FLEXIBLE WING RESEARCH AND DEVELOPMENT

By F. M. Rogallo

NASA Langley Research Center
Langley Station, Hampton, Va.

For Presentation at the Symposium on
Retardation and Recovery

Dayton, Ohio
November 13-14, 1962

FLEXIBLE WING RESEARCH AND DEVELOPMENT

By F. M. Rogallo

NASA Langley Research Center
Langley Station, Hampton, Va.

ABSTRACT

This paper reviews flexible-wing research and development projects recently completed or now in progress by the National Aeronautics and Space Administration or by the industry under contract to NASA or the Department of Defense.

L-3242

FLEXIBLE WING RESEARCH AND DEVELOPMENT

INTRODUCTION

When I was invited to present a paper on the subject "Rogallo Wing" I assumed that your program committee had in mind what has been called the "Paraglider," "Parawing," "Flexikite," "Flex-wing," "Flight-Sail," etc., or more broadly, the flexible-wing concept. Because nearly all of our publicized flexible-wing research and development has pertained to only one of the many possible configurations, the impression may sometimes be given that we are not considering other configurations or that they do not fall within the flexible-wing concept. To emphasize that this is not so, figure 1 of reference 1 is repeated herein, and attention is called to the two-lobe, single curvature configuration on which so much work has now been done simply because that configuration was arbitrarily chosen for a beginning. In preparing this paper I am assuming that you have seen my St. Louis paper (ref. 1) and the film shown there (Langley film L-688) and the earlier film shown in my 1961 IAS Presentation (Langley film L-593). The present paper will cover new projects or additional work on those of the previous papers.

THE 50-FOOT INFLATED-FRAME PARAGLIDER

Work has continued on the 50-foot inflated-frame paraglider discussed in reference 1. (See fig. 2.) Flights have been made with the full-size boiler-plate Mercury capsule at total weights of 2,000, 2,500, and 3,000 pounds using a particular rigging that provided nearly straight flight and a rather low angle of attack. Radio-control equipment is under construction that should allow investigations of the stability, control, and performance of this wing over a wide lift range in both straight and turning glides and during the landing maneuver. In addition to being the largest flexible wing yet built and having the heaviest payload yet carried, this wing has a very limber frame that will allow it to increase its span during the flare, which may improve its landing characteristics relative to gliders with a more rigid frame.

THE NASA FLIGHT RESEARCH CENTER MANNED PARAGLIDER

The NASA Flight Research Center at Edwards, California has built and flown two additional versions of the manned paraglider previously discussed in reference 1. The I-A version shown in figure 3 has been flown numerous times by four different pilots of varying backgrounds and experience, and the general concensus is that the craft maneuvers and handles quite well at a w/s of 4.25 and a L/D maximum of 3.8, according to Victor W. Horton of the Flight Research Center.

When I was at Edwards in August of this year I witnessed several flights of the I-B version which had 100 square feet of cloth area and a flying weight of 660 pounds for a w/s of 6.6 and an estimated L/D maximum of about 3, values of these parameters very near those estimated for the Gemini paraglider landing system to be discussed later. All the landings I was privileged to witness were very good.

GEMINI PARAGLIDER

The Gemini paraglider landing system is shown in figure 4. The deployment sequence is shown at the bottom of the figure. Models of this configuration have been investigated in wind tunnels at the Langley and Ames Research Centers, and flights of radio-controlled models are being made at NASA Flight Research Center. I saw one of the early flights of a 1/2-scale model in August of this year. As mentioned, many manned flights have already been made at Edwards with a paraglider having approximately the wing loading and lift-to-drag ratio expected for the full-scale version of the Gemini-paraglider landing system. Development of this system is being done by North American, McDonnell, and Goodyear under contract from the NASA Manned Spaceflight Center.

THE INFLATED MICROMETEOROID PARAGLIDER

A full-scale model of the inflated micrometeoroid paraglider is shown in figure 5. This model was investigated in the Langley full-scale tunnel, mounted as shown in figure 5, and was investigated in gliding flight after release from a helicopter. In these latter studies it was released from a cable attached successively to the nose, tail, wing tip, and the bottom of the instrument pack. In all drops it attained its normal steady glide attitude after a very few oscillations. Inflated micrometeoroid paragliders, which are being built by Space-General under contract to NASA will be lofted to an altitude of 700,000 feet by means of an Aerobee rocket at Whitesands. Micrometeoroid impacts on the 200 square feet of instrumented wing surface will be telemetered to the ground receiver. The micrometeoroids and their effect on the wing will be studied after recovery of the paraglider subsequent to its landing.

RYAN FLEX-WING AND FLEEP

Reports are now available covering wind-tunnel and flight investigations of model and full-scale versions of the Ryan flex-wing shown in figure 6. (See refs. 2 and 3.) Although flown successfully for 25 hours (ref. 3.), the full-scale machine did not have entirely satisfactory flying and handling qualities, and a NASA flight research program was initiated that was expected to remedy these deficiencies. At the beginning of this program, while a check flight was being made of the machine in its previously flown condition, the machine was wrecked. The Ryan Aircraft Company is at present under Army contract to build several more machines of this general configuration, called the "Fleep," a contraction of the words "flying jeep."

MARINE RECONNAISSANCE DRONE

The Ryan Aircraft Company built for the Marine Corps several small photo reconnaissance drones like that shown in figure 7. Photographs of particular objects on the ground were taken from these radio-controlled drones.

INDIVIDUAL DROP AND PRECISION CARGO DROP

An artist's conception is shown in figure 8 of an individual drop paraglider that I saw under development at Yuma, Arizona last August. The payload at that time was a dummy, but after completion of developmental work using radio-controlled dummies it is anticipated that these paragliders will be investigated in flight by men who will control them to the desired landing spot by direct manipulation of the harness lines. Prior to deployment, the wing is carried in a backpack like a parachute. This work and a parallel development of a radio-controlled precision cargo-drop paraglider using essentially the same wing are being done by Ryan under contract to the Army.

TOW GLIDERS

Although the towing of manned paragliders has been demonstrated by NASA Flight Research Center as previously discussed, by Flight Dynamics, Inc., of Raleigh, North Carolina, and by others, the towing of uncontrolled paragliders has been limited as yet to rather small models. The Ryan Company is now under contract to the Army to design, build, and fly several unmanned cargo-tow gliders to carry 1,000 pounds of payload when towed behind a helicopter as shown in figure 9. These gliders can be kept on the tow line during the landing, or they can be cut loose in flight and landed under radio control from an aircraft or a ground station. After this technique is developed it may have very wide applications for both military and civil uses whenever surface transportation is impractical.

PARAWING L/D VERSUS C_L

Results of an exploratory study of some effects of parawing geometry on performance are shown in figure 10. The lift-to-drag ratio L/D, which is an indication of the glide ratio or of the thrust required, is plotted as a function of the lift coefficient C_L, which is an indication of the lifting capability of the wing. The four wings investigated had cloth surfaces attached to rigid leading edges and keels. The two wings with lowest $(L/D)_{max}$ had straight leading edges and conical surfaces as shown in the lower part of figure 11 and the two wings with highest $(L/D)_{max}$ had curved leading edges and cylindrical surfaces as shown in the upper part of figure 11. In addition to the improvement in maximum L/D, the cylindrical wings exhibited flyable characteristics to much lower values of C_L than the conical wings, indicating a much greater speed range potential. The conical wings were superior at high values of C_L. The performance and stability parameters obtained in this exploratory investigation are being prepared for publication, and a more complete investigation is under way.

STABILITY AND CONTROL

Aerodynamically a nonporous flexible wing is identical with a rigid wing of the same shape. Much of the wealth of aerodynamic information and experience on rigid wings is therefore applicable to flexible wings, including the methods for obtaining stability and control. Proper account must be taken of the flexibility of the wing surface and of the frame. In some designs in order to simplify the design problem a very rigid frame has been used, but this expedient increases the structural weight and the difficulty of packaging or stowing the wing. Other advantages of a flexible frame are a reduction of fragility and the possibility of obtaining control by flexing the wing without need for hinges. A wide variety of shape and location of stabilizing and control surfaces and other devices may be used with flexible wings as is done with rigid wings if desired, but many applications, as for example, the NASA Flight Research Center manned glider have proved that a single piece of cloth can be made to provide lift, stability, and control.

PACKAGING AND DEPLOYMENT

Several methods of packaging and deploying paragliders with rigid-tube frames have been developed and demonstrated by the NASA. A long slender package was attained by merely hinging the tubes at the apex for an early investigation involving gliders rocket launched from Wallops Island. In the Saturn booster recovery investigation the length of the package was reduced to half by adding another set of hinges in the middle of each tube. And in the investigation of a space-capsule recovery system an even shorter package was effected by use of telescoping tubes of many segments.

The packagability of inflated-frame paragliders is obvious. Several methods of deploying such gliders are available. Some have been demonstrated and others are under investigation by NASA and others.

The packaging and deployment capability of spring-edge paragliders is utilized by the recently marketed "Friendship-7 Paraglider Toy," and this system should find more serious application.

MATERIALS

Although nylon, dacron, Mylar, and other fabrics and plastics are adequate for construction of flexible wings for moderate temperature applications, a substantial effort is needed to develop better materials designed especially for this use to have the greatest possible strength-to-weight ratios and dependability under all operating conditions to which they might be subjected, even after years of use and exposure to the elements.

In some applications, for example, the recovery of space capsules and boosters, paraglider membrane material capable of operating at high temperature is needed. Even with presently available materials a paraglider suitable for coming all the way from orbit to earth is possible, but may not yet be practical. An improvement in materials could make it practical.

CONCLUDING REMARKS

In this paper I have done no more than mention the parawing research and development projects that are actually under way or recently completed by the NASA or by the industry under contract to NASA and the Department of Defense. Time and/or security restrictions do not allow mention of the many other applications that have come to our attention, some of which are now under serious consideration.

After more than 15 years of study and experiment with flexible wings I have come to the conculsion that many things that can be done with rigid wings or parachutes can be done better with flexible wings. Flexible wings are a new, important, and fascinating field of aerospace research. It's big enough for all of us. Come on in.

REFERENCES

1. Rogallo, Francis M.: Paraglider Recovery Systems. For Presentation at IAS Meeting on Man's Progress in the Conquest of Space. St. Louis, Mo., April 30, May 1-2, 1962.

2. Johnson, Joseph L., Jr.: Low-Speed Wind-Tunnel Investigation to Determine the Flight Characteristics of a Model of a Parawing Utility Vehicle. NASA TN D-1255, 1962.

3. Flexible-Wing Manned Test Vehicle. Prepared by Ryan Aeronautical Company, San Diego, Calif. U.S. Army, Transportation Research Command, Fort Eustis, Va., TCREC Tech. Rep. 62-25, August 1962.

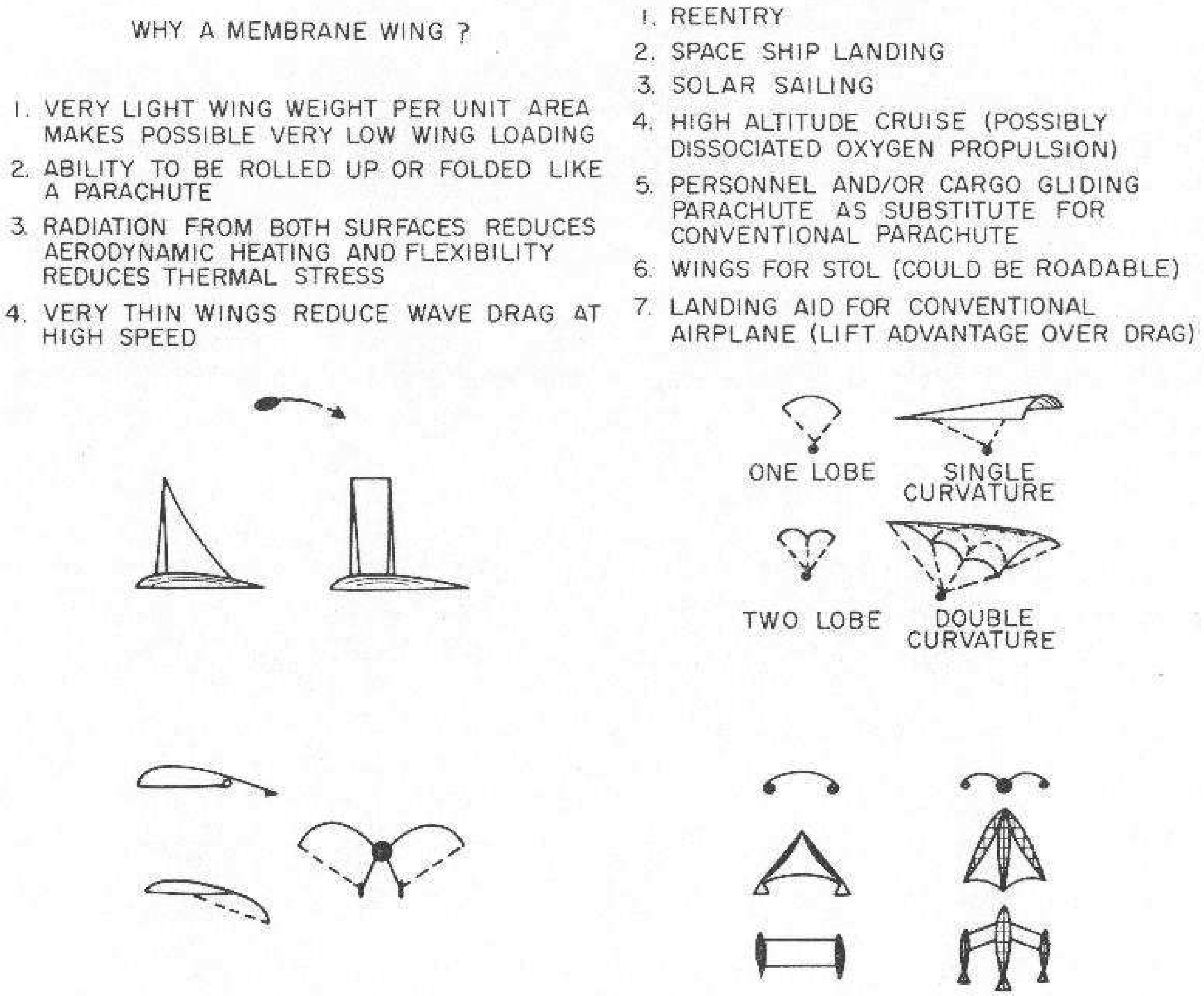
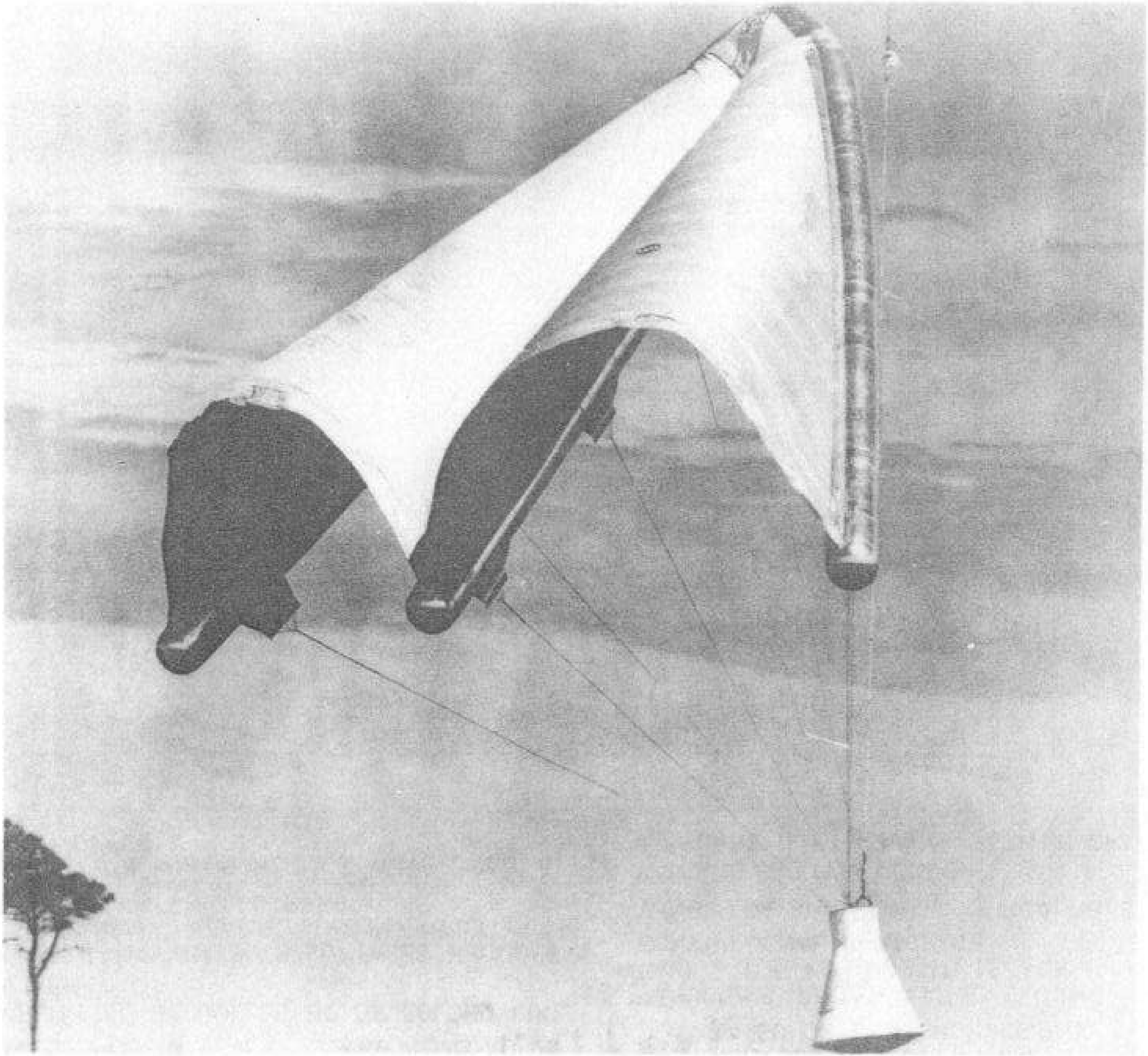


Figure 1.- Flexible-wing concept as presented to Langley Committee on General Aerodynamics, December 19, 1958.



NASA
L-62-2680

Figure 2.- Fifty-foot inflated-frame paraglider with boiler-plate Mercury Capsule being lifted by a helicopter.

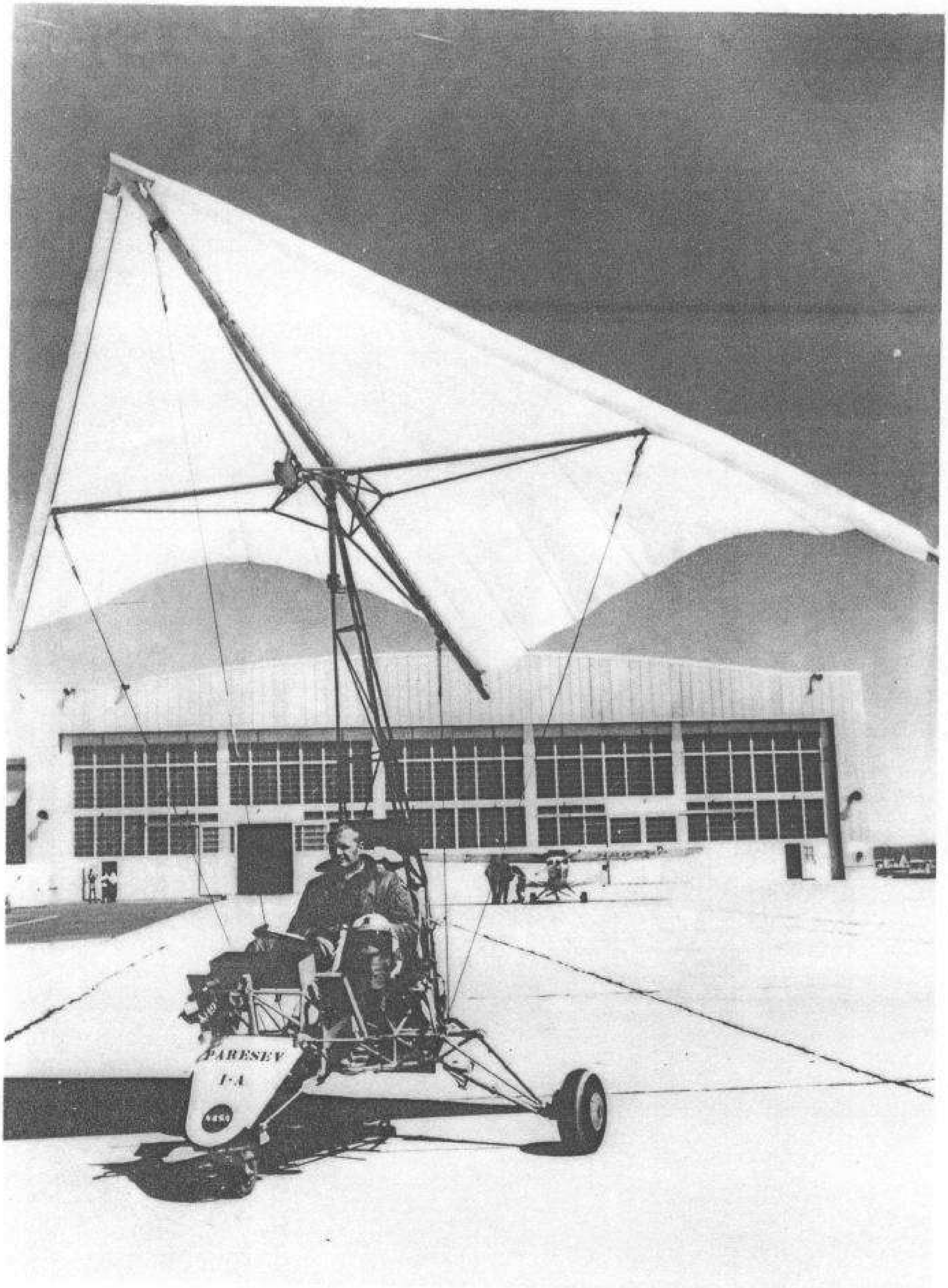
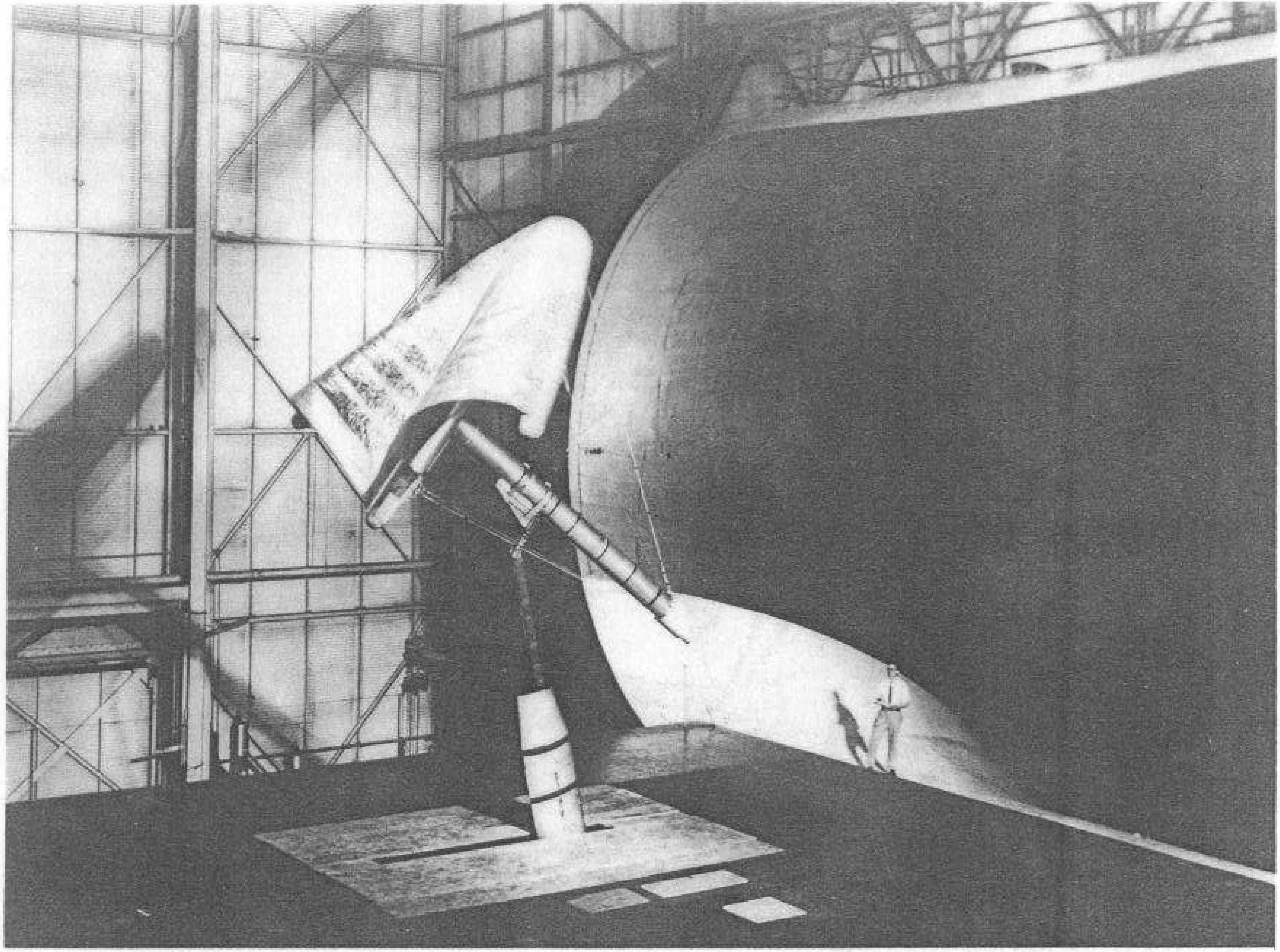


Figure 3.- Paraglider research vehicle I-A, built and flown at NASA Flight Research Center, Edwards, California.



NASA
L-62-5996

Figure 5.- Inflated micrometeoroid paraglider in Langley full-scale wind tunnel.

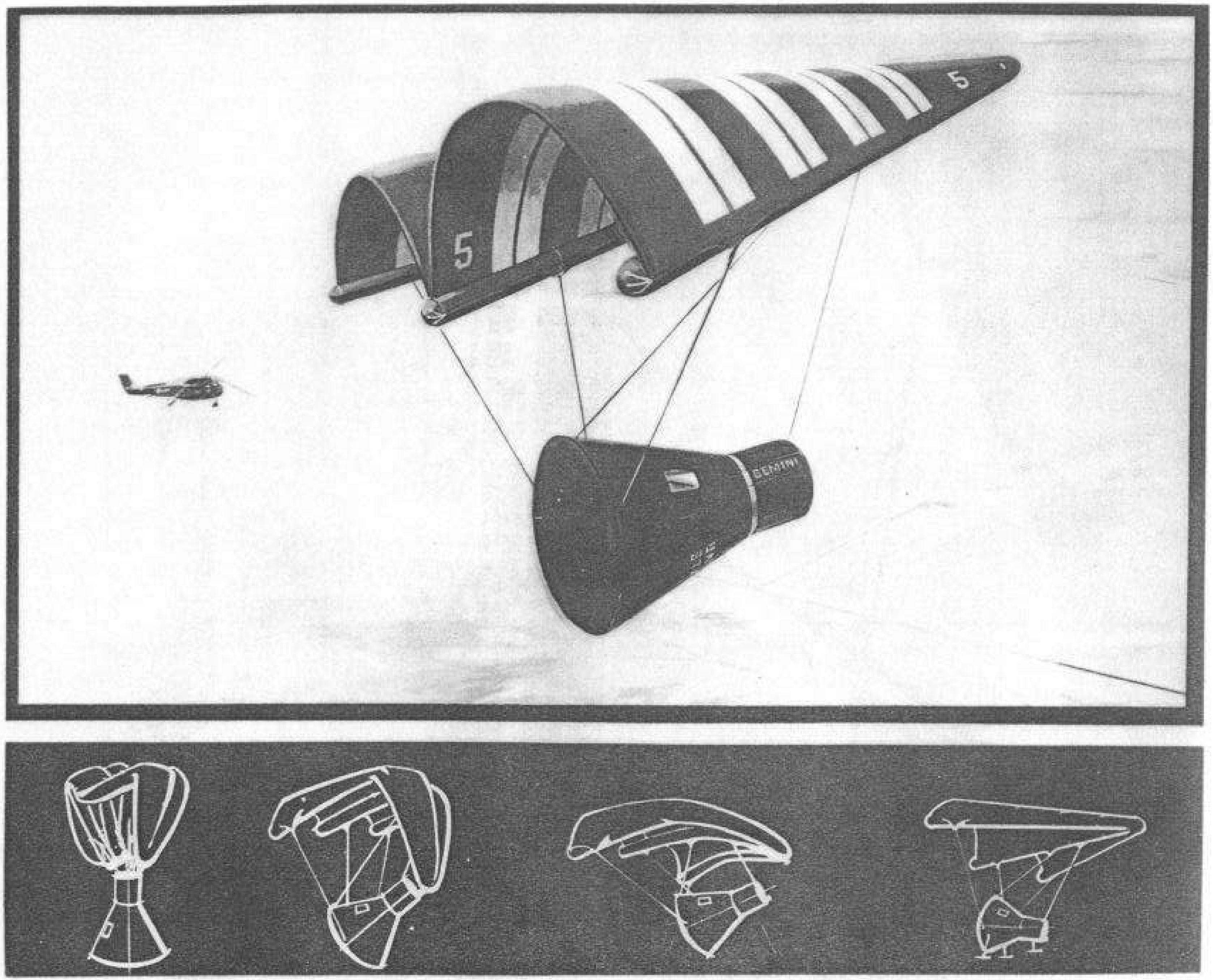


Figure 4.- Artist's conception of Gemini paraglider landing system.

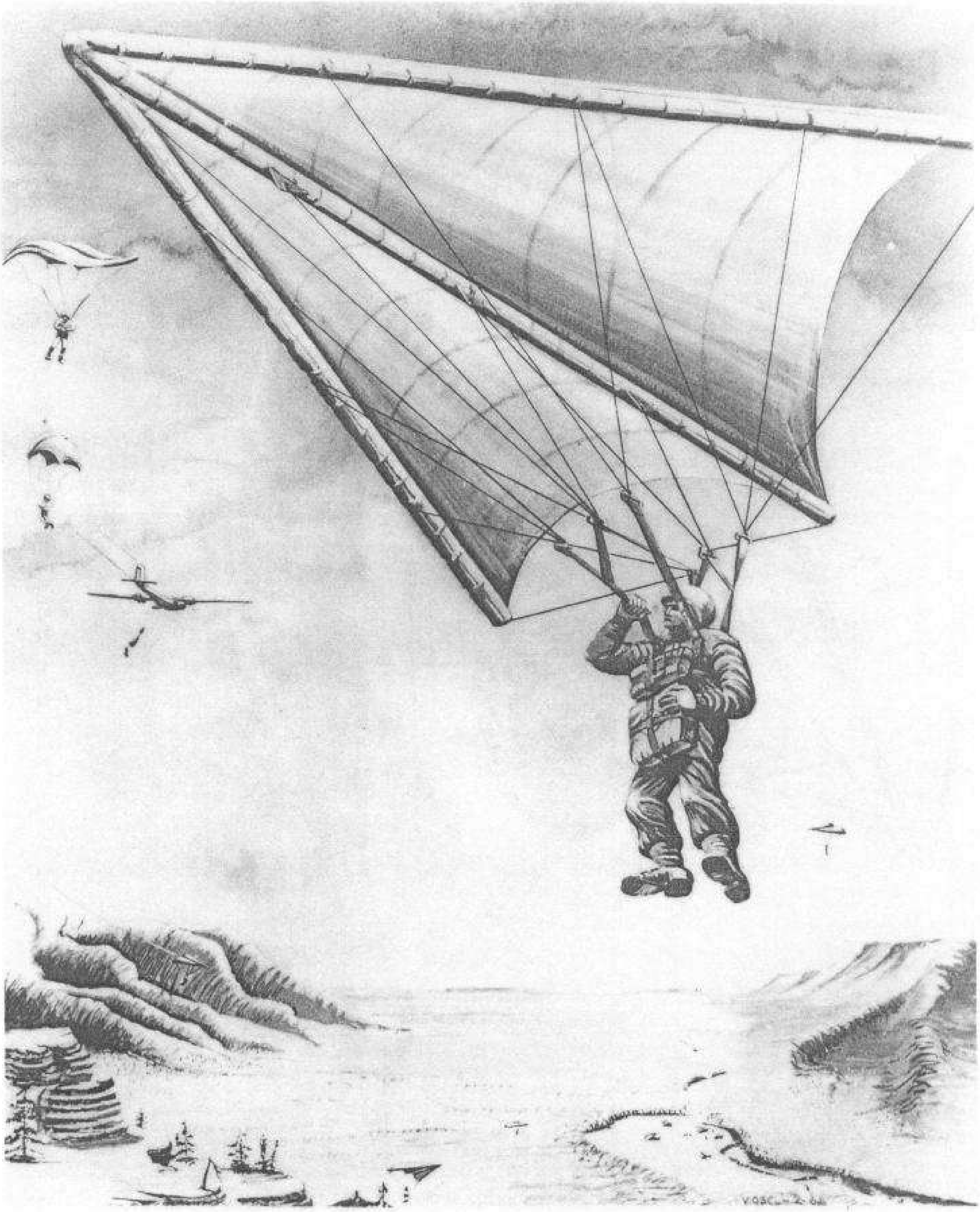


Figure 8.- Artist's conception of individual drop paraglider being developed by Ryan for the Army.

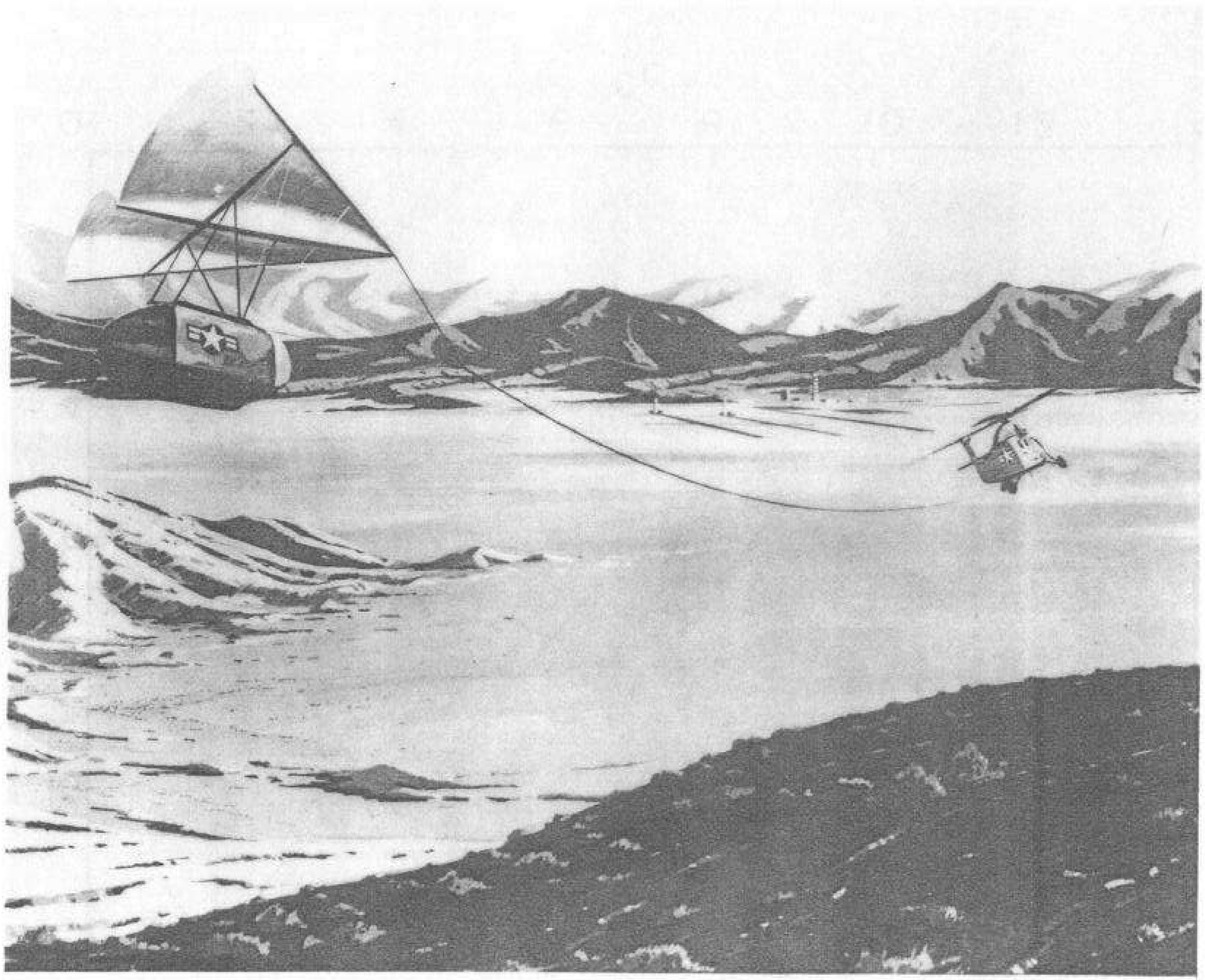


Figure 9.- Artist's conception of cargo tow glider being developed by Ryan for the Army.

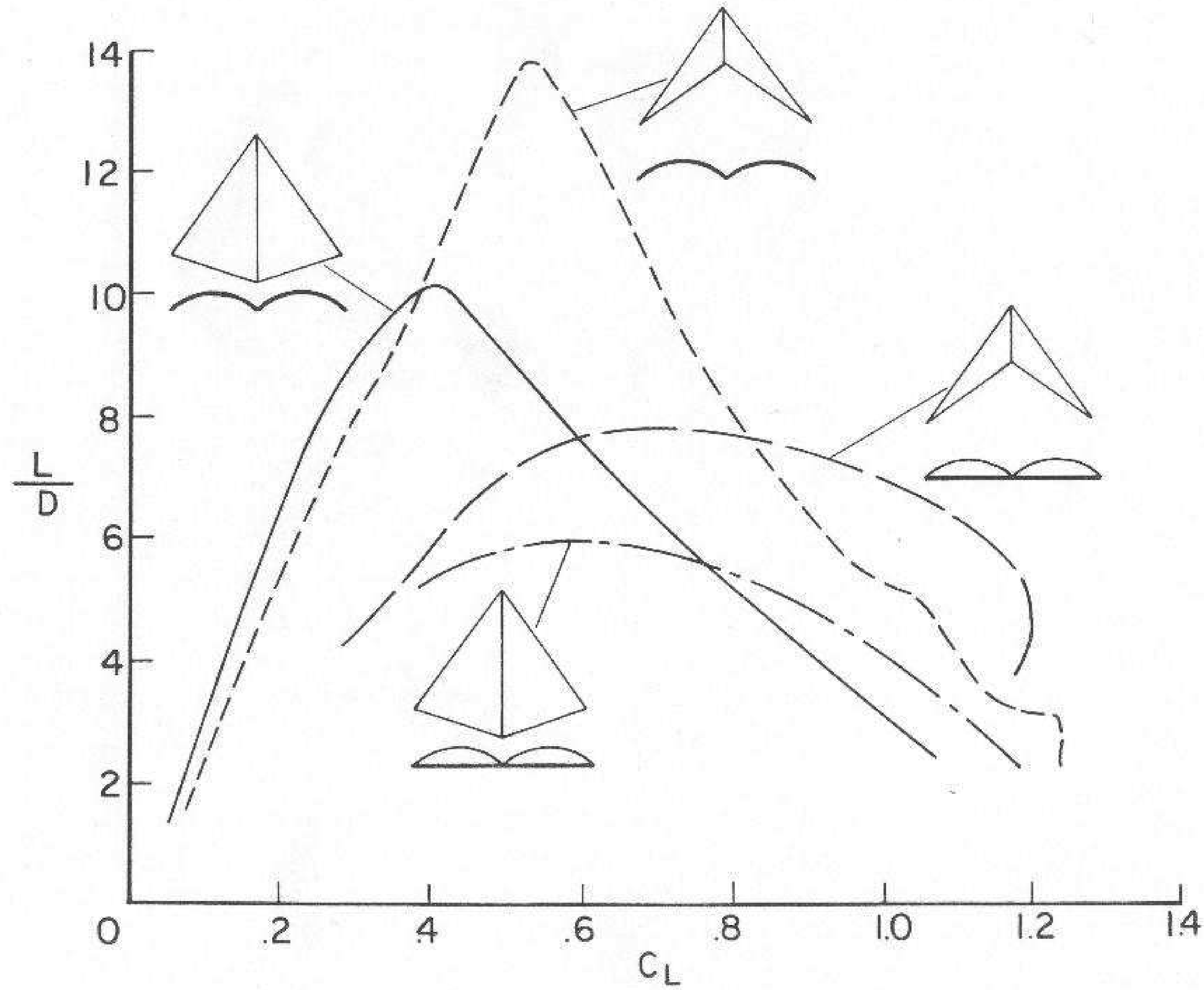


Figure 10.- Lift and drag characteristics of parawings with conical and cylindrical surfaces.

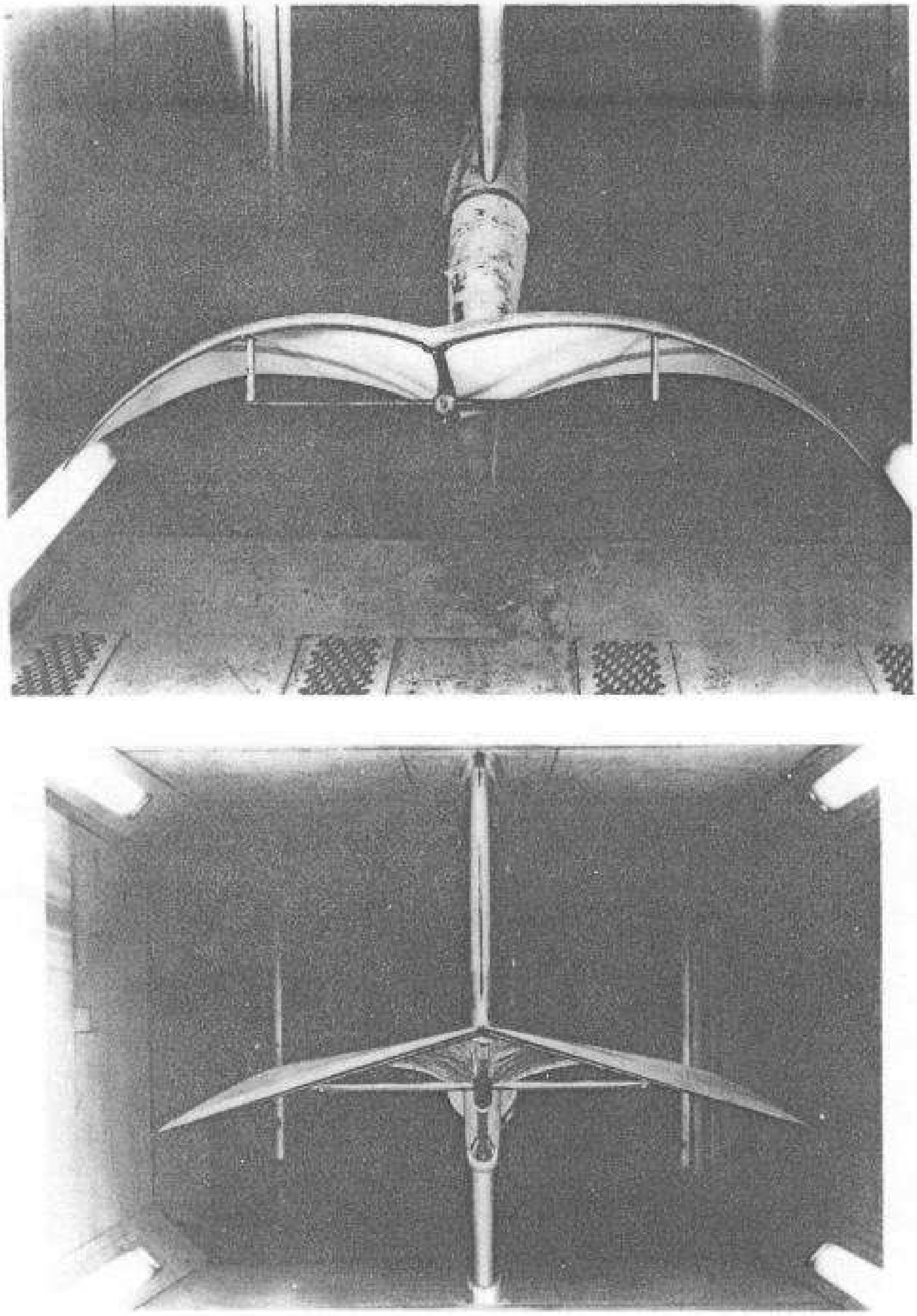


Figure 11.- Parawing models under investigation in a Langley 7- by 10-foot wind tunnel.