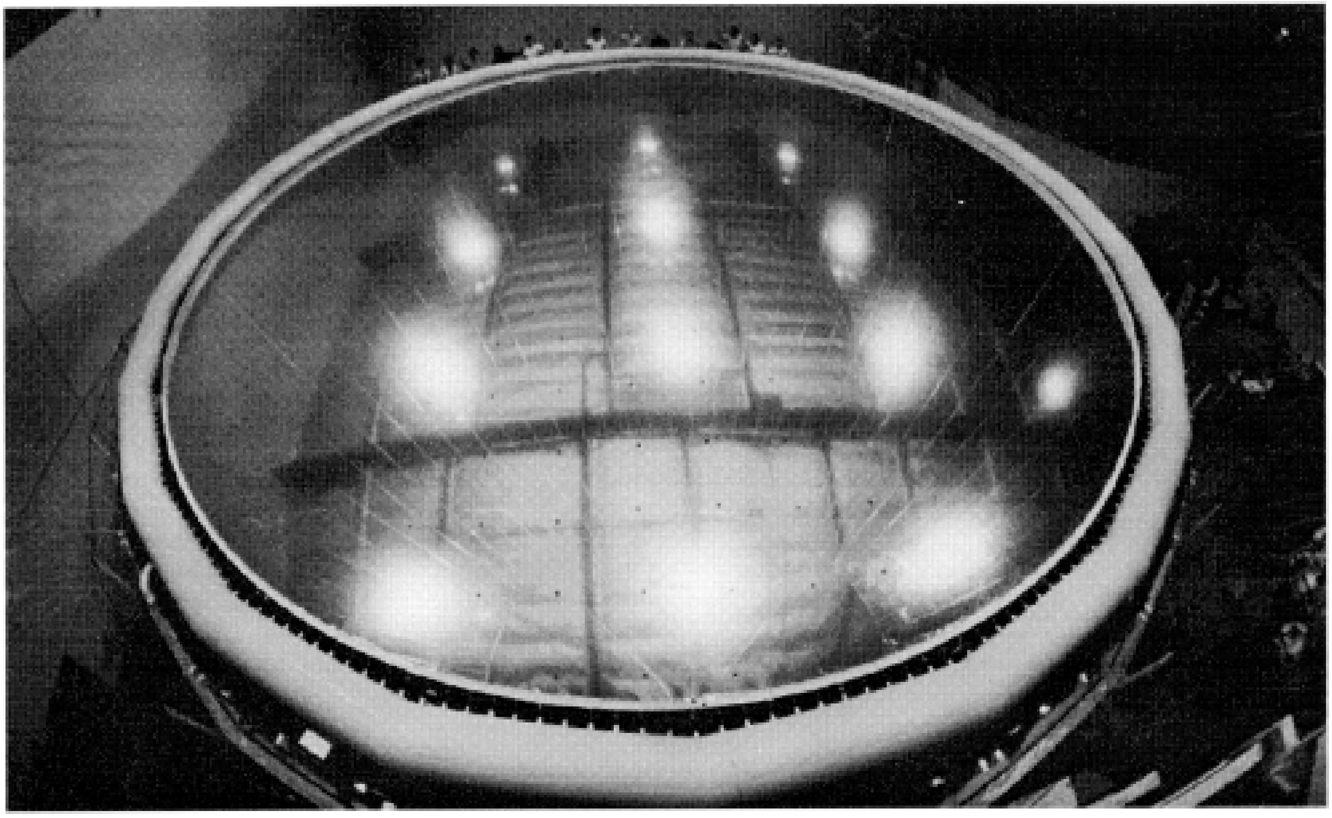

Fig.6 Inflated Reflector

Summary

Development of Precision Inflatable Space Structures has been on-going for about the last three decades now. Many short-term space flights and numerous ground test systems have yielded invaluable information on the behavior of these structures in space, both directly and through analysis of the ground tests.

The 1996 Inflatable Antenna Experiment (IAE) will demonstrate the deployment and in-space dimensional stability of large inflatable structures. Current research and development methods in the materials arena are focusing on the longevity and long term stability of both thin film and inflated-then-rigidized materials which are used for structural supports in the Precision Inflatables Technology. In addition, analytical tools that allow accurate prediction of the behavior of these structures under mechanical and thermal loads in space are to a large extent complete, except for the challenging simulation of deployment. More work is also need in the manufacturability and testability of large (30 meter aperture class, or larger) precision inflatables.

But most importantly, we need to have numerous long duration (few months to a few years) test flights that prove this highly promising and revolutionary technology, while at the same time giving our future program managers the confidence they need to start employing it increasingly. The payoff of this technology to Space Science, Space Commercialization and the competitiveness of the U.S. in space arena, is immense.

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