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STATUS OF SUPERPRESSURE
BALLOON TECHNOLOGY IN THE UNITED STATES

E. D. Angulo, J. G. Guidotti, and C. E. Vest
Spacecraft Integration and Sounding Rocket Division

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GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland

FOREWORD

The FR-2 satellite program being undertaken jointly by the United States and France involves interrogation of constant-level balloons by an earth-orbiting satellite. Goddard Space Flight Center administers the program for the United States. This report summarizes findings of the Goddard FR-2 team's initial investigation of the superpressure balloon industry, with particular attention to potential problems in design, fabrication, handling, materials, and field operation.

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SUMMARY

Superpressure balloon technology in the United States has lagged behind other space-age technologies. Long-life superpressure balloons have not been flown with satisfactory reliability. Problems of design, fabrication, and testing must be solved if large numbers of superpressure balloons (as many as 1500 for the FR-2 (Eole) program) are to be flown reliably and at reasonable cost.

This paper presents the results of literature searches, together with observations arising from direct contact with the few U.S. firms producing superpressure balloons. It is recommended that a funded development and testing program be initiated to bring balloon technology to a satisfactory level, not only for the benefit of the FR-2 program, but for the future atmospheric research programs as well.

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STATUS OF SUPERPRESSURE

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INTRODUCTION

The term "superpressure" in balloon technology designates a balloon which displaces a fixed volume of air and therefore floats at a constant-pressure altitude (i.e., air-density level) regardless of changes in temperature. At any given pressure level, this constant-pressure altitude is a very nearly constant true altitude which varies only a few hundred feet either diurnally or seasonally. These balloons can theoretically remain aloft for long periods because dumping ballast at night and releasing gas in the daytime is not necessary to maintain the desired altitude.

In atmospheric research, long-term data on higher altitude phenomena can be obtained through the use of balloons, and the superpressure balloon is the best foreseeable answer. However, research in this field is limited, and many problems with this type of balloon remain unsolved.

Under the stimulus of the joint United States - France weather satellite program, designated Eole by France and FR-2 by the United States, a survey of United States balloon technology has been made. By pointing out areas of deficiency, this report may stimulate interest in the solution of outstanding problems. As balloon technology in Europe is approximately parallel with that in the United States, no convenient shortcut is available through borrowed knowledge.

Planned Applications for Superpressure Balloons

Two major programs currently require the use of superpressure balloons. One is a United States-only program, GHOST (global horizontal sounding technique); the other is the joint United States - France FR-2 program. Each of these programs could use balloons in the thousands. Dozens of less ambitious investigations would be conducted if the balloons were available economically.

The FR-2 program is a unique combination of balloon and spacecraft technology. The prospect of successfully launching a spacecraft to interrogate large numbers of balloons is good, because spacecraft technology has advanced rapidly during the past few years. However, the process of fabricating balloons (which will drift with southern hemisphere winds, uncharted at present) has not benefited from this advanced technology. It follows that the balloons must be considered the critical element in the program.

SUPERPRESSURE BALLOON TECHNOLOGY STATUS, 1966

A search of the literature, together with meetings and contacts with industry, indicates that the first superpressure balloons in this country were built as early as 1957 under both Office of Naval Research (ONR) and Air Force Cambridge Research Laboratory (AFCRL) contracts.

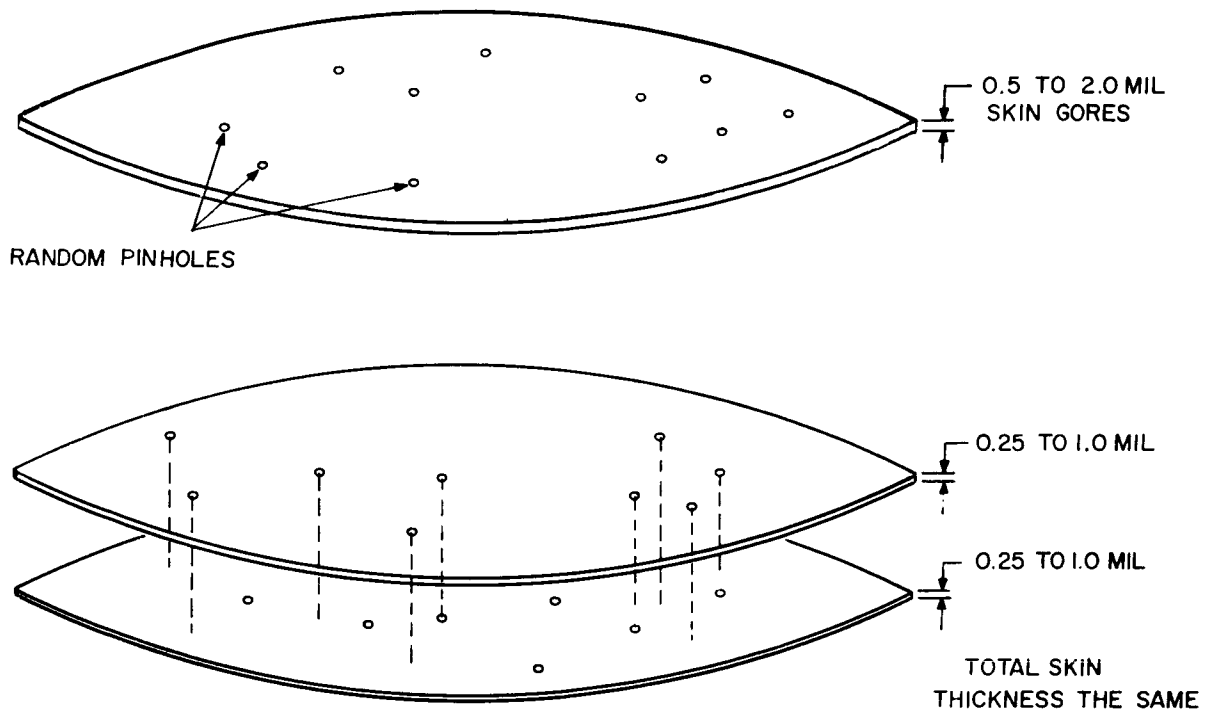
These early products were partially successful, in that they served to verify the superpressure balloon theory. Of several companies in the United States involved in this early work, two have a great deal of know-how: J. T. Schjeldahl and Raven Industries, Incorporated. Other companies such as General Mills, Litton, and Minneapolis Honeywell have been in the superpressure balloon business in the past. Winzen Research, which has built superpressure balloons, was not active in this field at the time of this survey.

Present Status

The National Center for Atmospheric Research (NCAR) and AFCRL are doing most of the current work with superpressure balloons. NCAR estimates it has flown a total of 100 such balloons. The most recent program involved 48 superpressure balloons; of this number, 21 remained aloft for at least 30 days and 3 for more than 100 days. All the superpressure balloons now being manufactured are made from Dupont Mylar film. The early balloons were single-thickness film, but the more recent balloons are fabricated from 2-ply film of the same total thickness exclusive of the adhesive bond. The reason for the double ply is to decrease the chance of exposed pin holes; Figure 1 demonstrates this effect. The best Mylar film available contains a random number of pinholes, and little has been done to improve this situation. The use of Mylar for balloons is such a small part of the Mylar business that the producer has no incentive to improve the film; the pinholes result from the manufacturing process, and are considered a normal flaw over which there is no positive control.

In fabricating superpressure balloons, flat Mylar sheets are cut into gore segments which are glued to one another with a G. T. Schjeldahl Company adhesive (Figure 2), a Dupont product which Schjeldahl reworks for use in this application. Raven Industries uses these same products in manufacturing balloons, and the French manufacturers use the same techniques.

Some of the Mylar balloons have been reinforced with rayon or dacron scrim between layers (Figure 3). The use of scrim depends upon the size of the balloon and the amount of weight it must lift.



NOTE THAT ONLY A FEW PINHOLES
WILL BE ALIGNED WHEN TWO SHEETS
OF FILM ARE BONDED TOGETHER

Figure 1. Bilaminate Mylar Technique

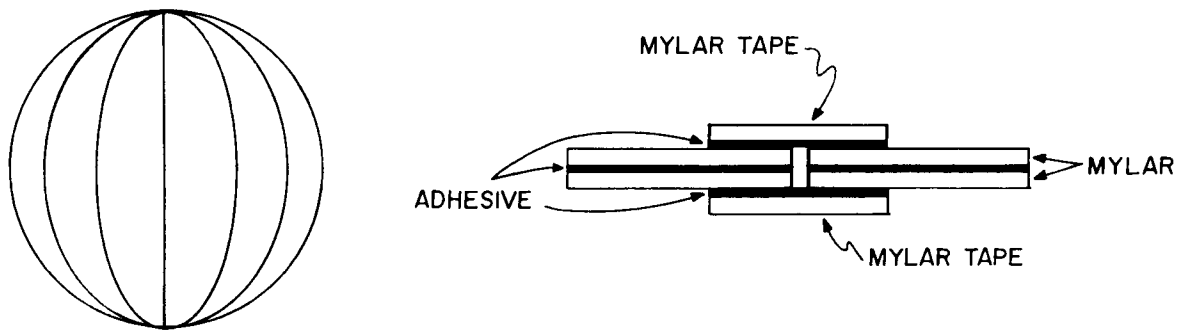


Figure 2. Gores and Gore-Binding Technique

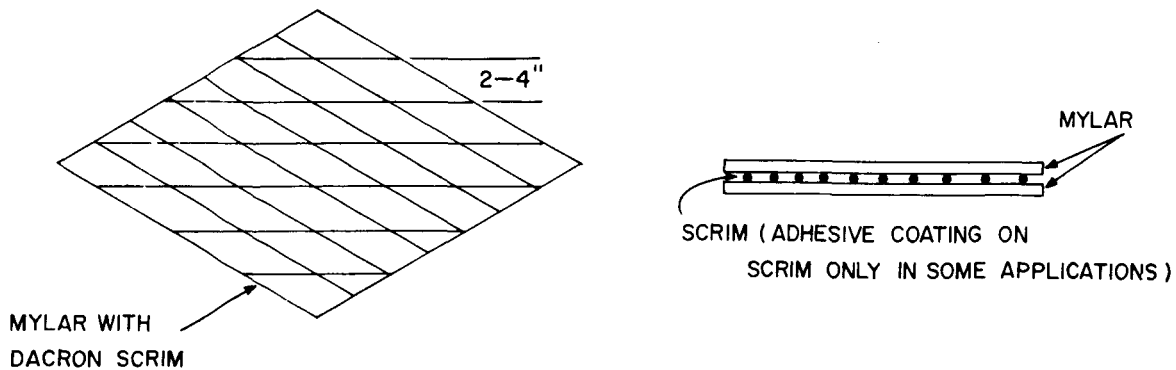


Figure 3. Mylar with Dacron Scrim

In summary, the balloons applicable to the proposed programs are currently fabricated from Dupont Mylar using numerous gores bound with an adhesive seam or adhesive tapes to form a near-spherical shape.

Testing and Results

The literature indicates that early balloons were made of elastic materials inside a fabric outer envelope. This technique was abandoned because of the low weight-to-lift ratio and the fact that the fabric deteriorated under exposure to ultraviolet and hot and cold cycling, not to mention problems of icing and material creep. Only when such synthetics as polyester (Mylar), Saran, and Kapton became available did the superpressure balloon come into its own.

Mylar is almost exclusively the synthetic material used for superpressure balloons because the other materials are limited by the difficulty in finding the proper adhesive to join the gores. Polyethylene is easily heat-sealed but tends to creep; without scrim it lacks the shape retention required for a long-life superpressure balloon, and is used primarily for short-term high-altitude experimentation.

Testing. Tests of synthetic materials have included:

- Material strength
- Material diffusion properties
- Aging
- Reaction to ultraviolet radiation
- Hot and cold cycling

- Moisture adsorption
- Cold brittleness
- Limited life test

The manufacturers have conducted these tests in a variety of chambers (see appendix).

One obvious conclusion is that the test programs can be improved. A test specification should be prepared for use in evaluating a complete balloon (or preferably a group of balloons) in an environmental chamber simulating flight conditions. This test would answer questions about the behavior of imperfections such as pinholes and seams at float altitude under hot and cold (i.e., day/night) conditions, two problems which are least understood and most difficult to simulate.

Before launch, present users assign to each balloon a flight-life confidence factor based on leak rates considered tolerable. This has worked out badly so far and the reason for early failures is unknown. Although the test envisioned above would tie up a large chamber for a long time, the economics of the proposed programs will make it less expensive in the long run to know the causes of failure beforehand and to institute proper quality control. Improved fabrication techniques, followed by a meaningful inspection procedure, should make it possible to increase present balloon reliability and reduce the loss of costly instrumentation. The loss rate is 7 out of 10 balloons launched, a discouraging factor for many programs. The impact on cost involves not only balloons and electronics but also the launch crews, communications, and other subtle items such as having two or more balloons mistakenly answering to the same address.

Test Results. Although the trip reports in the appendix indicate some of the users involved, and imply a degree of success, the tests conducted last summer were the first meaningful indicator.

The NCAR Status Report for March through August 1966 represents an effort to evaluate superpressure balloon life. The balloons were fabricated by J. T. Schjeldahl and Raven Industries for the NCAR 200- to 500-mb tests.

Before launch, the balloons were to have been pressure-checked for leaks and repaired if necessary. A maximum leak rate was established, and a confidence factor was assigned to each balloon used in this test to predict the number of days it would remain at float altitude. This technique offers no better than a 30-percent chance of making a proper prediction.

A thorough review of techniques used in preparing balloons for launch shows that there is much room for improvement. The following items have been discussed with NCAR for the purpose of making future testing more meaningful.

- Prepare an airtight chamber for 6-foot balloons, and evacuate the chamber to float altitude.
- Monitor the leakage, using a manometer outside the chamber hooked to a metal gas supply cylinder at one end and the balloon to the other end. This arrangement will cause gas to flow as the balloon in the chamber leaks gas to the chamber. Another crude method would be to simply equip the chamber with a manometer and to monitor the increase in chamber pressure as gas leaks from the balloon.

Quality Improvement

To improve balloon quality, companies in the superpressure balloon field have proposed:

- Development of improved fabrication techniques
- Development of a more comprehensive inspection program
- Development of better packaging methods
- Control of techniques in the final (prelaunch) make-ready procedure

If the above items are treated properly, the manufacturers say that balloons fabricated to the current specifications could last at least 90 days with a confidence factor as high as 90 percent. It is hard to believe that these simple solutions will solve the problem of obtaining good, reliable balloons; all the remedies are simple, and it seems that such obvious corrective steps would already have been tried.

As noted in the trip reports, at least one of the companies plans to eliminate the largest part of the balloon uncertainty by building one-piece balloons. The trouble with this solution is cost; without some outside sponsorship, a number of years must elapse before meaningful results are available. The same company also plans to use some sort of inner tube reinforced by fiberglass windings; the latter idea may be the first to be undertaken, because the cost is lower and the equipment for its development is available.

Problems Recognized by Industry

The problems, as envisioned by present fabricators and users, are:

- Material flaws (pinholes)
- Inadequate inspection techniques
- Inadequate packing and shipping techniques

To this list should be added:

- Inadequate testing criteria
- Inadequate launching procedures
- Inadequate knowledge of the adhesive behavior at float altitude under day/night conditions
- Poor or nonexistent launch restraints (wind and weather problems)

Balloon Users

Agencies involved in superpressure ballooning are:

- AFCRL — (Project Moby Dick)
- ONR — (Project Transosonde) (cylindrical balloon)
- WADC — (Wright Air Development Center)
- NRL — (Project Transosonde)
- NCAR — (Project GHOST)

As early as 1944, the Japanese used the Fugo balloon-bomb to launch 9300 balloons against the United States. Some of these balloons were equipped with radio beacons to permit the Japanese to determine the trajectories and forecast expected trajectories for future bombings. Wind patterns at the 10-km level were plotted, and the information was used in subsequent launches, which were not successful.

This was the beginning of the idea. Using constant-level balloons for research on air currents, etc., was a logical next step. But from 1944 to the present, technological progress with superpressure balloons has been slow. A major effort is required to correct this situation.

BALLOON SIZE CRITERIA (E. D. Angulo)

A brief literature search has been conducted for design criteria to use in determining an optimum size for superpressure helium balloons. Reports, papers, and proposals accumulated by the FR-2 project team were reviewed.

An altitude of 300 mb (about 30,000 ft) is the specified working height for the FR-2 balloons. A payload weight of between 5 and 15 pounds has been informally discussed, and a balloon diameter of approximately 6 feet has been mentioned. The following information may provide a better understanding of the relationship between working altitudes, payload weights, and balloon diameter.

Assume a balloon diameter of 6 feet working at a 30,000-ft altitude and solve for payload weight:

<u>Source of Information</u>	<u>Film Thickness (mils)</u>	<u>Stress (psi)</u>	<u>Payload Weight (lb)</u>
GHOST program	2.0	9,800	0.66
Raven Co.	2.0	10,000	1.40
L. A. Grass (AFCRL Report #297099)	1.5	10,000	1.10

Although these sources do not reach unanimous conclusions, they agree that a 6-foot diameter is much too small for the payload weight in question. Next, the curves from the Grass report were used to solve for balloon diameter, using various payload weights at a 30,000-ft altitude:

<u>Weight (lb)</u>	<u>Required Diameter (ft)</u>
5	9.8
10	11.8
15	13.8

The required balloon must therefore be twice as large as anticipated. In view of the concept of never deflating a balloon after it has been pressure-tested (to avoid possible leaks from folding for shipment), the larger diameter takes on added significance. Figure 4, a set of curves developed by the Raven Company, shows essentially the same balloon-to-payload relationship as that given by Grass.

IMPROVING BALLOON TECHNOLOGY

The National Research Council has recommended a 3-year balloon development program. The fabricators claim that the present balloons can be fabricated to a reliability factor of 90 percent. The users make similar claims.

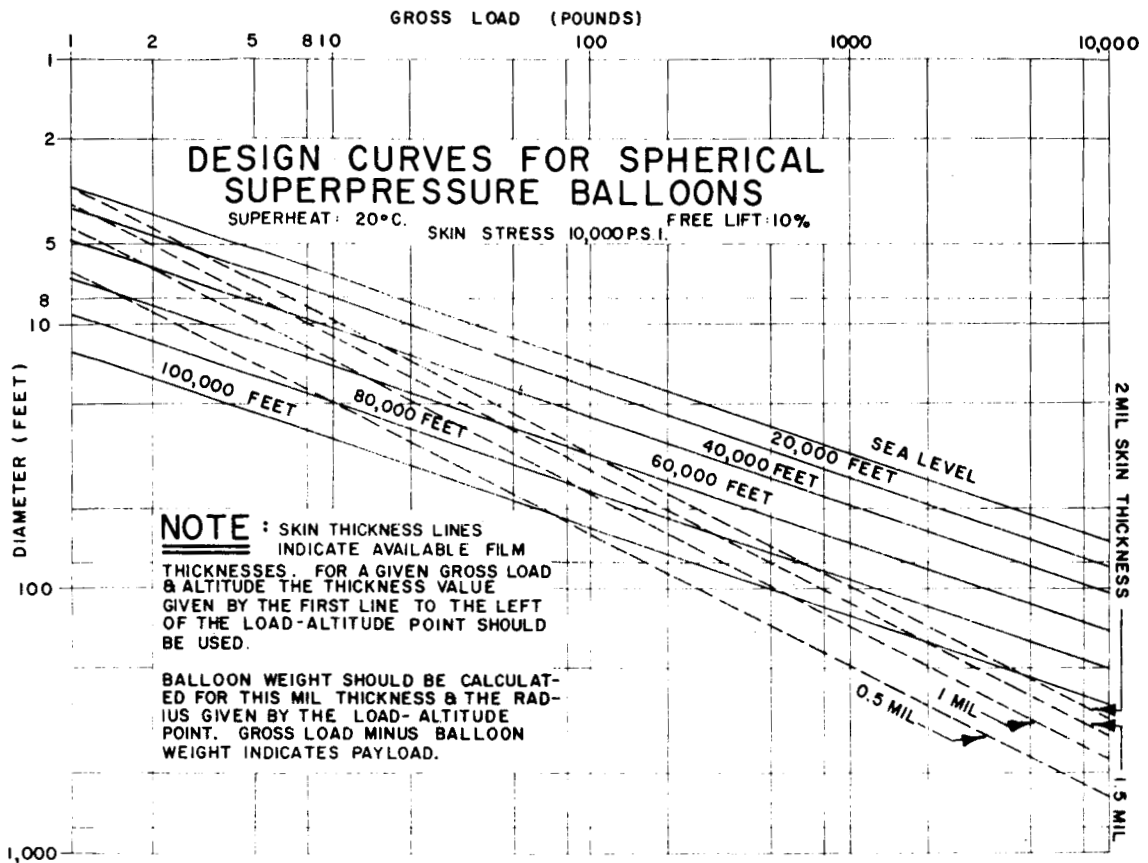


Figure 4. Balloon Size vs. Payload (Raven)

The facts do not substantiate the estimates by the present users and fabricators; indeed, the figures seem to indicate conclusively that the Research Council is heading in the proper direction, that of directing efforts toward improving balloon technology.

The time has come for a serious study of this problem. A reliable balloon is a must for the success of the pending meteorological programs, both from a systems concept and from the standpoint of the cost of replacing defective or short-life balloons.

Advantages of a New Type of Balloon

The logical approach would be to make a one-piece balloon. Among the many advantages would be:

- Elimination of 90 percent of the handling during fabrication
- Elimination of approximately 400 feet of seams which are currently hand-fabricated using adhesives
- Production of a potentially smaller balloon by eliminating seams and adhesives which increase balloon weight
- A decrease in potential safety hazard because of the smaller balloon
- Reduction of inspection time
- Reduction of repair time
- Reduction of the cost per balloon
- Reduction of damage in packaging by elimination of hard-to-fold seams
- Reduction of the number of field operations in prelaunch testing and repairing
- Removal of one possible cause of balloon failure consisting of some 400 feet of suspect seams, which often lack uniformity

Advantages of an Improved Test Procedure

Balloon testing has been mainly a fly-and-try operation, although attempts have been made to pretest and evaluate each individual balloon. Statistics on 48 balloons flown in a recent GHOST test series show, for 30 balloons flown at 200 mb, a failure rate of 38 percent based on a 30-day flight lifetime, 76 percent on a 90-day flight lifetime, 86 percent on an over-100-day flight lifetime. The remaining 18 balloons were flown at 500 mb and had an average life of 6.5 days, with 3 balloons up for 13 to 19 days. For the FR-2 program, these are not acceptable balloons.

A really thorough investigation is imperative for the success of all programs involved. A review of the conduct of programs such as Echo shows that much thought was given to preparing test procedures which simulated the pertinent parameters. The superpressure balloon program needs such an approach. Outlined in a previous section is a start, in that evaluation of the gore-shaped balloon in an adequate chamber could help to explain the failure mode. The reason for early failure is still unknown.

In addition to this test, other tests could be designed to determine how pinholes erode, if indeed they do. Effects of rough-weather launching should also be investigated, and at the same time, water adsorption and icing should be studied.

The culmination of all this preliminary testing would be the preparation of meaningful test procedures and the definition of mandatory inspection points and critical balloon defects, so that the user could establish what can be bought, which in turn would save hundreds of man-hours in prelaunch testing.

Prelaunch test procedures are far from adequate. Use of a simple test chamber would cut down the time required for testing, as well as increase the expected balloon lifetime. The equipment envisioned would consist of a chamber in which the balloon would be inflated while a standard gas bottle was being filled. The two would be connected by a water manometer which would sense equal pressures in the bottle and the balloon. The chamber containing the balloon could then be partially evacuated; if the balloon leaked, the gas in the bottle would bubble into the balloon, or the manometer could be read to determine the leak rate. Such a system would produce answers in hours rather than days.

This idea has been discussed with NCAR and appears to be a great improvement over present testing procedures.

In conclusion, the available literature indicates that the technology has suffered from a lack of funds to investigate adequately what constitutes a good, reliable superpressure balloon system. A systematic approach to defining a good superpressure balloon is needed before any work can be initiated.

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Appendix

TRIP REPORTS

C. E. Vest: G. T. Schjeldahl Company, July 6, 1966

J. G. Guidotti: G. T. Schjeldahl Company, August 1, 1966

C. E. Vest: Raven Industries, September 1, 1966

J. G. Guidotti: Raven Industries, September 9, 1966

DATE: July 6, 1966

TO: S. Stevens
Explorer & International Project Management Offices
Spacecraft Integration and Sounding Rocket Division

FROM: C. E. Vest
Mechanical Systems Branch
Spacecraft Integration and Sounding Rocket Division

SUBJECT: TRIP REPORT TO SCHJELDAHL CORPORATION; FR-2 BALLOON
AND PAY LOAD PACKAGE MATERIALS — JUNE 27 AND 28,
1966

Personnel contacted at Schjeldahl were R. Slater (vice president and general manager), R. Wiltz (program manager) and J. Feeney (electronics specialist). J. Guidotti and C. Vest represented GSFC's FR-2 project. Mr. Slater is the knowledgeable man in the balloon field at Schjeldahl, as he has been with them since the company began and is aware of the work of Dr. Lalley of NCAR and L. A. Grass of AFCRL.

A number of points covered during the discussions are summarized as follows:

These men have met some of the French people assigned to FR-2 and have discussed the balloon situation with them (superpressure balloons). They have the safety problem with the FR-2 and FAA. FAA will not commit itself as to the maximum size particle (density, etc.) that can be ingested into a jet engine. FAA says, you do some experimental work and show us what the particle does to the engine, and we will evaluate the data and let you know what we think. Very good. But someone in the Washington, D. C., area is doing work on this, which I will follow.

Schjeldahl does not use thread-reinforced balloon materials for the superpressure units, but a double-layer 0.0005- to 0.001-mil layers glued together with a polyester adhesive) Mylar (polyester plastics material).

Schjeldahl has made thin batteries using a paste electrolyte which leak after a time (not specified). The thin-film battery is felt to be the answer and some in-house effort is being expended on this problem (no indication of magnitude).

The balloon packaging (for shipment) has produced some leakers at the place where there is a triple-folded corner. The leakers are those balloons

having a skin less than 0.001" and greater than 0.002 inch thick (total thickness). Mr. Slater feels that as long as the balloon skins are in the 0.001- to 0.002 in. thick range, no leakers due to packaging will be experienced. This has not been confirmed by test as yet.

Schjeldahl is submitting an unsolicited proposal to GSFC (Klienberg, Building 21) regarding antenna, sensors, transmitters and receivers for a specific balloon. Schjeldahl will actually supply the four items above and will propose the optimum power supply (thin-film battery, isotopic supply, etc.) This will be a 50-60K program. I will follow this.

The experience in small superpressure balloons (a 12.5 foot-diameter balloon is the smallest "production" balloon) is limited. Production experience is limited also, due to the small number of a specific size balloon manufactured. Mr. Slater feels that a better product can be made with more production (why not?). Fewer than 50 superpressure balloons have been flown; two-thirds of these have been experimental, and have not been allowed to fly until they came down on their own but have been destroyed after 2 weeks or so. Very little data on long-life balloons (one up for 90 days, still up).

Discussed three plastic materials; polyester (Mylar), polypropylene, and "H" film. Mylar has been used for all superpressure balloons flown to date. Polypropylene balloons have been made, but problems are being experienced with the adhesive at the taped joint. Polypropylene is lighter, stronger, and more radiation-resistant, and has a greater modulus than Mylar, but the manufacturers cannot get a good adhesive for the seam. The "H" film is much superior to both in radiation resistance but has greater density with less strength, and is not as suitable for balloon structural material.

Each balloon presently requires 20 to 40 gores, but it may be possible to use 12 gores, thereby reducing both the weight and the packaging problem.

There has been some discussion about assembly of the balloon at the release site vs. the factory (this is in regard to packaging and shipping problems). I feel that the balloon should be assembled at the factory, and solve the other problem.

Mr. Slater was asked what his feeling was for the chances of getting 512 balloons launched to altitude to stay put for 30 days. He felt that 90 percent of 512 would function properly if all ground operations were performed 100-percent correctly. Using present-day operational techniques, approximately 50 percent of 512 balloons would achieve the desired goal. This low rate is essentially due to poor ground-handling and loading techniques.

Dr. Lalley of NCAR will be back July 8 from the southern hemisphere where he has finished flying some balloons (the >90-day balloon) and Mr. Slater is going to see him on that date. At this time, they will discuss the latest flights, and particularly package and leakage problems.

Schjeldahl has produced the Echo 1, Echo 2, and PEGOES devices, and did an Advance Materials Development study for Rebound (contract NAS5-1190). This report is partially but not completely applicable to FR-2 balloons because of the ambient temperature and vacuum conditions of the evaluation.

I asked, "What particular materials problems do you feel should be investigated?" Mr. Slater stated the following:

1. 90-day inflation test (or until failure) using a full-size balloon in the Langley wind tunnel.
2. Ultraviolet irradiation test at temperatures of altitude, having one side hot and the other cold. This would be a 12-hour-on, 12-hour-off test cycle.
3. Leakage of balloon material. This would involve the inherent leakage of the material using diaphragm specimens.
4. Development of standard detailed production procedures for manufacturing of the balloons. Mr. Slater feels that this is one of the very critical problems with balloon technology.
5. Flight testing of 50 balloons.

A time schedule was discussed. Items 1, 2, and 3 could be completed in about 6 months at \$50K; 1, 2, 3, and 4 in about 9 months at \$80-\$90K; and all 5 items in 2-3 years at a cost as yet undetermined.

I asked about a summary report of the present state-of-the balloon technology, including past history. Mr. Slater said such a report could be compiled in about 60 days, at a cost of about \$10K.

In conclusion, I feel that this trip was very beneficial in gaining knowledge of the balloon field: the materials of construction, the production problem, the leakage problem, the packaging problem, and the lack of correlated data on the limited number of superpressure balloons that have been flown. This visit also points up the fact that more effort on my part is necessary before any reasonable recommendations can be made. In the meantime, I will follow up on the

jet engine ingestion work, the proposal to Klienberg, and the outcome of the Lalley-Slater meeting.

Charles E. Vest

DATE: 1 August 1966

TO: FILES

FROM: J. Guidotti
FR-2 Project Coordinator

SUBJECT: TRIP REPORT TO G. T. SCHJELDAHL CORPORATION, NORTHFIELD, MINNESOTA: 27-28 JUNE 1966

On 27 June, C. Vest and I met with representatives of the G. T. Schjeldahl Corporation, Northfield, Minnesota.

Attendees were:

For G. T. Schjeldahl Corporation,
R. J. Slater, vice president
R. Wiltz, program manager
J. Feeney, electronic specialist
For GSFC,
C. Vest
J. Guidotti

The purpose of meeting was to find out all we could about current status of balloon technology and thin-film circuits.

It turns out that, except for actually building and flying balloons, very little has been done in the areas of testing. During the meeting, the following facts were brought out:

1. The number of superpressure balloons fabricated to date is quite small.
2. The techniques used in fabrication include:
 - Using two sheets of 0.005-inch Mylar in fabricating each gore section
 - Using a proprietary adhesive for joining the gores
 - Adding reinforcing at the heavily loaded ends of the balloon. This is done by extra plies of Mylar or actually nylon-reinforced Mylar.
 - Preparing detailed operation procedures for the fabrication, assembly, packaging and shipping of each order. These procedures include workers' fingernail length, clothing to be worn, and head cover when required.

- Thickness of successful balloons has not exceeded 1 to 2 mils. Anything over 2 mils results in a folding and packaging problem. The specific problem is leaking at the trifold points, usually due to filament breakage.
 - Material (Mylar) supposedly can be crumpled during the seaming process without affecting its integrity. This is a point which could stand investigation.
 - Mylar is a directional material and the double layer accomplishes two things:
 - Strengthens the balloon
 - Decreases the leakage problem; using two plies, one ply covers holes in other, etc. Mylar has a random number of holes per square foot and no improvement is expected in material fabrication.
 - A rule of thumb is that one pound of balloon (material) will carry one pound of payload to any altitude (20 percent superpressure).
 - Current balloons can stand ultraviolet rays at 45 degrees for up to 6 months.
3. Three different materials were discussed:
- Mylar is currently being used. Due to the number of inherent pin-holes and the fact that its strength is directional, the superpressure balloons are fabricated from at least two plies.
 - Polypropylene is both stronger and lighter than Mylar. An acceptable adhesive is the only holdup to its use for balloon fabrication. Polypropylene also has greater radiation resistance.
 - Although "H" film is superior to both Mylar and polypropylene in radiation resistance, it is heavier and not as strong. The thinking is that a liner of "H" film within the Mylar or the polypropylene might produce a balloon with better overall performance.
4. Another technique to be explored is the use of 12 gores instead of the 20 to 40 currently used. The number of seams increases the gas diffusion and direct leakage through holes in non-adhering points: thus, fewer seams, less leakage.

5. Mr. Slater summed up his presentation by stating his opinion that, provided the following minimum effort was expended, the chance of having 512 balloons survive for 6 months or more would be 90 percent. The steps he recommends are:

- Inflation test in a wind tunnel at LaRC for 90 days (or until failure)
- Exposure to ultraviolet at temperatures for the various altitudes, keeping one side hot, the other cold, cycling for 12 hours on and off
- Investigation of materials leakage problems, using diaphragm specimens
- Development of detailed fabrication procedures
- Development of detailed handling procedures
- Development of detailed testing procedures, perhaps a test chamber at the launch site
- Review the desirability of fabricating at launch site. This is far-fetched but recommended.
- Flight-test of 50 balloons

6. Although Dr. Lalley of NCAR has had a balloon aloft for over 90 days, other balloons could have survived as long, provided such things as overflight privileges were extended and the balloons did not have to be destroyed prematurely.

7. The other area investigated was thin-film development. The GHOST package electronics were displayed, and it became obvious that the battery is a limiting problem. At this point in the meeting, reference was made to a number of people at FAA who have been contacted for a definition of what a jet engine will ingest. The following three people were mentioned:

B. Kemery, equipment project manager
T. Horraf, propulsion project manager
M. Collins, equipment

These FAA contacts will not state positively one way or another; their attitude is, you tell us, or we will wait until there is a requirement.

8. G. T. Schjeldahl Corporation has tried unsuccessfully to produce a thin-film power pack. Leakage at low temperatures was evidenced in their latest attempts.
9. Things to be resolved:
 - A state-of-the-art report on balloon technology which Mr. Slater estimated to cost 10K
 - A 150-200K (estimated) effort to investigate and flight-test item 5, time estimated at 2-3 years
10. G. T. Schjeldahl Corporation's experience in this field includes ECHO 1 & 2, PEGOES, a Rebound study, and the superpressure work conducted for NCAR. Dr. V. Lalley's reports, which are available, include:
 - Rebound study for C. Gunn and J. Corrigan on contract NAS5-1190
 - The Global Horizontal Sounding Techniques (GHOST) report to the National Academy of Sciences Committee on Atmospheric Sciences
11. G. T. Schjeldahl Corporation is submitting an unsolicited proposal to Klienberg, GSFC, regarding antenna, sensors, transmitters, and receivers, for a specific balloon. The proposed program will cost approximately 50-60K.
12. G. T. Schjeldahl has been contacted by the French and will look into the prospect of becoming actively involved.

J. G. Guidotti

cc:
Mr. Baumann
Mr. Stevens

DATE: September 1, 1966

TO: Samuel R. Stevens
Explorer & International Project Management Offices
Spacecraft Integration and Sounding Rocket Division

FROM: Charles E. Vest
Mechanical Systems Branch
Spacecraft Integration and Sounding Rocket Division

SUBJECT: TRIP REPORT: RAVEN INDUSTRIES

On August 25-26, 1966, J. Guidotti and I visited Raven Industries of Sioux Falls, South Dakota, to discuss the fabrication and testing of superpressure balloons. J. A. Winker discussed Raven's interest and capability in this field. He also showed us the Company's facilities.

Mr. Winker discussed the use of Mylar as the most acceptable material to date. The problem, as he sees it, is packaging the finished balloon to prevent folding breaks and subsequent leakage. The pinhole problem inherent in Mylar has been practically eliminated by the use of bilaminated films. (Raven purchases bilaminated Mylar from the Arvery Corporation, Chicago, Illinois.) The present gore-seaming technique has been developed to the point where leakage at the seams is very minimal.

As regards future development in balloon materials and fabrication technique, Raven is doing a minor amount with company funds on fabricating a one-piece balloon with glass-filament winding at the high-stress areas. The company has proposed to NCAR the fabrication and testing of a superpressure balloon using a Mylar "T" material (40,000-psi tensile strength in the machine direction vs. 20,000 psi in the transverse direction. The Mylar film now being used has 20,000-psi tensile strength in both directions) reinforced with glass filament winding in the 20,000-psi direction.

Raven conducts a visual inspection, using polaroid light glasses technique, on all incoming films and a room temperature and a cold temperature (-65°C) test on each finished balloon (the balloon is pressured).

In summation, Raven Industries seems well qualified to fabricate and test superpressure balloons, as it has knowledgeable personnel and adequate facilities.

Charles E. Vest

DATE: 9 September 1966

TO: FRENCH FILES

FROM: J. G. Guidotti
FR-2 Project Coordinator

SUBJECT: TRIP REPORT: RAVEN INDUSTRIES OF SIOUX FALLS, SOUTH
DAKOTA, AUGUST 25-26, 1966

Attendees from Raven:

James Winker
John A. Peasley
Smith

Attendees from GSFC:

C. E. Vest
J. G. Guidotti

The meeting was quite informal and Mr. Winker acted as spokesman for the Raven group. The following items were brought out during the discussions.

1. Raven is sponsoring an in-house effort to develop a one-piece balloon. The materials used in this work were not disclosed. Balloons to be fabricated by this technique will be about 10 to 12 inches in diameter.

The size was chosen because the company is confident that it can scale up to at least a 6-foot diameter balloon. An undercurrent throughout this discussion was that an input of funds could speed up this work.

I told them that our visit was not solely to inform ourselves of what is going on; hopefully, we could see a reason for recommending to the French that certain companies are in advance, and they should look into the work going on in these companies. Any contract for hardware would be between the company and France.

2. Polypropylene material is still being considered; however, because of its lower strength, scrim is required for the heavier payloads.
3. Raven has a glass-filament-winding capability, and NCAR has been talking of sponsoring a program to produce spheres wound from both glass filament and nylon.

4. A new material, Kapton, which has high strength was discussed. I understood it would be a likely substitute with proper adhesives for the gores. Mr. Winker did not elaborate on this, but the impression I received was that Raven hopes to develop balloons by other techniques.

It was somewhat amazing that one of the pending proposals by Raven to NCAR indicates that Raven is proposing to filament wind balloons using various fibers. This idea was proposed by the project office at a meeting attended by NCAR on June 10, 1966; the proposal is dated August 10, 1966, and indicated a high level of confidence in the technique.

5. Raven has built a number of 34-foot superpressure balloons for AFCRL in Cambridge; although these balloons were successful, no test was made of the amount of time they remained aloft.
6. Motorola funded a much larger procurement of superpressure balloons. This program was also successful, but again no details were available.
7. Raven Industries does not have an in-house capability on thin-film electronics. Mr. Winker noted that Raven is only interested in fabricating balloons along with the command system required to perform balloon functions; i.e., dump ballast, open valves, and/or deploy parachute and equipment.
8. Raven is using bilaminated Mylar in balloon fabrication; Raven does not do the laminating, but purchases the material from the Avery Corporation of Chicago. The adhesive used in seaming the gores is a Schjeldahl item, which in turn is purchased from Dupont.

It seems that, after exhaustive tests of adhesives, a Dupont series UT-100-400 was found to be acceptable with some work on the part of G. T. Schjeldahl, which prepares the adhesive in a workable form. Raven is also evaluating an adhesive, manufactured by Bostic, which is heat-applied and thermosetting.

9. Raven has conducted all of the tests that G. T. Schjeldahl has conducted. Some are:

Wright Field test chambers; leakage rate checks in a chamber built for such tests; pressure checks and test to 10,000 psi for material and seam verification for balloons up to 8 feet in diameter; cold temperature pressure test to -65°C , using a 10-foot chamber with a balloon pressure of 10,000 psi.

10. Quality Control — Raven conducts a 100-percent inspection on the laminated material. This inspection consists of passing the material between two sheets of polaroid film: using this technique, the inspector can detect a 1-mm pinhole as well as inclusions and adhesive buildup between the laminates.

It was noted that this inspection is expensive, accounting presently for 30 percent of the balloon cost. The advantages so far are balloons with fewer pinholes, fewer major inclusions which are potential failure points, and less adhesive buildup which often produces wear points due to the stiffness, protrusion, etc., inherent in such a defect.

11. Materials Control — Raven-prepared specifications are used in procurement of the Mylar and the adhesive. The company also has specifications covering major and minor discrepancies in fabrication of the thin laminated sheet, as well as detailed specifications which controlled the validity of the product, such as, adhesive strength of the bond and weight per 100 sq. ft. of the finished product.
12. Facilities: Raven has the capability to fabricate a balloon up to 380 feet in diameter.

- Testing:

- Materials
- Adhesives
- Joints
- Leak rate
- Pressure
- Ultraviolet damage

- Winding

Raven has a spiral winding machine in a separate building; the machine was being used to wind large fiberglass tanks.

- Machine Shop

Small shop, adequate for maintenance and limited amount of structural work associated with building gondolas; in addition, some chassis-forming and drilling equipment was available.

- Assembly

Areas where electronic components were being welded to printed circuit boards (not soldered) and areas for soldering component assembly, with checking stations, were in operation.

13. Other

Personnel in the balloon division numbered 30 people, of which about six were engineers; others were technicians and fabrication types.

An organization in England called Mellinex ICI produces nylon and polyester fibers.

Raven is working on balloons which will eventually carry 800 lb of payload to 155 thousand feet.

Cost of 2-meter balloons made in groups of 10 will be about \$380 each.

Balloons which have gone to 20-mb altitude cost \$1500 each.

Raven is working on a scheme to outfit a personnel carrier with a decontamination capability.

The company is presently fabricating large containers for the food and chemical industry.

J. G. Guidotti

cc:

Mr. Baumann

Mr. Vest