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Chapter 2

COMING DOWN WITH THE ROGALLO WING: EARLY IDEAS ABOUT RETURNING TO EARTH FROM SPACE*

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Early thinking about spaceflight slighted the question of landing at journey's end. Spacefaring, not the return home to Earth, challenged theory and excited imagination. Only one aspect of the return attracted much notice. Traveling between planets demanded immense speed, which spaceships must somehow shed lest they become meteors reentering the atmosphere. Several theorists suggested using the atmosphere itself to absorb spaceship energy. The slowed ship might then glide safely to ground. Unfortunately, gliding required wings, and rigid wings posed baffling heat transfer problems during reentry. Parachute landing became the choice when manned spaceflight began; no one really liked parachutes, but anything else looked worse. For a moment in the early 1960s, though, Francis Rogallo's lightweight flexible wing promised a better answer. This paper centers on his invention and its adoption by the National Aeronautics and Space Administration (NASA) as the landing system for Project Gemini.

RETURNING TO EARTH IN EARLY SPACEFLIGHT THOUGHT

As early as 1903, K.E. Tsiolkovsky in Russia noted that an "impossibly large supply of explosives ... would be needed" if spaceships were braked in the same way they accelerated -- that is, with rockets.[1] In 1926 he proposed using the atmosphere as a brake to absorb spaceship energy.[2] Tsiolkovsky, like most early prophets of spaceflight, assumed spaceships would carry crews. Thus winged gliding seemed the likely means of bringing the slowed ship safely to ground. In the United States, Robert H. Goddard likewise believed that piloted spacecraft might glide down. But his work stressed the role of unmanned rockets, and that meant parachutes. In 1920 he foresaw an unmanned rocket back from the Moon braking in the atmosphere, then landing by parachute.[3]

Unpublished or little known, neither Tsiolkovsky nor Goddard had much early impact on spaceflight thought outside their homelands. Not so Walter Hohmann in

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Germany. He devoted a chapter of his seminal 1925 book, *Die Erreichbarkeit der Himmelskörper*, to the "Return to Earth." Like Tsiolkovsky, he judged rocket braking too costly and so preferred using air. He also described just what that meant. Returning spaceships would approach the atmosphere tangentially, pass through a series of braking ellipses, then glide under pilot control to a landing.[4] In this, as in other areas he touched, Hohmann's systematic and penetrating analysis carried the subject to a level not surpassed for decades.

Meanwhile, Hermann Oberth reviewed "The Landing" as a chapter of his comprehensive *Wege zur Raumschiffahrt* in 1929. The only one besides Hohmann to treat the subject in detail, he raised the question of reentry heating. Gliding looked easy, but wings posed troubling heat transfer problems. Parachutes, he thus concluded, might be the best choice for crewed spaceships as well as unmanned rockets.[5] The issue persisted unresolved, as theory moved toward practice during the next decades. In the 1950s, when the United States began its spaceflight program, the central problem remained, in fact, just the one Oberth feared -- reentry heating. One way to avoid the dilemma emerged from an unlikely source, an aeronautical engineer's research on kite-like wings. The scene was tidewater Virginia, site of the Langley Aeronautical Laboratory of the National Advisory Committee for Aeronautics (NACA).

ROGALLO'S WING

The story began in 1945 with Francis M. Rogallo pondering future research. He had joined Langley after graduating from Stanford University in 1936. With almost a decade of experience under his belt and World War II ending, Rogallo judged the time ripe for research on what he called unconventional vehicles. Among the likely prospects which he thought might win Langley funding were hydrofoils, ground-effect machines, vertical or short take-off and landing aircraft, or flexible wings. But he was wrong; NACA declined to support such far-fetched ideas. Still Rogallo persevered. Joined by his wife, Gertrude (and later by other family members and friends), he tackled flexible wings on his own.[6]

Economics influenced the choice. Flexible wings lent themselves to low-cost private work as other exotic concepts clearly did not. Practical need was not the whole story, though. Inspired by visions of pterodactyls and Leonardo da Vinci's ornithopters, Rogallo had been "dreaming about flexible wings since childhood."[7] First he reviewed past uses of flexible materials in aerodynamic surfaces. Studying parachutes, kites, sails, and windmills convinced Rogallo that he had something. Integral to aircraft design since the Wright Brothers (indeed, since Cayleys' work a century earlier) though they were, rigid wings were not the last word in airfoils. Rogallo tried fixed models in a home-made wind tunnel, tethered models flown as kites,and free-flight models flown as gliders.[8]

Because the kite versions of the idea "appeared to be the nearest to a useful marketable application," Rogallo and his wife filed their patent claim for a "Flexible Kite" on 23 November 1948.[9] Although presented as a toy, the new device, if enlarged and strengthened, might also serve "military or other purposes." The flexible-wing principle could also "be applied to man-carrying devices, such as airplanes, parachutes and gliders" by adding "stabilizing and control surfaces" to the wing and hanging a support framework from the kite body. The patent was allowed on 20 March 1951.[10] (See Figure 1.) In trying to market the toy, Rogallo hoped both to promote the flexible-wing idea and to finance further research.[11] He enjoyed some success, and in 1952 saw the Aeroflex Corporation of New Haven, Connecticut, formed "to promote the flexible wing concept" by making what they named the Flexi-Kite.[12]

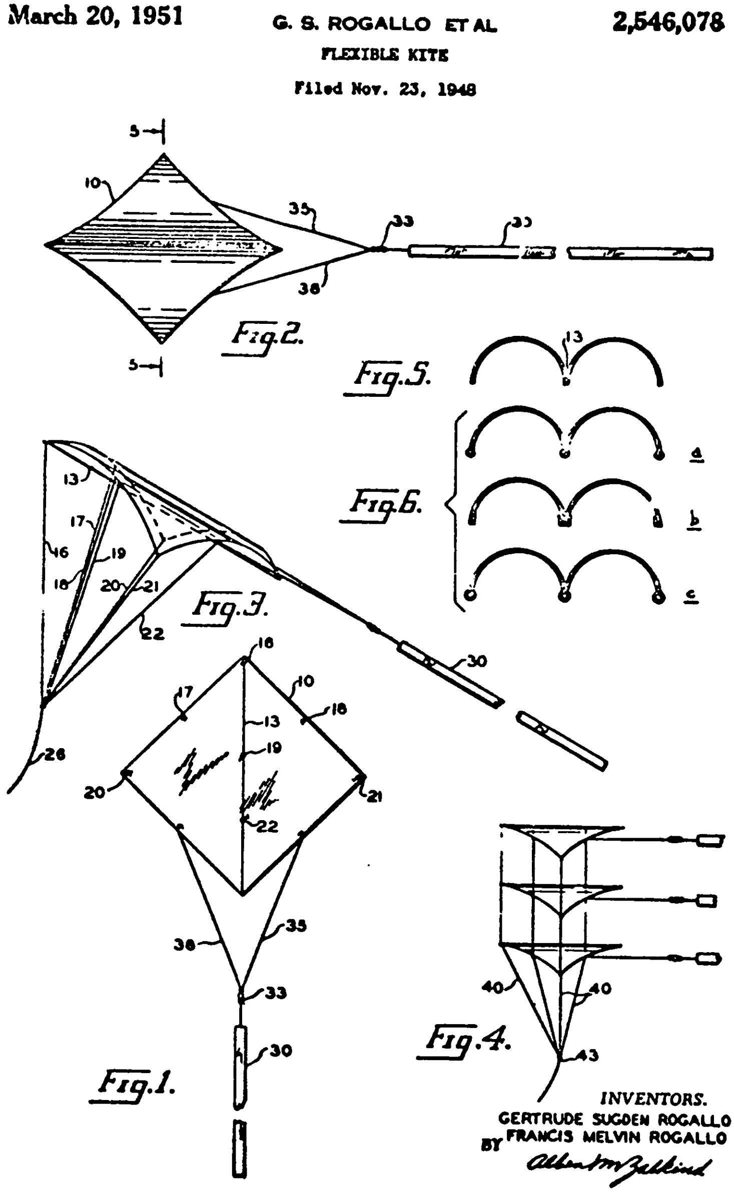

Figure 1

Significantly, 1952 also saw Rogallo first link his idea to space travel. Chancing across a magazine article, he recalled being struck by the "beautiful illustrations depicting rigid-winged gliders mounted on top of huge rockets. I thought [they] might better be replaced by vehicles with flexible wings that could be folded into small packages during the launching."[13] Rogallo's efforts to promote this insight--or any other serious use--met scant success. Colleagues mostly dismissed his work as "the kite business." Marketing the Flexi-Kite "hindered and delayed serious acceptance of the concept," concluded a rueful Rogallo. "Toys should copy the real thing and not the other way around."[14] When in June 1954 he suggested adding research on flexible wings to the NACA budget, he was again rebuffed. He met much the same response when he offered a paper to the International Aeronautics Society: "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."[15] *Sputnik* changed all that.

NASA AND THE PARAGLIDER

Galvanized by a Soviet satellite in orbit, the United States geared up for the space race. NACA, research-oriented and perhaps even somewhat stodgy, metamorphosed into the far larger, richer, and bolder National Aeronautics and Space Administration. Suddenly, Rogallo found listeners. In December 1958, NASA not yet three months old, Langley's prestigious Committee on General Aerodynamics heard him describe how a flexible wing could help "space ship landing."[16] Committee members responded warmly, and Rogallo moved his work from garage to laboratory. Engineers from NASA's Space Task Group also listened. Just formed at Langley to direct Project Mercury, the first United States manned spaceflight program, the Space Task Group also sought long-term goals. A meeting with Rogallo in March 1959 provoked thoughts in the minds of some STG engineers of using the Rogallo wing to land an advanced version of the Mercury capsule and so avoid recovery by parachute at sea.[17] (See Figure 2.)

But that was a distant prospect. Meanwhile, the Space Task Group had Project Mercury itself to conduct, and wings of any kind still posed too many questions for so urgent a project. Wind tunnel tests of several shapes for manned spacecraft failed to settle the issue, but NASA chose the design judged least likely to cause engineering problems. The Mercury capsule became a blunt, high-drag, zero-lift body landed by parachute.[18] Ballistic reentry and parachute landing promised the quickest program because military money had already paid for much research on blunt-body reentry and parachutes seemed both familiar and reliable. But that approach had long-term defects, as a NASA official explained to the Senate Appropriations Committee in 1960: "Ballistic reentry pays for its simplicity with landing point dispersions that will be operationally unacceptable for extended use."[19]

Research on the Rogallo wing at Langley did not depend on any link to technological development. Since NACA's founding in 1915, Langley had remained an applied research laboratory committed to solving a broad spectrum of aeronautical engineering and technical problems, chiefly in aerodynamics. Converting research findings into useful machines had always fallen outside Langley's mission, a task for the armed forces and other agencies NACA served. When Langley became part of

NASA, it largely retained its old orientation despite the much-expanded mission of the new organization to which it now belonged.[20]

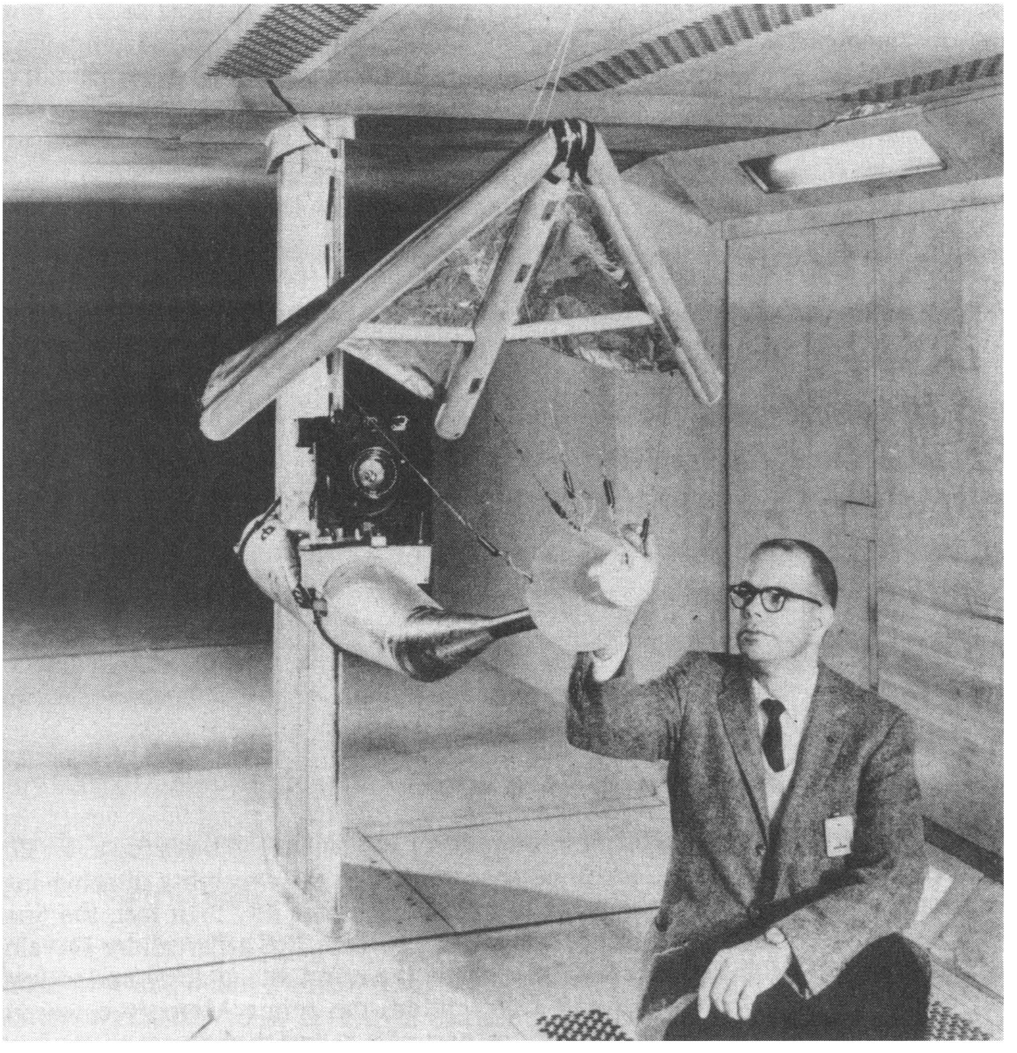

Figure 2 Wind-tunnel setup for determination of line loads and complete glider static aerodynamic characteristics.

Improving Rogallo's wing, in any event, demanded nothing more than work the laboratory had done for decades. By 1960 the Langley team had conceived a novel spacecraft landing system and christened it Paraglider. The lightweight parachute-wing hybrid would remain safely packaged during most of a mission. Deployed only after reentry, it would then allow a pilot to fly the now winged spacecraft to an airfield landing.[21] Promising research, however, could only carry the effort so far. If the paraglider were ever to become more than a wind-tunnel subject, it must tie its fortunes to a development project. The lunar landing program, Project Apollo, seemed a likely choice. Apollo had not yet become an approved project early in 1961, but the prospects looked good and much work had already been done.

In January 1961 Paraglider entered the Apollo picture from two directions. Marshall Space Flight Center contracted with two companies to study paragliders for recovering spent-booster stages.[22] Meeting almost at the same time in Virginia, a technical liaison group on Apollo configuration and aerodynamics heard a strong Langley case for a paraglider as a spacecraft landing system: "The feeling at Langley is that if the paraglider shows the same type of reliability in large-scale tests . . . that it has achieved in small-scale tests, the potential advantages of this system outweigh other systems." Despite such promise, Apollo engineers remained doubtful.[23]

Further meetings with Rogallo and his colleagues during early 1961 only convinced them that much work still lay ahead. Apollo would need a very large version of the Rogallo wing. This meant major changes and hard questions. How could such a structure be inflated and spread in midair? All tests so far had used prespread wings, and no one had ever successfully deployed an inflatable structure of any kind in flight. Other questions, too, demanded answers. How was the paraglider to be packaged? Could a pilot see well enough from the spacecraft for flying and landing?[24] Whatever its promise, the concept clearly needed further study. Skepticism from Apollo engineers, however, might not matter very much. Another Space Task Group team was looking at an advanced Mercury program, for which paraglider seemed even better suited.

PARAGLIDER FINDS A DEVELOPMENT PROJECT

In May 1961 the Space Task Group awarded three short-term $100,000 study contracts to three different companies, each to produce a paraglider design with problem areas defined. The best design would then become the basis for a development contract to "provide the modified spacecraft with the capability of achieving a controlled energy landing through the use of aerodynamic lift."[25] In fact, the Space Task Group soon labeled the three design studies Phase I of a Paraglider Development Program.[26] Monitored by STG engineers, the effort was quickly under way.[27] Engineers from McDonnell Aircraft Corporation, the prime Mercury contractor, also kept close tabs on paraglider work as part of a separate contract to study advanced Mercury concepts.[28]

James A. Chamberlin, the Space Task Group's engineering manager for Mercury, included a paraglider landing system in his plan for the so-called Mercury Mark II, an improved version of the Mercury capsule he unveiled for his colleagues in June 1961.[29] In mid-August the first phase of paraglider development ended with a showing that the concept was feasible.[30] When Chamberlin and his colleagues had completed a preliminary Mark II project development plan that same month, land landing via paraglider had become one of its six stated objectives.[31] Plans for the second phase, a two-part systems R&D effort, quickly followed. Phase II, Part A, called for eight months of further study to complete the design. Phase II-B would require the contractor to build a prototype system, to conduct flight tests, and to complete a final design. Finally, Phase III would see paragliders produced and pilots trained to fly them.[32] The Phase II-A contract went to North American Aviation, Inc., of Downey, California. On 20 November 1961 NASA informed the company it had the contract and could begin work.[33] (See Figure 3.)

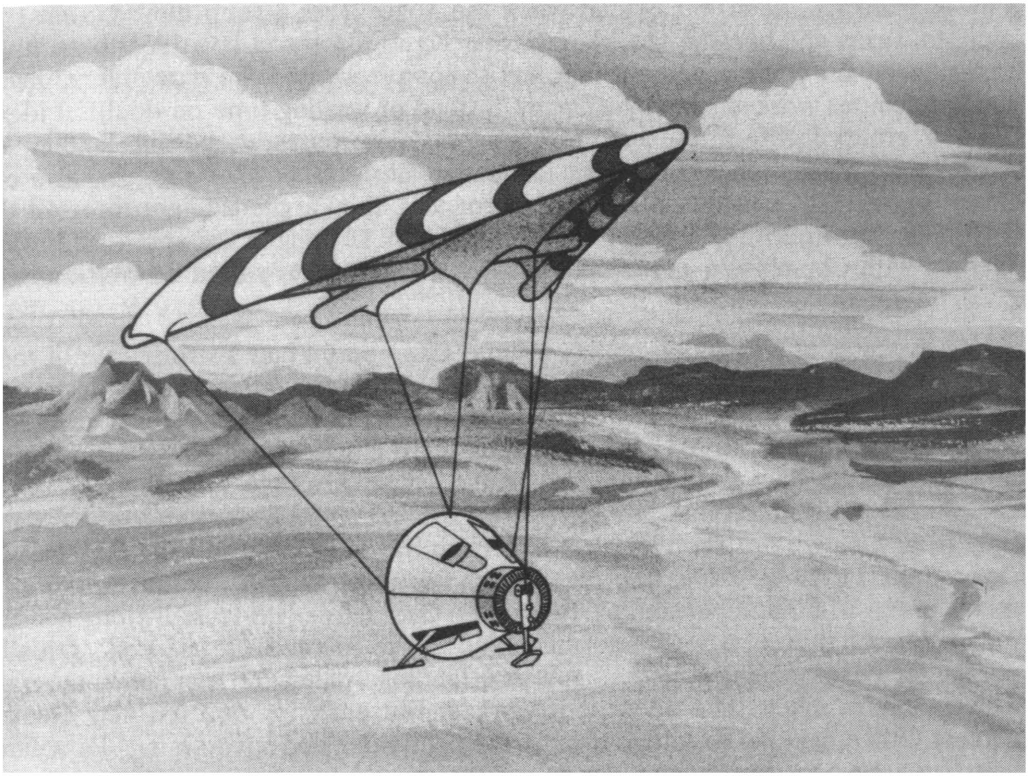

Figure 3 Artist's concept of a paraglider - full deployment (NASA Photo S-62-2965).

The North American version of a paraglider comprised a delta wing with inflated keel and leading edges, from which the spacecraft hung on five cables. Flight control was achieved by reeling in or paying out the cables, while the wing held its shape through the interaction of aerodynamic forces and suspended load. An early decision based all test vehicles on the Mercury Mark II design: "Power requirements, control actuation, landing gear, etc., should be compatible with the MK II spacecraft, where MK II is sufficiently firmed up for this to be practicable without delaying the full-scale test program." Even at this early date, the interface between paraglider and spacecraft posed hard questions: How were the glider and its gear to be stowed? How would the paraglider be deployed? Sequenced? Jettisoned? What kind of cockpit controls and displays would be needed? How would the paraglider system fit in with the spacecraft emergency escape system?[34] Such questions helped fuel the controversy that surrounded the paraglider.

Notably cool to the basic concept was Max Faget's Engineering and Development Directorate, the center of Apollo work. Opposed to an Apollo paraglider, Faget's engineers saw only an untested idea fraught with problems.[35] The key question remained "whether the deployment reliability of a single paraglider will equal that of a main and back-up chute system."[36] Failure of the wing to deploy properly would mean certain death for the astronauts.

Rogallo had been left behind when the Space Task Group moved from Virginia to Texas and became the Manned Spacecraft Center in late 1961, but Chamberlin faced the same argument that had so long frustrated the paraglider's inventor. Parachutes worked, so why change? Instead of wasting time on doubtful ideas, Faget's group favored research on improved parachutes to permit landing on land.[37] The Flight Operations Division under Christopher C. Kraft, Jr., also opposed paraglider. Relying on an untried concept, they argued, might threaten the astronauts' safe return.[38] When the proposed Mark II became the approved Project Gemini with Chamberlin as project manager, Kraft promptly filed his objections to paraglider.[39]

Advocates of paraglider landing such as Chamberlin had a strong case of their own. For Gemini, Chamberlin envisioned a working spacecraft, easier than Mercury to maintain, service, repair, and use. Such a spacecraft could hardly rely on a task force to fish it from the sea after every mission. Paraglider promised a shortcut to airfield landings, just the kind of change that might promote spaceflight from experimental to routine operation. In these goals Chamberlin enjoyed support not only from his own project office but also from the astronauts and the Flight Crew Operations Division.[40] Despite the critics, he also retained the respect of top managers at Manned Spacecraft Center, who had learned to trust his engineering judgment. Chamberlin was determined to make paraglider succeed. Initially, paraglider development aimed simply at a landing system for manned spacecraft, which Gemini might then adopt if it worked. But early in 1962 the new Gemini Project Office decided to integrate fully the paraglider and spacecraft.[41] Paraglider now firmly belonged to Project Gemini.

Despite his successful career in a foremost research agency, Francis Rogallo had for more than a decade pursued his idea for a flexible wing along the classic path of the lone inventor. Until *Sputnik*, he could never convince NACA officials to sponsor his research. Opportunity came when NASA replaced NACA. Even with help from his colleagues at Langley, however, Rogallo could do no more than advance his concept from flexible wing to paraglider. Converting an idea into a working machine required a development project. It also required overcoming objections from those who regarded the Rogallo wing as risky and untried. That task fell to James Chamberlin, who championed Paraglider as the landing system for Project Gemini. His success in winning NASA support for the project and becoming project manager insured that Rogallo's invention would have its chance.[42]

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41. Lester A. Stewart to Procurement Officer, "Letter Contract NAS 9-167, Paraglider Development Program, Phase II-A," 22 January 1962, with enclosure, "Suggested Revisions to Statement of Work for Letter Contract NAS 9-167"; Richard J. Crane to North American Aviation, Change Notice No. 1, Contract NAS 9-167, 8 March 1962.

42. For the fate of the Gemini paraglider, see Barton C. Hacker, "The Gemini Paraglider: A Failure of Scheduled Innovation, 1961-1964," paper presented at the XVIIIth International Congress of the History of Science, Hamburg and Munich, August 1989. On the later career of the Rogallo wing, see the references on "Hang Gliding" in *Air and Space History: An Annotated Bibliography*, edited by Dominick A. Pisano and Cathleen S. Lewis (New York: Garland, 1988), pp. 192-193.