PARAWINGS FOR ASTRONAUTICS

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In previous talks I have found that people are interested in the history of this concept. I will therefore begin with a review of the history under two headings - Pre-Sputnik I and Post-Sputnik I. I will then very briefly discuss parawing applications, advantages, configurations, structures, and materials, and then show you a film of the flight of several parawing vehicles that we thought had some interest relative to astronautics.

PARAWING HISTORY BEFORE SPUTNIK I

Although parawing history on earth may have begun with the pterodactyl 150 million years ago, and Leonardo DaVinci is credited with some proposals for using such wings in manned flight about 500 years ago, I would like to skip to 1945 when I began a serious and continuous study of the subject.

In 1945, at the close of World War II, we started thinking about unconventional vehicle concepts including hydrofoil boats, ground-effect machines, V/STOL aircraft, and flexible wings. We did not find any organization willing to support research and development in these areas at that time; so we decided to do what we could privately as time permitted. Gradually our efforts seemed to focus on flexible wings, first on configurations roughly resembling boat sails, then on those more like parachutes, and then on configurations somewhere in between boat sails and parachutes.

Before the end of 1948 we had developed a flexible kite which we called Flexi-Kite and a gliding parachute which was later named paraglider. The flexible wing appeared sufficiently promising to us to merit a patent application at our own expense; the application was filed in 1948 and allowed in 1951.

From the outset, the parawing was proposed as a wing for gliders, and powered aircraft for military and civil use, but the proposals were not taken seriously. When meeting friends and acquaintances, the inventors were generally greeted with the query, "How's the kite business?". Labeling of the entire project as "kite business" stemmed from our use of kites as one of our experimental methods and from our early attempts to have the Flexi-Kite placed on the market in order to illustrate the parawing principle and hopefully

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to help finance our work. I will not dwell further on the long and interesting history of the Flexi-Kite, except to say that it hindered and delayed serious acceptance of the concept. Toys should copy the real thing and not the other way around.

From 1945 until about 1952 the motivation had been purely aeronautical, but around 1952 Colliers Magazine ran an exciting series of stories about space flight, with beautiful illustrations depicting rigid-winged gliders mounted on top of huge rockets. I thought that the rigid-winged gliders might better be replaced by vehicles with flexible wings that could be folded into small packages during the launching. In August of 1952, I was fortunate enough to be included in a luncheon group that also included Dr. Willy Ley, one of Colliers consultants, to whom I mentioned my thoughts about flexible wings for astronautics. But the time was not yet ripe.

In March of 1953 I was interviewed by Associated-Press Feature Writer, Saul Pett, whose resulting story of April 25, 1953, included the following paragraph:

> "The same principle might prove very useful in the days when rocket ships commute regularly between planets, Rogallo says. A rocket ship returning from Mars could pop out flexible wings as it enters the earth's atmosphere and glide the last 100 or 200 miles home, saving the stockholders that much fuel."

That fuel saving bit at the end was Pett's contribution, possibly the only reason he could see for using wings. Remember, in 1953 the man in the street was not the expert on space flight that he is today. 1953 was several years before Sputnik I.

We had continued steadily our private research on the parawing, both outdoors and in our home built wind tunnels, and in 1954 felt that a greater effort should be made to gain acceptance of the concept for aerospace applications. In April a presentation including model glider demonstrations was given to the local reserve unit of Air Force ARDC. In June, a proposal to include parawing research in the NACA budget was made. A paper was proposed for the annual meeting of the IAS, the first that actually reached the program committee after several tries, but rejection arrived which included this statement, "Although the paper is out of the ordinary and looks like it might be fine to hear, it just does not fit into our program."

We continued our private research and our efforts to spread the word. Many were amused, but none was willing to support the concept in the aerospace field during the Pre-Sputnik I era.

PARAWING HISTORY AFTER SPUTNIK I

The launching of Sputnik I seemed to shock the aeronautical research community to such an extent that it began to consider seriously many unconventional ideas. The parawing was one. Shortly after NASA was formed in 1958, we began to make a few crude wind-tunnel and model-flight investigations of parawings in the 7- by 10-Foot Tunnels Branch. In December a presentation was made to the Langley Committee on General Aerodynamics, and gradually people in other divisions became interested and volunteered to investigate parawings in their facilities.

During 1959 cloth parawings were tested in the 4-foot supersonic wind tunnel at Mach 2 and others were deployed at high altitude (150 to 200 thousand feet) at Mach numbers near three, rocket-launched from Wallops Island. In August, Dr. VonBraun invited me to give a presentation to some of his people at Huntsville. Business was picking up.

In April 1960, a paper entitled "Flexible Reentry Gliders" was given at the SAE National Aeronautics Meeting. This paper was an abridged and censored version of one entitled, "Lifeboats for Astronauts," which was considered too visionary for presentation at that time. Also in the spring of 1960 parawing briefings were given at Ryan and North American at their request. Both companies began company-funded studies. In the fall I received a request to present a parawing paper at the January Annual Meeting of the IAS. Before the end of 1960 Ryan had begun building the powered man-carrying "Flex-Wing" at their own expense. The parawing business was improving.

In January of 1961 I presented the requested parawing talk at the IAS Meeting in New York and in March repeated it at local chapter meetings in Lancaster, California, and San Diego. While in San Diego I witnessed the first flights of the "Ryan Flex-Wing," with Lou Everett in the pilot's seat. I was nervous. Also early in 1961 the Marshall Space Flight Center, the group I had briefed in 1959, gave Ryan and North American contracts to study the feasibility of recovering Saturn boosters by means of parawings. NASA in-house investigations at Marshall and Langley were also made. These studies indicated that recovery of the C-2 was feasible, and the recovery project would have been continued had the C-2 not been cancelled. The first parawing contract let by the Department of Defense was to Ryan for flight tests of the "Flex-Wing," which tests were completed in 1961, and the aircraft then sent to Langley for investigation in the full-scale tunnel. It looked like parawings were here to stay.

Thereafter the numbers of projects and contracts increased too rapidly for specific mention in this brief summary, but many of the flight articles are shown in NASA Film Serial No. L-805 entitled, "Paraglider Recovery Systems."

By the summer of 1963 it appeared that the concept had achieved world-wide acceptance and that the time had come for us to give the Government royalty-free license to use our patents, which we did in a ceremony in Washington on July 18, 1963. We feel confident that the civil and military agencies of the government will carry on this work, and we hope private industry will promote use of the concept for business and pleasure as effectively as they have for astronautics and military aeronautics. So much for history. Now a word about what it is for and what it is.

ASTRONAUTICAL APPLICATIONS

The most obvious application of the parawing is for recovery of space vehicles and boosters in the atmosphere of earth and other planets. The wing may be deployed in space to provide controlled reentry and glide to the chosen landing site, or it may be deployed after reentry, as now contemplated for Gemini, to provide controlled glide and horizontal landing. Even on a lifting reentry body, a parawing might improve the post-entry flight or landing characteristics.

Another potential use is for the transportation of men, supplies, and equipment in space operations on Mars and other planets including earth. We were recently asked to consider the specific problem of a flying machine for surface-to-surface transport on Mars. This is a challenging problem that could have some fallout for application here on earth where potential passengers are more plentiful.

It has been suggested that parawings be used to transport empty boosters between recovery point, factory or reconditioning point, and launch site. Such systems could be either self-propelled or towed by another aircraft. Mid-air hookup or transfer from one tow vehicle to another is also possible. Mid-air recovery of paragliders has been demonstrated.

There have been several papers written on the theory of solar sailing. Very lightly loaded parawings may be a means of putting such theory into practice. And if we consider the fringe of the atmosphere we might find some method of propelling an extremely light wing loading aircraft by solar energy, dissociated oxygen, or more conventional means.

ADVANTAGES

Parawings offer good aerodynamic performance in terms of lift coefficient and lift-to-drag ratio but, as with rigid wings, high performance has its price which should be paid only when high performance is necessary. The ability to vary the vehicle speed by varying the lift coefficient in flight may also be important. Although we have developed parawings with lift-to-drag ratio near twenty (see attached fig.), these wings have had rigid frames which would be objectionable in many applications. We are also investigating parawings with a minimum of stiffening, and feel that maximum lift-to-drag ratios as low as two might be useful in some applications.

Compact storage is generally desirable and often necessary in space operations, and weight reduction is even more important than in aircraft. Parawings have low weight and packed volume relative to rigid wings, about the same as the pure drag parachute.

CONFIGURATIONS

Aerodynamic investigations have been made of parawings with a variety of geometric variations, including sweep, aspect ratio, and fabric shape. Some of the results are published in the attached list of reports by NASA authors.

In nearly all of the parawing vehicles flown so far, the payload has been suspended below the wing, but other configurations are being considered. In my 1954 presentation to the Air Force Reserve Unit, the first paper of the attached list, parawing vehicle configurations were divided into three types according to location of the load carried, as follows:

Suspended load

Load at keel

Load at keel and leading edges

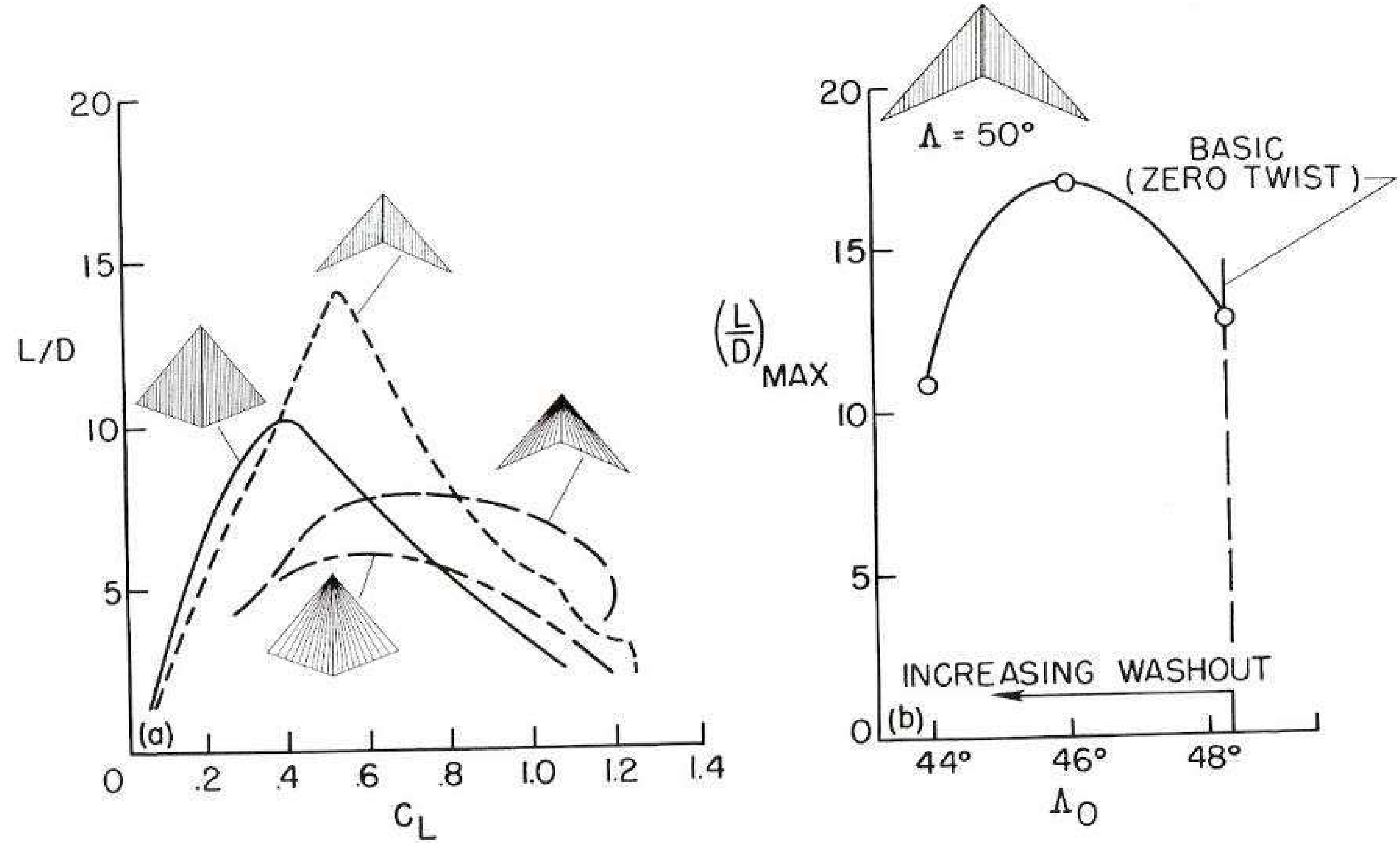
Geometrically, parachutes are similar to the first type and conventional aircraft to the second, approaching the third when fitted with heavy tip tanks or other stores.

STRUCTURES

The lifting surfaces of parawings are flexible membranes of relatively large curvature so that the lift may be sustained with a minimum of bending or compression load in any part of the structure. Kites and gliders have been made of nothing but string and rubbery film, pure tension structures. Performance and other functional characteristics can generally be improved, however, by the judicious addition of local stiffening, as is well known in the garment industry. Parawing stiffening can be located in the membrane, either concentrated as in sail battens or spread more evenly through the membrane, but stiffening is generally found only in the frame to which the membrane is attached. Most of the parawing vehicles developed so far may be classified as rigid frame, springy frame, or inflated frame, but the low performance type popularly called gliding parachutes can be made with no stiffening whatever.

MATERIALS

Parawings have been made of a great variety of flexible materials. For low-temperature applications, organic fibers and films are generally used. For temperatures above the range of organic materials, ceramic and metallic materials can be used, either separately or in combination. Materials used so far generally have been developed for other purposes. Parawings could be improved and their range of application broadened if greater effort were made to develop materials and fabrication methods especially suited to parawings. Specific parawing applications, moreover, require particular strength, stiffness, leakage, heat resistance, and other characteristics. No one material will be suitable for all applications.



(a) Effect of planform and canopy shape.

(b) Effect of adding washout to a basic cylindrical parawing.

Lift-drag ratios for 50° swept parawings.

PARAGLIDER PUBLICATIONS

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5. Naeseth, Rodger L.: An Exploratory Study of a Parawing as a High-Lift Device for Aircraft. NASA TN D-629, 1960.

6. Hewes, Donald E.: Free-Flight Investigation of Radio-Controlled Models With Parawings. NASA TN D-927, 1961.

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8. Fournier, Paul G., and Bell, B. Ann: Low Subsonic Pressure Distributions on Three Rigid Wings Simulating Paragliders With Varied Canopy Curvature and Leading-Edge Sweep. NASA TN D-983, 1961.

9. Taylor, Robert T.: Wind-Tunnel Investigation of Paraglider Models at Supersonic Speeds. NASA TN D-985, 1961.

10. Hatch, Howard G., Jr., and McGowan, William A.: An Analytical Investigation of the Loads, Temperatures, and Ranges Obtained During the Recovery of Rocket Boosters by Means of a Parawing. NASA TN D-1003, 1962.

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16. Wornom, Dewey E., and Taylor, Robert T.: Aerodynamic Characteristics of a Flexible-Canopy Paraglider Model at a Mach Number of 4.5 for Angles of Attack to 360° and Sideslip Angles From 0° to 90°. NASA TN D-1776, 1963.

17. Layton, Garrison P., Jr., and Thompson, Milton O.: Preliminary Flight Evaluation of Two Unpowered Manned Paragliders. NASA TN D-1826, 1963.

18. Burk, Sanger M., Jr.: Free-Flight Investigation of the Deployment, Dynamic Stability, and Control Characteristics of a 1/12-Scale Dynamic Radio-Controlled Model of a Large Booster and Parawing. NASA TN D-1932, 1963.

19. Sleeman, William C., Jr.: Low-Speed Investigation of Cable Tension and Aerodynamic Characteristics of a Parawing and Spacecraft Combination. NASA TN D-1937, 1963.

20. Johnson, Joseph L., Jr., and Hassell, James L., Jr.: Full-Scale Wind-Tunnel Investigation of a Flexible-Wing Manned Test Vehicle. NASA TN D-1946, 1963.

21. Naeseth, Rodger L., and Gainer, Thomas G.: Low-Speed Investigation of the Effects of Wing Sweep on the Aerodynamic Characteristics of Parawings Having Equal-Length Leading Edges and Keel. NASA TN D-1957, 1963.

22. Sleeman, William C., Jr., and Johnson, Joseph L., Jr.: Parawing Aerodynamics. Astronautics and Aerospace Engineering, June 1963.

PARAGLIDER RECOVERY SYSTEMS
NASA Film L-805

Deployment of rocket-launched paraglider with aluminum tube frame.

Radio control of paraglider with aluminum tube frame.

Deployment and control of paraglider with inflated frame (Army-Ryan).

Micrometeoroid paraglider.

Free-air model flights.

Tests in vacuum sphere (NASA-Space General).

Booster recovery.

Controlled flight in full-scale tunnel.

Free-air flight.

Towing of Booster-like body (Army-Ryan).

Apollo-type space capsules.

Controlled flight of rigid frame models in full-scale tunnel.

Controlled outdoor flight of rigid frame model.

19-foot keel inflated-frame model.

50-foot keel inflated-frame model, 3000 pounds.

Gemini-type space capsules.

19-foot keel inflated-frame model.

1/2-scale Gemini model (NASA-NAA)

Controlled flight of lifting-body space capsule in full-scale tunnel.

Controlled flight of winged vehicle in full-scale tunnel.

Flight trainers.

Tow glider.

Ryan flex-wing.

NASA-Langley, 1963