[redacted]

This prop. no. superseded by new one dated 6 Jan 58

Jib - Balloon Powered

25X1

November 8, 1957

[redacted]

25X1

COPY

Attention: [redacted] Code 461

25X1

Subject: [redacted] Proposal No. 11510-A - Small Plastic Airship

25X1

Reference: (a) Request for proposal on Phases II and II dated 1 November 1957
(b) Proposal No. 11510 dated 20 September 1957

Gentlemen:

[redacted] is pleased to submit herewith proposal No. 11510-A covering phases II and III of the Small Plastic Airship.

25X1

This proposal will be considered a supplement to reference (b) and the same terms and conditions will apply. The two points covered in the enclosed technical discussion will be as follows:

1. Raise the airspeed of the vehicle at ceiling from 30 knots to 50 knots (no wind condition).

2. Add the design objective that the vehicle should be field inflatible in surface winds up to 15 knots.

The estimated cost of phases II and III is $192,748 plus a fixed fee of $13,492 for a total of $206,240 of which a cost breakdown is enclosed herewith (Schedule A).

The proposed delivery schedule is pointed out in Schedule B.

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ORIG CLASS M PAGES 36 REV CLASS
JUST NEXT REV AUTH: HR 70-2

2.140

We are very happy to have been of further assistance to you. If there are any questions or if we can be of further service to you, please advise.

Very truly yours,

[redacted] 25X1

Contract Administrator

Approved by [redacted] 25X1

Proposal and Contract Administration

Copies to [redacted] 25X1

COPY

COST ESTIMATES

SCHEDULE A

Phase II			
Labor			
Research Department			
Principal or Senior Scientist	1,557 hrs. @ $4.10		$6,384
Balloon Manufacturing Department			
Senior Engineer	3,700 hrs. @ $3.85	$14,245	
Development Engineer	600 hrs. @ $3.45	2,070	
Draftsmen	1,500 hrs. @ $2.65	3,975	
			20,290
Balloon Operations Department			
Senior Engineer	4,050 hrs. @ $3.85	15,593	
Draftsmen	1,600 hrs. @ $2.25	3,600	
Technicians	2,800 hrs. @ $2.00	5,600	
			24,793
Burden			
Research Department	1,557 hrs. @ $3.30	5,138	
Balloon Manufacturing Dept.	5,800 hrs. @ $2.75	15,950	
Balloon Operations Dept.	8,450 hrs. @ $2.15	18,168	
			39,256
Material and Fabrication Costs			23,900
	Total Phase II		$114,623
Phase III			
Labor			
Research Department			
Principal and Senior Engineers	692 hrs. @ $4.10	2,837	
Balloon Manufacturing Dept.			
Senior Engineer	1,000 hrs. @ $3.85	3,850	

Balloon Operations Dept.			
Senior Engineer	1,100 hrs. @ $3.85	$4,235	
Draftsman	200 hrs. @ $2.25	450	
Technicians	2,550 hrs. @ $2.00	5,100	
			$16,472
Burden			
Research Department	692 hrs. @ $3.30	2,284	
Balloon Manufacturing Dept.	1,000 hrs. @ $2.75	2,750	
Balloon Operations Dept.	3,850 hrs. @ $2.15	8,278	
			13,312
Material and Fabrication			20,900
			$50,684
Total			165,307
10% Contingency			16,531
Total Costs			181,838
G & A @ 6%			10,910
			192,748
Fee @ 7%			13,492
Total Selling Price			$206,240

Helium for tests in Phases II and II	GFE
Portable Mooring Mast	GFE
Large, Hanger-type building for inflation tests	GFE

TIME SCHEDULE B

COPY

Phase II

Months:

1 - 3	Detailed Design Drawings
4 - 6	Construction of Design Model
7 - 9	Flight tests of design model and modification of detailed design drawings

Total - 9 months

Phase III

Months:

1 - 3	Fabrication of Prototype Model
4	Final Acceptance Tests

Total - 4 months

TECHNICAL DISCUSSION

Proposal 11510-A

Phase II of the proposed program is a developmental and testing phase. It will include the preparation of detailed manufacturing type drawings from which the first design model will be fabricated. The detailed design will be based on the preliminary drawings from Phase I. This portion of the work will be done in the Balloon Department. A photograph of part of this facility is shown in Figure 1.

The completed vehicle will then undergo inflation and flight tests. The initial inflation tests will be conducted in an area protected from the wind, preferably in a large, hangar type building. The initial flight tests will be conducted during relatively calm days and a portable mooring mast will be required during the initial flight tests to permit its re-use on successive days without deflation. As the ground crews and pilots become more experienced with the vehicle, tests will be conducted under varying wind conditions to test the vehicles compliance with the design objectives outlined in Phase I of this program. During the inflation and flight tests minor vehicle modifications may be made.

The manufacturing drawings will be finalized to incorporate corrections and/or modifications or deficiencies discovered during the manufacturing and testing periods.

Phase III of the proposed program will include the construction of a prototype vehicle from the finalized drawing in Phase II, flight tests, and delivery of the sponsor. The flight tests will be conducted in the presence of the sponsor and will be conducted to determine the vehicle's compliance with the design objectives outlined in Phase I of this program.

September 12, 1957

Proposal 11510

SMALL PLASTIC AIRSHIP

Prepared for

[redacted] 25X1

Prepared by [redacted] 25X1

Geophysics Section

Approved by [redacted] 25X1

Physics & Chemistry Research

[redacted] 25X1

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

PROPOSAL 11510

TECHNICAL DISCUSSION

I. OBJECTIVE

The objective of this proposal is to outline the areas of research and development which are necessary for, and which will culminate in, the preliminary design of a minimum size plastic airship. This work is an outgrowth of the program initiated under Contract [redacted]. The work to date has been conducted on a very broad basis, applicable to the LTA field as a whole, without limitation as to size, altitude, endurance, etc. Although the proposed work is directed more toward a definite goal, the approach will continue to be based on sound fundamental principles and laws rather than on convention. In those cases where the laws are not written or specified, or written and not verified, an attempt to do so will be made, but only in those cases where the knowledge gained from such laws will be beneficial to the design of a minimum size, but extremely useful, plastic airship. 25X1

II. INTRODUCTION

The powered lighter-than-air field has received considerable attention since its inception in the nineteenth century. Unfortunately, the technological advances of the recent decades have not been applied in any coordinated manner to this field. In most cases the available data, although voluminous, fits no natural pattern. Very little is known about the real reasons for favorable results in some cases and for less favorable results in others. The best results have been obtained largely by a process of trial and error. The results of such developments are available only in the form of designs with specific geometric properties and not in the form of laws or facts that are responsible for the results. The progress on this program to date has been directed toward the establishment and/or understanding of the fundamental principles governing the design and operation of powered lighter-than-air vehicles. Although the program is now directed more toward a specific goal, a fundamental approach will continue to be utilized.

Although it is not believed possible to arrive at a completely optimum design within the scope and time of this program, it is expected that a design incorporating considerably advanced techniques will result. The program will emphasize the utilization and extension of those advantageous features which are inherent in the airship.

III. DESIGN OBJECTIVES

The preliminary design will be based on certain performance objectives and will be limited according to the availability of field equipment and personnel.

Ground handling difficulties are minimum for a minimum size vehicle. Idealistically the ground handling difficulties can be expressed as being proportional to the product of the volume, to the two thirds power, times the surface wind velocity squared. Also the structural efficiency, as defined by the ratio of payload to gross weight, diminishes with an increase in size[1]. For these and other reasons, emphasis will be placed on minimum size, commensurate with the performance objectives as listed below:

A. Payload, [redacted] and/or luggage - 400 lbs. 25X1
B. Cruising altitude - 7,000 ft MSL
C. Free ballooning capability - 2 hrs.
D. Cruising range at zero wind velocity - 100 miles
E. Minimum cruising speed capability at sea level (0-wind) - 50 ~~30~~ knots.

A high degree of flight stability as well as excellent maneuvering capabilities is essential. The vehicle must maneuver close to the ground while the payload is decreased by as much as two-thirds. These objectives will be increased wherever the gain can be obtained without increasing the vehicle size.

F. Field Inflatable

IV. PROPULSIVE ENERGY REQUIREMENTS

A basic problem common to most powered lighter-than-air missions is to propel a configuration with a maximum ratio of volume to weight through the atmosphere with a minimum expenditure of fuel and a maximum degree of directional stability and control.

Although considerable work has been conducted to individually optimize airship components, we believe it is essential to consider the airship structure together with its propelling, stabilizing and controlling devices as a unit. Components should be so designed and arranged to complement, rather than to interfere, with each other.

The analysis of the problem to approach an optimum configuration for the task will include giving consideration to such basic parameters as:

A. Shape and fineness ratio for:
  1. Size reduction.
  2. Increased resistance to applied aerodynamic bending loads.

B. Boundary layer suction for:
  1. Over-all energy requirement reduction.
  2. Directional stabilization.
  3. Directional control.

C. Conventional as well as rear propulsion for increased efficiency and controllability.

D. Ring tail and shrouded propeller versus conventional fins for:
  1. Thrust augmentation, particularly at low speed.
  2. Flow improvement around hull.
  3. Propeller efficiency increase and/or weight reduction of

stabilizing surfaces.

4. Structural strength increase.
5. Increased directional stability and control, especially at or near hovering conditions.

E. Engine air requirements (for cooling and combustion) and their possible relation to boundary sucked air.

A. There appear to be several configurations worthy of investigation in the early phases of this program. Some of these are:

1. Small fineness ratio:
    a. Aft propelled by ducted propeller serving also as the stabilizer.
    b. Some distributed boundary layer suction.
    c. Boundary layer air used for engine intake or cooling purposes.
2. Larger fineness ratio:
    Same as 1. above but without boundary layer control.
3. Large fineness ratio: (4.2 to 1)
    a. Stabilized by boundary layer control, eliminating the need for fins (as suggested by Dr. August Raspet).
    b. Conventional engine location.
4. Conventional arrangement with or without distributed boundary layer suction.

The components involved in the configurations of 1. and 2. are arranged to complement each other. Although the magnitude of the over-all reduction in drag is difficult to estimate, the arrangement presents a form of ideal propulsion called boundary layer propulsion. Configurations of 3. and 4. minimize balance and flow separation difficulties.

Boundary layer control is intimately involved in all four suggested configurations. Reductions in drag have to be closely measured against the increased complication to determine the degree of usefulness. Unfortunately, the theories are not verified at Reynolds numbers corresponding to those of a full size airship. Measurements are being conducted on other programs, and these results when they become available, as well as theoretical predictions and measurements on this program, will be applied to this analysis.

A list of apparent advantages for Configurations 1. and 2. is presented below. The full potential of Configuration 3. can only be estimated after more progress has been made on programs now underway, particularly those at Mississippi State College under Dr. August Raspet.

The degree of departure from the conventional shape (Configuration 4.) toward the short "fat" shape (Configurations 1. and 2.) will be evaluated in terms of its advantages as well as the complications involved in preventing flow separation. A series of shapes between these two extremes will be analyzed theoretically for their over-all advantages prior to the selection of a given shape for detailed investigation and preliminary design purposes. On the assumption that flow separation can be prevented at no great penalty by distributed suction on a shape such as presented in Figure 1, the following advantages are to be gained:

1. Propeller thrust is combined with stabilizing control surfaces to give low speed controllability at and near hovering conditions.

POSSIBLE CONFIGURATION FOR SMALL PLASTIC AIRSHIP

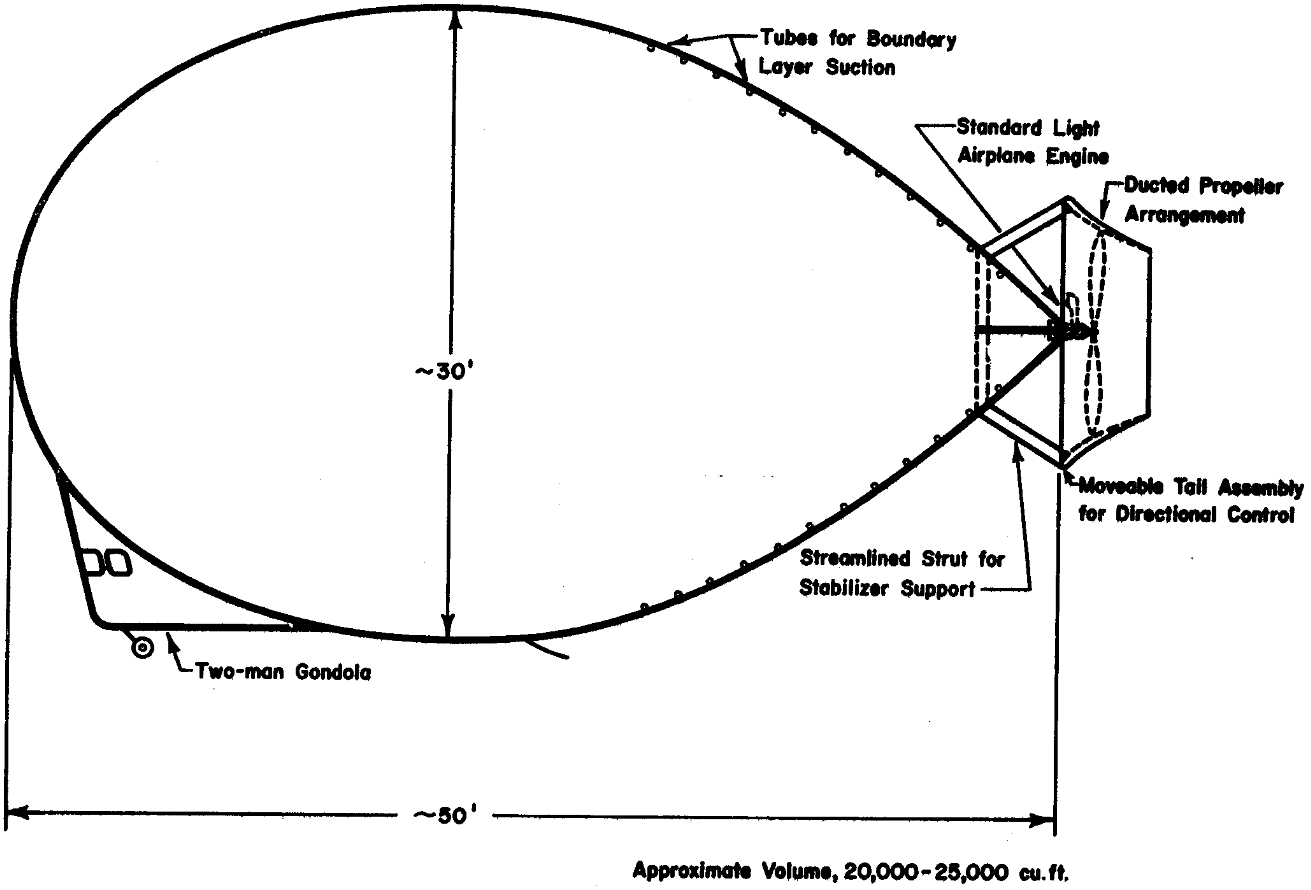

Figure I

2. When flow separation is prevented, the drag of an airship is largely a function of the ship's surface area. (Figure 2 shows the relationship between the Relative Surface Area and the Fineness Ratio for equal volumes of a body of revolution[1].) This reduction in surface area results in both drag and size reduction, which in turn reduces the propeller, engine and fuel requirements, with a further decrease in size of the envelope necessary to lift them.

3. The lift of a ring air foil has twice the lift of an elliptic flat plate that spans a diameter and has a quarter of the area[2]. It operates outside the ship's boundary layer with a resulting increase in effectiveness.

4. A ring tail can be designed to superimpose a favorable pressure gradient on the rear of the hull, which retards boundary layer growth and reduces drag.

5. The ring tail can be used to increase the mass flow through the propeller, with a net result of a gain in thrust without a loss in efficiency.

6. The propeller, like the ring tail, superimposes a favorable pressure gradient on the rear of the hull, which retards boundary layer growth and reduces drag. When the propeller is ducted, the pressure increment forward of the propeller is large and the pressure back of the propeller is nearly constant[3].

7. The ring acts as an end plate to the propeller blades and thus reduces the falling off in thrust toward the tips. The space between

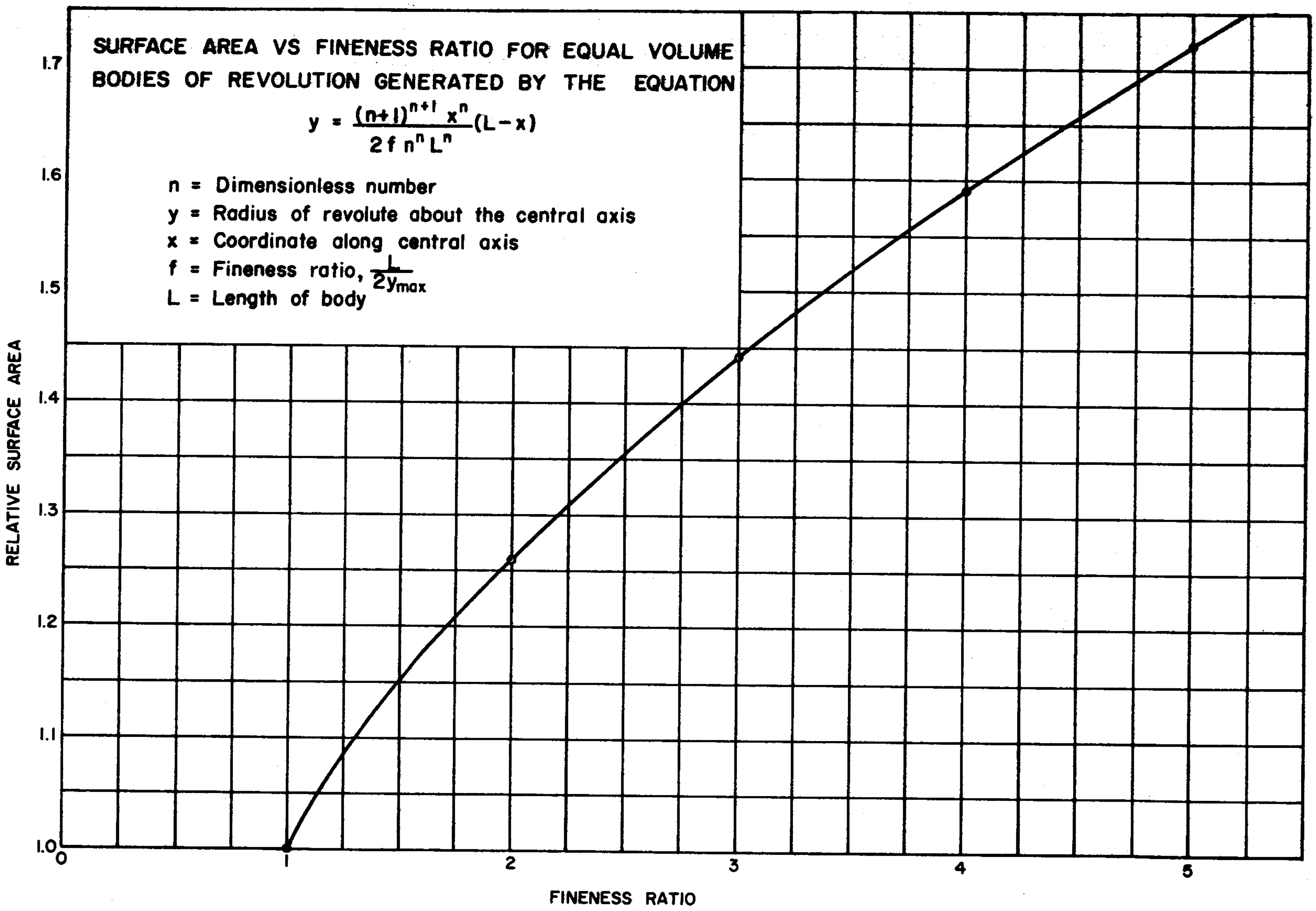
SURFACE AREA VS FINENESS RATIO FOR EQUAL VOLUME BODIES OF REVOLUTION GENERATED BY THE EQUATION
$y = \frac{(n+1)^{n+1}x^n}{2fn^nL^n}(L-x)$
n = Dimensionless number
y = Radius of revolute about the central axis
x = Coordinate along central axis
f = Fineness ratio, $\frac{L}{2y_{max}}$
L = Length of body
RELATIVE SURFACE AREA
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
0
1
2
3
4
5
FINENESS RATIO

Figure 2

the blade and the ring must be kept small. The ducted propeller would have much broader blades toward the tips, with a possible appreciable increased propeller efficiency. Ordinarily, the main consequence of the ring would be the increased skin friction drag on the ring. By proper propeller and fairing design, however, this loss will not be appreciable. This loss also must be somewhat discounted in this case because the ring eliminates the conventional tail surfaces and their high drag contributions. In one example[3], the ring and plate effect increased the efficiency by 11 percent.

8. By proper ring design, the forces interacting between the ring and the propeller can increase the efficiency by another increment. In the above mentioned example, this amounted to approximately eight percent.

9. Variable pitch propeller blades are required when the external rate of variance changes appreciably with flight speed. The presence of the fairing or ring makes it possible to keep the rate of advance actually experienced by the propeller more nearly constant, reducing the requirement for variable pitch blades. This beneficial effect arises from the fact that the velocity increment due to the ring is more pronounced at lower flight speeds.

10. The increase in static thrust for a ducted propeller can be spectacular[4], which, of course, is important in takeoff and landing, particularly from fields not considered airports.

11. The ducted propeller allows the use of a smaller diameter and

higher speed propeller, which results in a reduced propeller and engine weight in a small ship.

12. The ring surrounding the propeller is a safety feature, possibly of importance in field operations.

13. It is common practice to define the resistance to aerodynamic bending loads by the formula:

$$f = \frac{R^3 \pi \Delta P}{2\ell}$$

where:

f = resisting force

ℓ = length of the ship

R = largest radius

ΔP = pressure differential.

From this it can be seen that a ship of lower fineness ratio is ordinarily a much stronger ship, or conversely the ship can be made smaller for the same strength.

14. As the fineness ratio is decreased, a reduction in profile area is experienced. This in turn reduces the aerodynamic forces acting on the ship.

15. The aerodynamic loads on the stabilizing surfaces can be better absorbed by a ring tail configuration, which is inherently a superior type structure as compared to a cantilevered fin type.

16. A smaller ship has an increased structural efficiency[5]. A higher percentage of the gross load will be in payload. The arrangement

offers some advantages regarding boundary layer suction. It is possible that air requirements of the engine can be combined beneficially with the suction requirements of the boundary layer.

The problems in weight and balance do not appear to be insurmountable. Present day lightweight, high strength materials, as well as advanced stress analysis techniques and strained measuring devices, make such an arrangement appear feasible. Several engines suitable for rear installation are currently available.

Care must be exercised in defining a configuration which will be stable for both moored and flight conditions.

Other difficulties that may be encountered are incompatibilities between propeller diameter requirements and ring diameter requirements. Another important unknown at this time is the effect of the hull on the velocity of the air flowing in to the propeller. Once these items are determined, however, there are numerous parameters to be adjusted and compromised. Different techniques to replace conventional moveable control surfaces will be investigated. It is expected that inflatible pressure beams can be substituted for this purpose and will be the subject of considerable model as well as theoretical work.

It is realized that other programs evaluating ring tails and rear engine installations have been conducted. Reports on all of these programs have not been received. The reports reviewed to date[6] indicate the desirability of further investigation of these features.

V. FLUID DYNAMICS

A. Viscous Flow Theory

The resistance of an airship is due almost entirely to the viscous action of the fluid which causes the growth of a boundary layer of considerable thickness, this being aggravated by the extreme length of most airships.

Theoretical methods are now advanced to a sufficient degree to allow the calculation of the viscous drag of bodies of revolution[7]. Unfortunately, these methods utilize certain assumptions which have never been verified by in-flight boundary layer measurements on airships. The drag values for airships have been obtained experimentally, either by full scale deceleration tests or by wind tunnel methods. Large discrepancies have appeared in these data[8], due largely to a lack of understanding of the boundary layer growth mechanism which is sensitive to free air turbulence, surface roughness and the Reynolds number effect. A method described by Paul S. Granville[9] presents a procedure for calculating the viscous drag of bodies of revolution. It involves the detailed analysis of the development of the boundary layer from its origin on the nose, to a zone of laminar flow, to a transition zone between laminar to turbulent flow, to a turbulent boundary layer and finally to a frictional wake.

Required for this procedure are:

1. Profile dimensions.
2. Pressure distribution.
3. Body Reynolds number.

Although potential flow theory is adequate for obtaining pressure distributions about simple shapes, it is expected that the three dimensional electric analogy tank will be useful in obtaining pressure distributions about bodies with stabilizing surfaces and propelling devices attached. The Model will have to be of sufficient size to reduce meniscus difficulties.

It is essential that theoretical work be verified by detailed experimentation as extrapolation of the available information can be misleading. It is anticipated that detailed boundary layer profile measurements will be conducted in the field on a full scale captive balloon model having the airship shape and stabilizing method selected by theoretical analysis of the factors involved, as previously mentioned. Prior to this effort, however, a review of the boundary layer work conducted by Northrup Aircraft Corporation, and particularly the tests conducted on bodies of revolution in the low turbulence NACA wind tunnel at Moffet Field, California, will be made for possible applicability to this program.

It is expected that the boundary layer investigations conducted by the Aerophysics Department of Mississippi State College[10] under Dr. Raspet will be of considerable value in planning and executing this program, particularly with respect to the experimental technique employed and its relation to the various theoretical treatments.

Once the boundary layer profile is established for various stations of a given shape and configuration, intelligent estimates of the location, amount and distribution of suction can be made. According to Cornish[11] the section velocity is determined by an equation of the type:

$$V_o = (H + 2)\theta U' + \rho\theta' U - \frac{\tau_o}{\rho U}$$

where:

H = Boundary - layer shape parameter

θ = Boundary - layer momentum thickness

U = Local velocity

τ_o = Local wall shearing stress

ρ = Mass density.

Therefore, the suction velocity should be governed by reducing the momentum thickness without letting the local shearing stress get too high, i.e., low suction velocities largely distributed are preferable to concentrated large suction velocities.

The final degree of boundary layer suction must be evaluated in terms of added complication and weight as well as reduction of overall energy requirements and control advantages.

B. Electric Analogy Tank

The Electric Analogy Tank consists of an insulated trough partially filled with an electrolyte; usually a weak electrolyte such as ordinary water. An electric field is introduced into the tank by suitably placed electrodes. When a body is placed in the field, the body's effect on the field can be measured by a probe, tracing lines of constant voltage, which are also the streamlines surrounding the body. Detailed analysis of the flow surrounding any shape can be made. Such analysis can explain the superiority of one shape or configuration over another. One will probably be able to deduce criteria leading to optimum aerodynamic performance. It is possible also to study the effect of a propeller and a ring tail combination on the flow surrounding an airship configuration. The lift curve is found by varying the angle of attack. In these cases it is necessary to adjust the trailing-edge streamline to conform with the boundary conditions of smooth flow.

Use of the tank combines the visual advantages of a smoke tunnel with those of a high speed computer. In many instances it can solve problems that are impossible to solve by other techniques. Since the tank simulates perfect fluid theory, its limitations are largely the same as the perfect fluid theory. It is necessary to utilize viscous drag theory in combination with the tank to obtain resistance data. Progress to date at GMI has resulted in setting up the analogy tank and computer for three dimensional bodies of revolution. Test runs have been made on bodies of known pressure distribution. The streamlines plotted by the computer compare very favorably with known data[12].

Brower has recently established a method of obtaining the normal force on a body of revolution by use of the electric analogy tank[13]. This is a rather unique solution, since the perfect fluid theory has traditionally been plagued by D'Alembert's paradox that a body pointed at both ends immersed in an inviscid fluid stream inclined to the body axis sustains no force. Brower refined Von Karman's original work by applying the theory to one model, having a fineness ratio of six. This accounts for a vortex system, which is responsible for a normal force, being generated. He recommends this technique in those cases where one shape is to be thoroughly investigated.

C. Stability Analysis

The aerodynamic characteristics of a lighter-than-air vehicle are of fundamental importance in performing a static and dynamic stability analysis since both upsetting and stabilizing forces and moments are aerodynamic in nature.

Lift, drag, pitching moments, sideforce, yawing moments, rotary lift and rotary moment characteristics are all necessary for these computations. Static stability and equilibrium conditions for the moored or free flight condition of a lighter-than-air captive vehicle can be mathematically determined by solving the three equations, listed below, simultaneously[14]:

1. Vertical forces:

$$L \cos\beta + D \sin\beta + (B - W) = T \cos\theta$$

2. Horizontal forces:

$$D \cos\beta - L \sin\beta = T \sin\theta$$

3. Moments about C.G. (Center of Gravity):

$$\Delta Y \left[D \cos(\alpha - \sigma) - L \sin(\alpha - \sigma) \right] + (M_a)_{CB} - \Delta Y\ B \sin(\phi - \sigma) - T \ell_T = M_{CG}$$

where:

L = lift, LBS

D = drag, LBS

B = static Buoyancy, LBS

W = gross weight, LBS

T = cable tension, LBS

$(M_a)_{CB}$ = aerodynamic moment about Center of Buoyancy, FT. LBS

M_{CG} = moment about Center of Gravity, FT. LBS

ℓ_T = dynamic moment arm of tail lift with respect to C.G. The remaining terms appearing in these equations are defined in Figure 3 and apply to a moored captive balloon. For the free flight condition many of the terms are zero and a thrust term must be added. The results obtained from the solution of these equations apply to the ideal case of steady-state wind conditions. It is also necessary to investigate the dynamic response to time variable wind currents and gusts superimposed upon the steady wind current. For small displacements from the equilibrium condition, the pitching motion of the ship must satisfy an equation of the type:

$$I_e\,'\phi' + m''\dot{\phi} + m_1'\alpha + m_2'\phi = M_g\,(t)$$

where:

I_e = effective moment of inertia of the balloon in pitch, including virtual inertia of the envelope and fins

m_1' = slope of the aerodynamic pitching moment versus α at α_t

m_2' = metacentric stabilizing moment coefficient

m'' = rotary derivation of pitching moment due to rate of pitch.

ϕ and α are small angular displacements from the equilibrium balloon altitude.

M_g = pitching moment due to aerodynamic forces acting during the gust.

A similar analysis can be made for the ship in yawing motion. One important factor in lighter-than-air work is the large virtual inertia.

A mathematical stability analysis will be made as a part of the predesign analysis. In this manner it is possible to predict the effect of component designs of different or unusual arrangements as well as to define the control necessary for flight maneuvers.

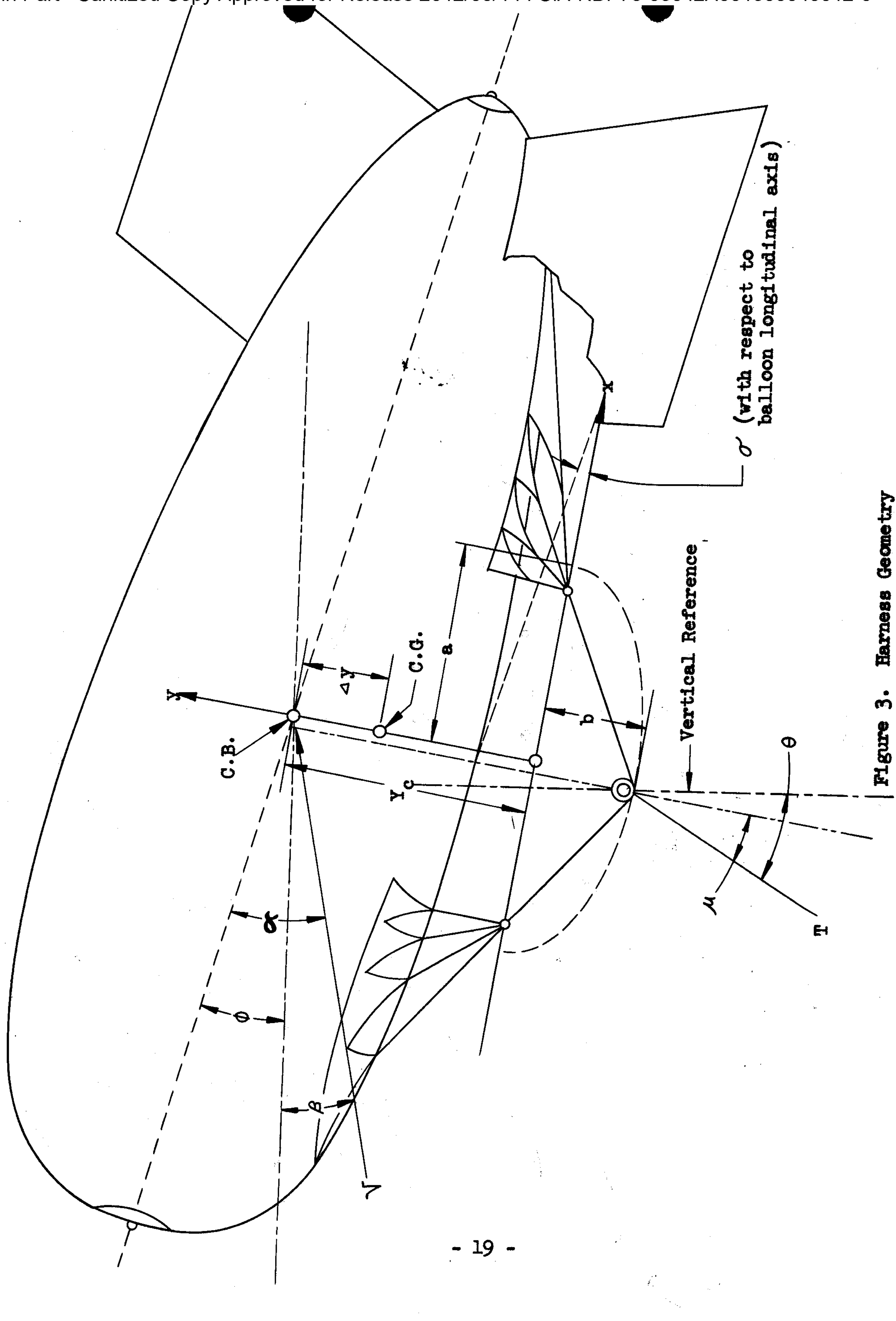

Figure 3. Harness Geometry

VI. STRUCTURAL REQUIREMENTS

Careful analysis will be carried out to determine the static and dynamic forces applied to the envelope. A model of the vehicle will be built and evaluation of fabric strain will be made. The work conducted to date at [redacted] under the title of Pressure Beam Mechanics will prove useful for this application. The findings of Zannoni, et al.[15], will also be of value. An operating pressure will be specified to provide adequate resistance to the envelope bending moments caused by static buoyancy, component weight, and aerodynamic forces in flight. Material exposure tests have been carried out and are reported in the final report[16]. Two or three of these materials will be selected early in the program for further weathering tests on this program. A material for the envelope will then be selected in view of these findings.

The vehicle will be provided with one or more ballonets, which are separate, internal air chambers. Multiple ballonets may have certain desirable trim and pitch control features. The main purpose of the ballonet is to allow the lifting gas to expand or contract without changing the size or shape of the main envelope. The expansions or contractions are caused by changes in atmospheric pressure, temperature and the vehicle altitude. The size, shape, location and ballonet material will be specified from these findings.

Past experience has shown that pressurization by centrifugal blowers is a desirable method. This type of blower, equipped with forwardly inclined vanes, has a characteristic of providing constant pressure at minimum power. Available aircraft-type equipment will be reviewed and optimum equipment will be selected.

VII. SPECIAL PROBLEM AREAS

A. Field Handling and Inflation

Special consideration will be given in the preliminary design to minimize field inflation and launching difficulties. Provisions for mooring the vehicle during this period will be provided. It is expected that shroud techniques can be developed to facilitate inflation for high wind launchings. Figures 4 and 5 show the shroud technique as applied to free balloon launchings for high wind conditions. Component selection and design for the vehicle will be influenced by the requirements of this type launching.

B. Controllability

Several new ideas regarding controllability of the airship have been advanced. It is expected that small laboratory models will be constructed to verify certain aerodynamic properties. Theoretical work, entitled "Inflatible Muscles," conducted in the first phase of the program will be beneficial in the analysis of these ideas.

C. Other Lighter-Than-Air Systems

The staff will be available to consult, discuss, and make preliminary estimates and calculations involving other lighter-than-air tasks. Figures 6 and 7 show two lighter-than-air vehicles which are used for specific task objectives.

Ip	X X
H	A Q X
D	A J X
Cl	K Q X X X

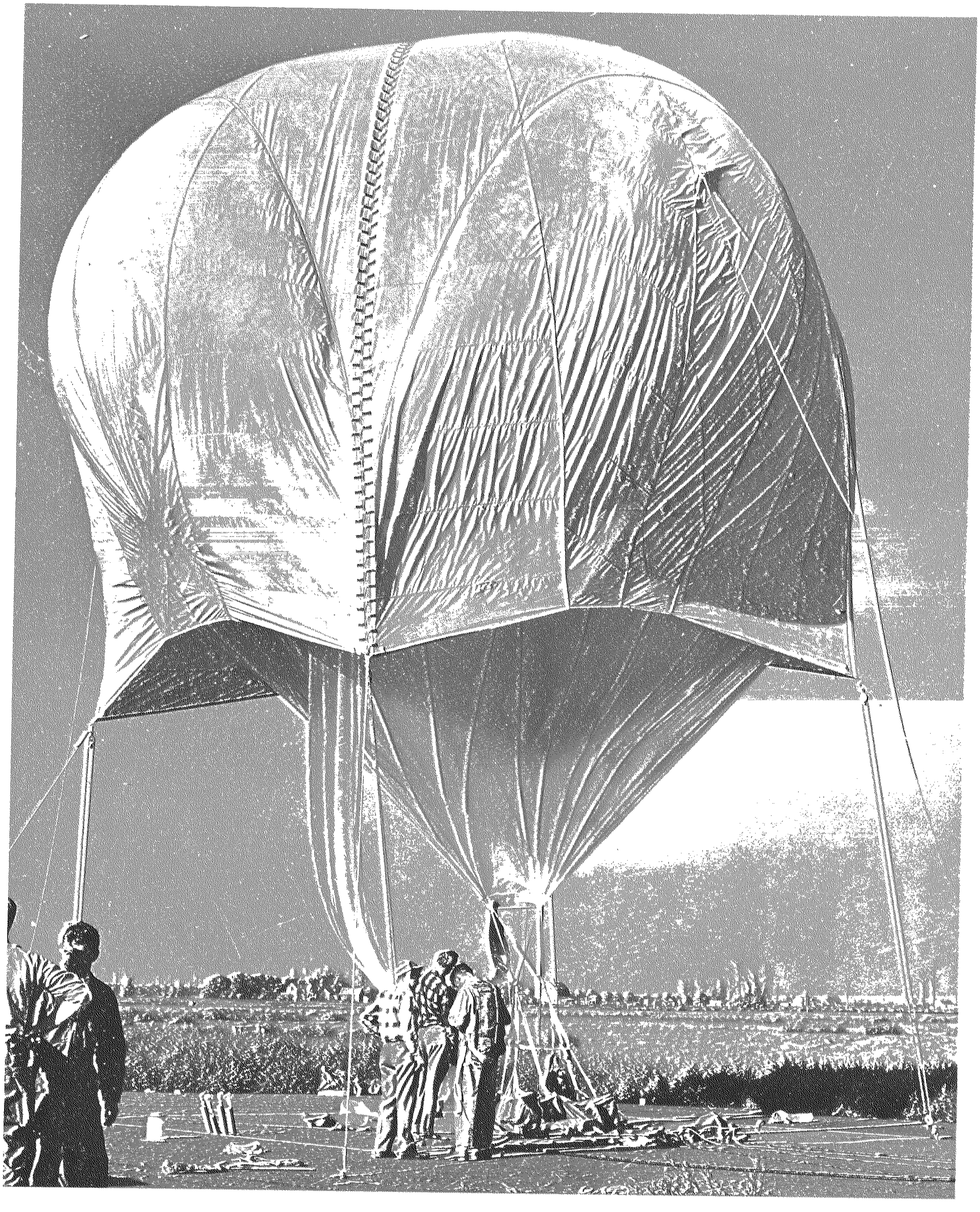

Figure 4. Shroud in Place, Protecting Balloon From Wind During Inflation Process.

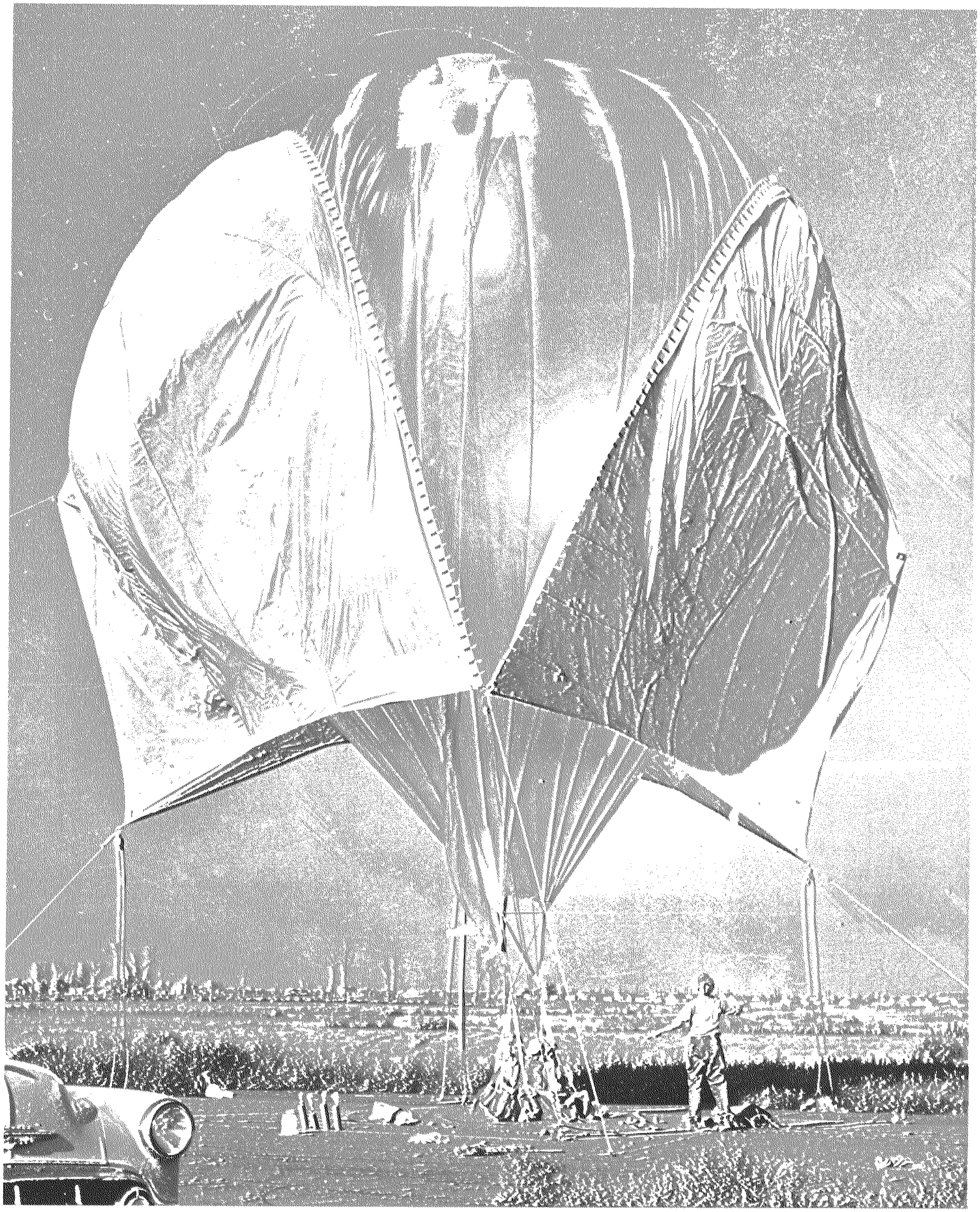

Figure 5. Shroud Being Removed

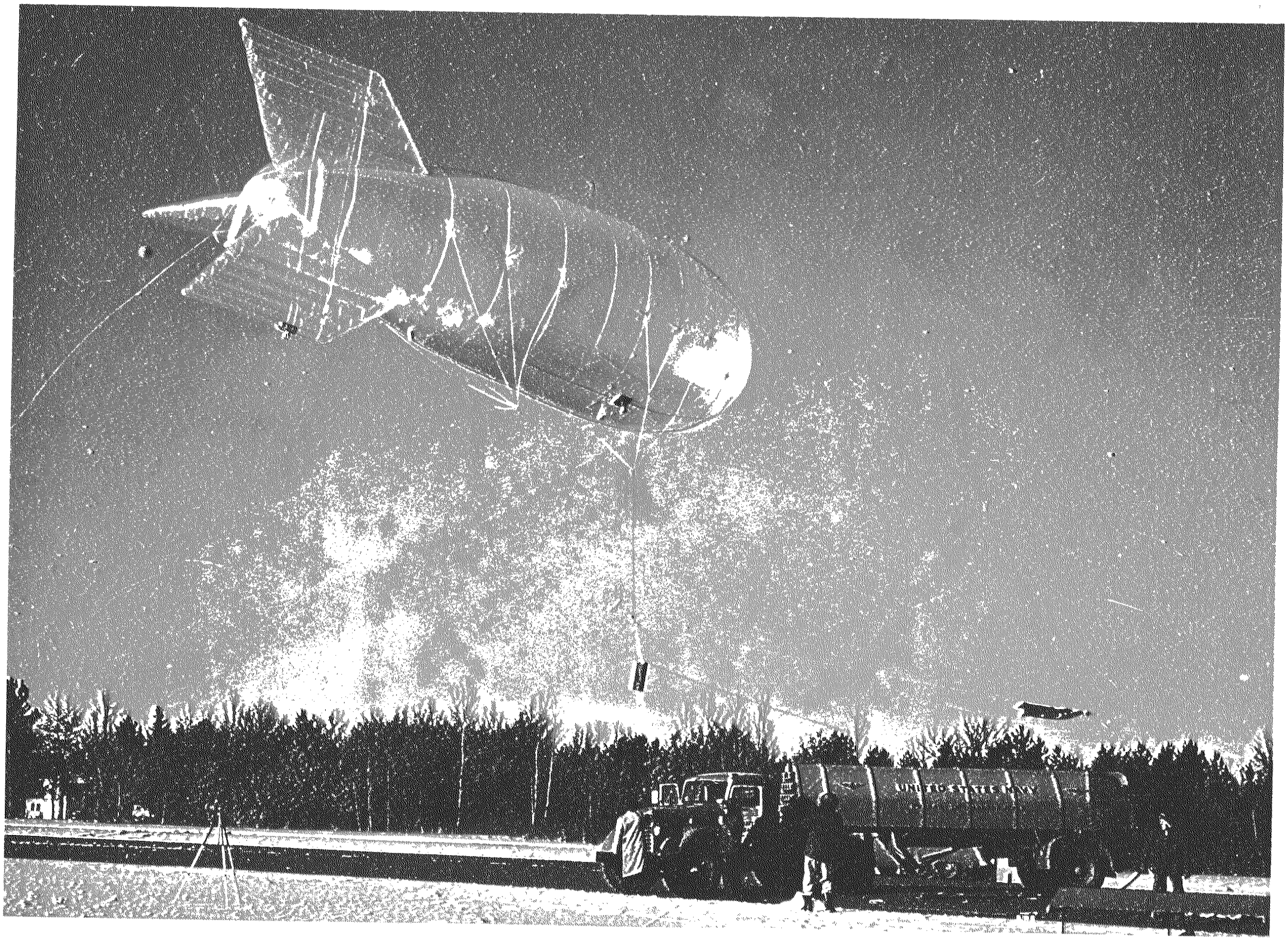

Figure 6. Model 13-S-8

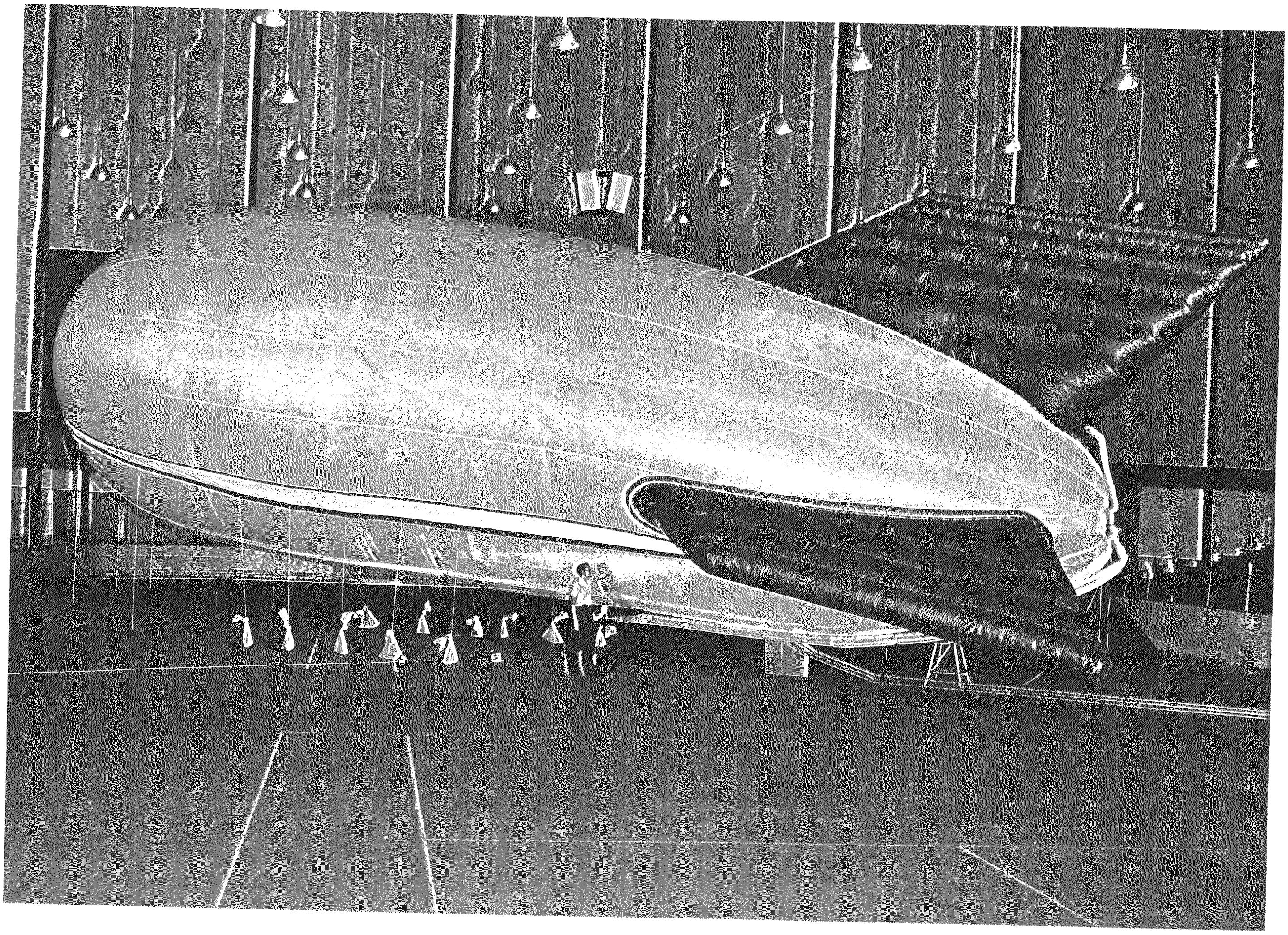

Figure 7. Model 21-3-8

VIII. PROPOSED PROGRAM

It is anticipated that the following sequence of events will take place:

Months 1 - 6

Continued theoretical analysis;

Trips to other establishments conducting related work;

Laboratory model work;

Continued review of published work;

Selection of a shape and configuration;

Review of available power plants and propellers.

Month 7

Design of model;

Continued theoretical analysis. — given on page 4

Month 8

Fabrication of model;

Continued theoretical analysis.

Months 9 and 10

Experimental evaluation of selected shape and configuration.

Months 11 and 12

Selection of standard aircraft engine and propeller;

Preparation of preliminary design report for small plastic airship.

IX. REFERENCES

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