On The Shoulders of Titans

A History of Project Gemini

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Dyna-Soar was a development project of the Air Research and Development Command (ARDC). The project received its name in October 1957 and Air Force Headquarters approval in November, some four years after study had begun on vehicles boosted into orbit [18] by rocket and gliding back to Earth under pilot control. Much of the work had been done under contract by Bell Aircraft Company. NACA joined the project in May 1958 to provide technical advice and help to the Air Force-directed and -funded program, an arrangement reaffirmed by NASA in November 1958. ARDC's consolidated Dyna-Soar development plan in October 1958 aimed the project specifically at developing a winged glider for return from orbit. Later X-20 replaced Dyna-Soar as the project's name.[74] Leaving gliders to the Air Force was no hardship since many in NASA, especially in the research centers, preferred the lifting-body approach.[75] As early as June 1959, STG could report promising results from studies of building some lift into a Mercury capsule.[76]

STG was also looking into a more radical approach to controlled spacecraft landing. Between 1945 and 1958, a Langley engineer named Francis M. Rogallo had been working at home on a flexible kite, its lifting surface draped from an inflated fabric frame. [19] In contrast to other flexible aerial devices like parachutes, a load-bearing Rogallo wing produced more lift than drag, though not as much as a conventional wing. But rigid wings could not be folded neatly away when not in use, and they were inherently far heavier. Rogallo first realized what this might mean in 1952, when he chanced across an article on space travel

> 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.[77]

Rogallo's efforts to promote his insight met scant success until late 1958, when the new American commitment to explore space furnished him a willing audience. In December, the Langley Committee on General Aerodynamics heard him describe his flexible wing and how it might be used in "space ship landing."[78] The group responded warmly, and work on the concept moved from Rogallo's home to laboratories at Langley.

A few months later, STG asked Rogallo for an informal meeting to discuss his research. Some of STG's top people, Manager Gilruth among them, showed up on 30 March 1959 to hear what Rogallo had to say.[79] Gilruth was impressed enough to suggest at a staff meeting two months later that some study go into a follow-on Mercury using maneuverable capsules for land landing.[80]

NASA Ten Year Plan

1960

First launching of a Meteorological Satellite

First launching of a Passive Reflector Communications Satellite

First launching of a Scout vehicle

First launching of a Thor-Delta vehicle First launching of an Atlas-Agena-B vehicle (by the Department of Defense) First suborbital flight of an astronaut

1961

First launching of a lunar impact vehicle

First launching of an Atlas-Centaur vehicle

Attainment of manned space flight, Project Mercury

1962

First launching in the vicinity of Venus and/or Mars

1963

First launching of the two-stage Saturn vehicle

1969-1964

First launching of unmanned vehicle for controlled landing on the Moon

First launching of Orbiting Astronomical and Radio Astronomy Observatory

1964

First bunching of unmanned lunar circumnavigation and return to Earth vehicle

First reconnaissance of Mars and/or Venus by an unmanned vehicle

1965-1967

First launching in a program leading to manned circumlunar flight and to permanent near-Earth space station

Beyond 1970

Manned flight to the Moon

Ejection seats not only promised to relieve a major source of trouble by getting rid of the escape tower, but they also furthered the concept of modularization, keeping each spacecraft system, so far as possible, independent. "The paramount objective in the program," according to Chamberlin, "was to dissociate systems." Ejection seats, in what he called "very happy coincidence that was fully realized at the time," also fitted in nicely with another design change, substituting paraglider for parachute recovery.[75]

STG had not displayed much active interest in Francis Rogallo's flexible wing concept after the initial flurry in early 1959.[76] Rogallo and his co-workers at Langley had pushed ahead with their studies in the meantime. By mid-1960, they had convinced themselves that a controllable, flexible wing could carry a returning spacecraft safely to land, thus providing "a lightweight controllable paraglider for manned space vehicles."[77] STG rediscovered the paraglider at the start of 1961 as a by-product of work on Apollo. A technical liaison group on Apollo configuration and aerodynamics met at Langley on 12 January.** In the course of describing his center's work for Apollo, the Langley representative mentioned the paraglider 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." Engineering design of large paragliders appeared to be no problem and would be demonstrated in manned and unmanned drop tests.[78]

Space Task Group engineers met informally with Rogallo and his colleagues in February, March, and April to explore the use of a paraglider in the Apollo program.*** The STG team was less than enthusiastic. They believed much work was yet to be done before the device [44] could be seriously considered as a landing system for Apollo. The biggest unknown was the deployment characteristics of an inflatable wing; no inflatable structure had ever been successfully deployed in flight. Other questions - how the paraglider was to be packaged, whether the pilot's view from the capsule would be good enough for flying and landing with it - were nearly as important and also largely unanswered. The STG team advised gathering at least six months of data before awarding any paraglider development contract.[79] At the same time, however, McDonnell engineers were looking at a paraglider for the modified Mercury, and Marshall Space Flight Center had already let two contracts to study paraglider as a booster recovery system. The idea clearly had promise, and in May 1961 Gilruth decided to contract for further study.

Three contractors each got $100,000 for two and a half months to design a paraglider landing system and define potential problem areas.**** The best design was expected later to become the basis for a development contract to "provide the modified [Mercury] spacecraft with the capability of achieving a controlled energy landing through the use of aerodynamic lift."[80] In fact, the design studies soon received a new name - Phase I of the Paraglider Development Program.[81] Observed by a small technical monitoring group from STG, the paraglider design studies were under way before May ended.# [82] McDonnell engineers also maintained close liaison with paraglider work, independent though it was of the Mercury Mark II study contract.[83] The redesigned Mercury, as presented by Chamberlin and Blatz to the Capsule Review Board in June, could he adapted to a paraglider landing system, once it was developed.[84]

The end of the first phase of the paraglider development program in mid-August, which proved the feasibility of the concept for recovery of manned spacecraft,[13] pointed to still another part Mark II might play. Mercury came back to Earth's surface via parachute. [55] Uncontrolled return made the ocean the best landing field. But this meant that each landing was a major undertaking in its own right, with fleets of ships and aircraft deployed to ensure the safe recovery of pilot and spacecraft. This clearly would not do if space flight were ever to become a routine enterprise. Fitted out with a paraglider system, Mercury Mark II might show the way to controlled recovery on land.

These were all, however, only ideas that needed to be hammered into specific proposals with goals, costs, and timetables. This was the purpose of the preliminary project development plan that Chamberlin and his co-workers began to prepare early in August 1961. The focus of their effort now shifted from the engineering design of an improved Mercury to framing the program such a capsule might serve. McDonnell reoriented work under its NASA study contract toward "basic and alternate missions for the MK-II Spacecraft" and increased the number of engineers assigned from 45 to 74.[14] At the same time, three McDonnell engineers, led by Fred Sanders, journeyed to Langley, where Chamberlin, aided by James Rose and several contracting and scheduling specialists,* was getting started on the preliminary plan for a new project, using the Mercury Mark II two-man spacecraft.[15] The first result was ready 14 August 1961.

The presence of a Mercury-type impact bag in the specification was another cautious note. The Mercury capsule had an inflatable bag that served to cushion the impact of landing. Although the paraglider promised greatly reduced landing stresses, the designers felt that work on the concept was not far enough advanced to allow them to rely on it entirely. No one really believed a either the tower or landing bag was going to be necessary but, faced with drawing up a specification for Mark II, McDonnell engineers chose to put on paper something they *knew* would work.[45]

Planning for the second phase of the paraglider program, a two-part system research and development effort, had already begun. In Phase II, Part A, the contractor was to spend eight months in further study of the design concept, chiefly to settle on what configuration would yield the best performance. The second part of Phase II called for the as-yet-unnamed contractor to build a prototype paraglider landing system, to conduct a series of unmanned and manned flight tests, and to complete a final design. The third and final phase of the program would see a paraglider system in production and pilots being trained to fly it.[46] On 20 November, North American received official word that it had been awarded the contract and was authorized to begin work.[47]

The same team that had monitored the paraglider design study for STG** now joined spokesmen for North American, Langley, and Flight Research Center to discuss putting Phase-II A into motion. They soon agreed that the half-scale models and full-size vehicle for [67] this phase should be based on the 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 practical without delaying the full-scale test program." Most wind tunnel testing would be done by Langley, while Flight Research Center, at Edwards Air Force Base, California, was to take charge of flight testing, all under the aegis of MSC. Even at this early date, the interface - that useful term for the region where two or more things share a common boundary - between paraglider and spacecraft was beginning to pose questions: how the glider and its gear were to be stowed; how it was to be deployed, sequenced, and jettisoned; what kind of cockpit controls and displays it would need; and how it would fit with the emergency escape system.[48]

When Gilruth and Chamberlin visited NASA Headquarters in late November 1961 to see Associate Administrator Seamans and report on the Mark II program, they had a good deal to talk about. Spacecraft design was just about settled, paraglider development was beginning, and some basic approaches to developing rendezvous techniques had been decided. Although Gilruth's and Chamberlin's meeting with Seamans did nothing to dampen their belief that project approval was only a matter of time, that time was not yet. Seamans was not quite ready to take the final step. November had been a busy month In NASA Headquarters, and the turmoil had touched the Mark II project.

The Paraglider Controversy

The one real exception to Gemini's smooth progress through its first half year was paraglider. Its development was a step ahead of the rest of Gemini, North American having been authorized to begin work on 20 November 1961, and the headstart may have accounted for the earlier signs of trouble.

Paraglider was controversial. Although GPO, and Chamberlin in particular, stoutly defended the concept, others in MSC had strong doubts. The Engineering and Development Directorate under Max Faget had been notably cool to the idea from the outset. The key question had been, and still was, "whether the deployment reliability of a single paraglider will equal that of a main and back-up chute system."[53] The long-time efforts of Langley's Francis Rogallo, inventor of the paraglider, to sell his concept had been repeatedly countered by the argument that parachutes had proved they could be relied upon to recover spacecraft. Instead of wasting time on an untried concept, Faget's group favored efforts to improve parachute technology to permit land landing. They advocated using a new form of parachute that could be steered, with landing rockets to cushion the final impact as the spacecraft touched down.[54]

Another source of opposition to paraglider was the Flight Operations Division under Christopher C. Kraft, Jr. Questions of reliability here took second place to concern for the operational problems posed [92] by paraglider in the Gemini program. For Kraft's division, using paraglider and using ejection seats were two sides of the same coin: one required the other, neither was reliable, and both promised immense practical obstacles to the safe return of the astronauts.[55] Kraft himself urged on Chamberlin, and later on MSC Director Gilruth, his objections to both systems.[56]

Paraglider critics found plenty of ammunition in North American's slow progress toward a working system. At first, paraglider development aim at landing system for manned spacecraft in general. Early in 1962, however, GPO decided that the program ought to be oriented explicitly to Gemini. North American faced a large new effort and a major delay, and not just because the Gemini spacecraft was much larger than the generalized model first planned for. The half-scale free-flight test vehicle would have to be redesigned to carry a flight control system, just as the full-scale model did. North American had to join with McDonnell to design a compatible landing gear system and check it out in a test program. And, finally, North American now had to develop and qualify emergency parachute systems for both half-scale and full-size test vehicles.[57]

This last demand, in particular, delayed North American, and it was mid-March before a subcontract for the emergency parachute system could be placed.[58] Norbert F. Witte, North American's project manager for paraglider, planned to begin free-flight tests of the half-scale model toward the end of May. With its wing inflated and deployed before it left the ground, the test vehicle needed no emergency parachute. It would be towed into the air by a helicopter and released to fly under radio control. This series of tests would allow North American engineers to see how well the paraglider flew, how precise flight control could be, and whether the vehicle could flare - raise its nose to increase wing lift and drag and slow its rate of descent - just before landing.[59]

These were all questions that needed answers, but the most crucial was still whether or not the wing would deploy in flight. That had to wait for the emergency parachutes, since the test vehicles were too costly to risk without a backup system. Witte expected to have the half-scale emergency system tested by the start of June, when deployment tests could begin. The full-size emergency parachute would take longer but ought to be ready by mid-July. There still seemed to be a reasonable chance to complete this phase of the development program by September 1962.[60]

Timing was critical for paraglider development, since its place in the Gemini program depended upon its meeting the very tight launch schedule. Despite snags in the current phase of the program, Chamberlin decided that North American needed to get started on the next phase, [93] a 14-month effort to design, build, and test an advanced two-man paraglider trainer, to start a flight simulation program, and to design and develop a fully man-rated prototype Gemini paraglider landing system.[61] That was in March 1962; by May the task was scaled down to require only the design of the prototype system, rather than its complete development. This was expected to reduce the time to five months from the date of the contract award.[62]

The project office still expected the paraglider to be ready on time, but warned in a 4 May schedule analysis that the program "will require close monitoring to prevent slippage." Paraglider was scheduled to be installed in the second Gemini spacecraft, which would be the first to carry a crew. The first spacecraft, since it was unmanned, was slated to come down by parachute. A prudent response to delays already incurred dictated that plans be laid for using a parachute system in the second spacecraft as well. By mid-June, GPO conceded that the paraglider would not be ready until the third flight.[63]

A Quick Smooth Start

Despite some doubts about the paraglider, Project Gemini was moving smoothly in the spring of 1962. GPO noted a certain tightness in launch vehicle schedules a might constrict the time needed to resolve any unexpected problems but concluded that close monitoring would help to bring the modified Titan II out on time. Late delivery of some components from McDonnell subcontractors threatened schedules for building the first two spacecraft, but the threat seemed modest. The target vehicle and its booster, Atlas-Agena, appeared to present no problems, even after a slow start, since a target was not needed until the fifth mission.[64]

Overall, August 1963 still seemed like a reasonable prospect for the first launch. But the ambitious timing of the second launch (the first manned flight in Gemini, earlier scheduled just six weeks after the first),[65] was now adjusted to allow a more realistic three months and set for November 1963. The rest of the program held to an every-other-month schedule, the 12th and final flight to be in July 1965.[66] From the viewpoint of the project office as it surveyed Gemini progress and prospects in its first half-year, there were no serious problems.[67]

Project Gemini had won approval in late 1961 over several competing rendezvous development proposals because its design was further along than those of its competitors and because its scope seemed to be limited enough to fit the relatively compressed span of time between the last flights in Mercury and the first mission in Apollo. That these reasons were valid appeared amply borne out by the rapid placement [94] of contracts during the first months of the project's official existence. Within a matter of six months, most major contracts had been awarded and a firm organizational framework had been established.

Some Foreseeable Problems and a Surprise

As Project Gemini moved from design into testing during the spring and summer of 1962, problems multiplied, although not (with one exception) beyond what might be seen as the normal headaches of a large-scale research and development project. Those areas that demanded the longest step beyond current practice were those where trouble threatened. The paraglider program, with its early start, began running into marked delays in planning and design before the rest of Project Gemini. When actual testing began in May 1962, only two contract months remained to settle on the best design for a paraglider landing system.

The first task was qualifying an emergency parachute recovery system for the half-scale vehicle. North American began on 24 May with a successful drop test at the Naval Parachute Facility in El Centro, California, near the Mexican border. Two failures followed before a second success, on 20 June. What should have been the final drop to complete qualification failed on 26 June, when the vehicle's electrical system shortcircuited. North American shuttled the vehicle 260 kilometers back to its plant in Downey for a closer look, which revealed a design flaw. The company reworked the test vehicle and returned it to El Centro for another try, on 10 July, with no better luck. This time the drogue designed to pull out the main parachute failed to do so. After another round trip to Downey for changes, everything worked on 4 September. GPO agreed with North American that the half-scale emergency landing system was now qualified. But two and a half months had been lost.

The full-scale emergency system proved even harder to qualify. First came design problems, then the parachutes were late in arriving. [99] North American could not ship the test capsule to El Centro until 20 July. The Air Force's 6511th Test Group, which ran the El Centro test range, demanded a special test to be certain the vehicle's pyrotechnic devices were safe - that delayed the first qualification flight until 2 August. It was a success, but more delays followed - first bad weather, then the lack of a launch aircraft. The second drop, on 21 August, was marred by one of the three main parachutes breaking loose. Damage was only minor, as it was in the next test, on 7 September, when two parachutes failed. Efforts to correct this problem took over two months. On 15 November, some four months after the full-scale emergency recovery system was supposed to have been qualified, the fourth drop was a disaster. When all three parachutes failed, the test vehicle was destroyed as it hit the ground. Clearly the system could not be relied upon. GPO directed McDonnell to furnish North American with a boilerplate spacecraft for further tests at some later date.[13]

These problems, however disheartening, should not have cast any shadow on the concept of a paraglider. The emergency parachute systems were intended only to back up testing; they were not part of the Gemini landing system. Yet the pattern of delays, errors, and malfunctions that marked North American's efforts to qualify the emergency system proved to be symptomatic of a lingering malaise. Paraglider advocates knew that the program would be made or broken, so far as Gemini was concerned, by the success or failure of flight testing, and time was limited. North American had been chosen over Ryan and Goodyear because of its first-rate job in testing the design during the summer of 1961.[14] But on 28 November, scarcely a week after North American received word to go ahead with paraglider development, NASA notified the company that it had been selected as prime contractor for the Apollo spacecraft. The impact on paraglider was catastrophic. North American froze the number of engineers assigned to paraglider, then allowed even that group to decline. The quality of work suffered as well, becoming, in the opinion of one NASA engineer assigned to the program, "abysmal."[15]

The pattern of trouble sketched in emergency system testing persisted when North American began testing the paraglider itself by flying half-scale models with wings inflated and deployed before they left the ground. Scheduled to begin in May 1962, these trials got under way in mid-August at Edwards Air Force Base, 100 kilometers north of Downey. North American's first try, on 14 August, got nowhere. Because a plug pulled loose inside the capsule, the wing, which was tied down for takeoff, failed to release after a helicopter had towed it to the proper height. The wing released too soon in the second try, three days later, although the capsule did go brief it into a stable glide. North American also achieved a stable glide in the third flight, on 23 August, but an erroneous radio command caused the vehicle [100] to come down too fast and suffer some damage in landing. The fourth flight was postponed twice, each time because someone forgot to charge the battery. Towed aloft on 17 September, the vehicle failed to release on command, voiding the test. Twice in a row, short circuits forced the contractor to call off the fifth flight test, the second time on 21 September.[16]

That same day, James Chamberlin, MSC Gemini Project Manager, ordered North American to halt flight tests of the half-scale paraglider. He expressed "growing concern" over "the repeated unsuccessful attempts of S&ID [North American's Space and Information Systems Division] to conduct satisfactory predeployed half-scale paraglider tests." Flights were not to resume until the contractor had reorganized its paraglider project and could spell out just what it intended to do about the test vehicle's electronics and pyrotechnics and the company's own checkout and inspection procedures.[17]

North American had already made some moves along the lines Chamberlin demanded. The paraglider effort was raised to the status of a major program, and George W. Jeffs was named Paraglider Program Manager on 1 September 1962. Norbert Witte, the former project manager, stayed on as Jeffs' assistant.[18] Jeffs was something of a corporate troubleshooter, and he had the respect of the NASA engineers working on paraglider.[19] This augured well for the future, but, in the meantime, a fully successful flight test had yet to be performed.

North American reworked the half-scale vehicle in its plant, then shipped it back to Edwards Air Force Base on 15 October for another try. A bad ground transmitter stalled matters for a while but, on 23 October, the fifth test flight was a complete success.[20] Even with all its problems, the series of tests had met its main goal, showing that the paraglider was stable in free flight.[21] But predeployed flight testing ended more than two months late, and the crucial deployment flight tests - spreading the paraglider wing in flight - had not even begun.

In the meantime, other problems were beginning to compete for the attention of the overworked project office. Like the paraglider, ejection seats had been a controversial innovation in manned spacecraft, and their development problems also gave critics an early opening. The reasons were much the same. Both systems were a long step beyond current practice, both presented test problems not clearly related to their final roles, and both were subject to changing requirements that imposed makeshift adjustments, further complicating matters.

Although ejection seats were widely used in military aircraft, they were designed to give pilots a chance to survive, not to guarantee that survival. Manned spacecraft levied more stringent demands. Most critical was the "off-the-pad abort mode." Before liftoff, the spacecraft perched some 45 meters from the ground atop a shell filled with potentially explosive chemicals, the Titan launch vehicle. [101] However rigorous the precautions, there was always the danger of some mischance setting it off. For a length of time that might stretch into hours before they were airborne, the crew would be aboard with no recourse, should that mishap occur, save their ejection seats. The Gemini seat had to be able to propel itself from a starting point 45 meters in the air in a trajectory stable enough to get clear of an exploding booster and high enough to allow parachutes to open. No existing seat could do that, and developing one that could was the crux of the Gemini effort.[22]

Reprogramming Gemini

The project office had already moved to reprogram Gemini, to alter the course of the program and compel the contractors to [109] conform to the newly limited budget. Reprogramming was much more drastic in some areas than in others. Paraglider escaped almost untouched. McDonnell's spacecraft effort took some trimming but remained much what it had been. The launch and target vehicle programs, the Air Force portion of Gemini, endured the most far-reaching changes. Plans for testing the Gemini launch vehicle were sharply cut back. Target vehicle testing was even more drastically curtailed; for some months, in fact, whether Agena still had a Gemini role was an open question.

Chamberlin Departs

[123] The dispute between NASA and the Department of Defense about who was to have the last word in Gemini, whatever might be its long-range impact, agitated only the highest echelons. MSC engineers knew little of what was going on and, in any case, had their hands full with their own problems. Gemini reprogramming had slowed the rate at which money was being spent, but costs still spiraled upwards. Although stretching out the program was bound to offset immediate savings by larger total costs unless parts of the program were chopped out, the size of the increase soon surpassed anything that might have been expected. Meanwhile the revised program suffered from the growing severity of the technical problems that had afflicted it before and during the fall budget crisis. Paraglider testing and Titan II anomalies loomed largest.

Despite some talk about dropping paraglider from Gemini to meet fiscal constraints, paraglider development came through largely unscathed. While other major systems suffered more or less drastic cutback paraglider's budget expanded. By the end of 1962, contract changes and overruns had raised the price of the current phase of paraglider development from four and a half to over seven million dollars.[22]

North American Aviation, the paraglider contractor, was still having problems with flight testing. The success of 23 October 1962, which concluded the test series of a half-scale model launched with its wing already deployed, proved only a respite. The next step was trying to deploy the wing in flight. North American refitted the half-scale test vehicle at its plant in Downey, California, and shipped it back to Edwards Air Force Base for its first flight test, scheduled for 27 November. The all-too-familiar pattern of minor problems, mostly electrical, delayed the flight day by day until 10 December, and then the results were disappointing. The capsule tumbled from the helicopter, fouling the drogue parachute intended to pull the can in which the wing was stored away from the paraglider. Wing inflation intensified the tumbling and the emergency drogue parachute ejected too soon. When the capsule spun down past 1600 meters, the minimum recovery altitude, radio command detached the wing and allowed the capsule to descend on its emergency parachute.[23]

The next attempt, on 8 January 1963, after its share of delays, produced even worse results. There was no tumbling, but the storage can was late in separating; so the capsule was falling too fast when the wing started to inflate and its membrane tore. As the capsule fell below 1,600 meters, its wing not yet fully deployed, emergency recovery was ordered to no avail. The main parachute remained packaged, and the capsule crashed. Picking through the wreckage, North American [125] inspectors found that a squib switch in the emergency parachute's electrical system had misfired. That was not the only problem, but it was the most discouraging--the switch was a standard item, much used in the space program and not known to have failed in 30,000 successive firings. GPO warned North American to be sure everything that had gone wrong was corrected before trying again.[24]

A month later, North American reported to the paraglider coordination panel that five distinct failures had been spotted, studied, and fixed. The panel was convinced, but Chamberlin was not. After an extended meeting with George Jeffs, manager of the paraglider program for North American, Chamberlin decided to give the trouble plagued half-scale flight-test program another chance.[25] Once again, the current crop of troubles had little impact on plans for the next phase of development, which covered the rest of flight testing, pilot training, and paraglider production. Part of Phase III, gearing up for production, was worked out and under way by 22 January. North American's proposals for the rest of the program were ready by the end of the month. GPO approved and, with the concurrence of NASA Headquarters, readied a new contract.[26] But the Office of Manned Space Flight had second thoughts and stopped the procurement action "for the time being."[27] The halt proved to be permanent.

The Gemini paraglider program foundered on North American's third attempt to deploy a half-scale wing in flight. Although the first two flights had been at least partial successes, the third, on 11 March, offered no comfort at all, The storage can failed to separate, so the wing could neither eject nor inflate. When the radioed command to deploy the emergency parachute produced no response, the second half-scale test vehicle joined the first as wreckage.[28] Paraglider testing came to an abrupt halt.

Gemini's other major headache early in 1963, Titan II, posed a far greater threat to the program as a whole. There would still be a Project Gemini without paraglider, but not without Titan II. Despite some hopeful signs, the status of the launch vehicle remained very much in doubt. The central problem was still the lengthwise vibration, or Pogo, that bounced the vehicle while its first-stage engine was burning; but other technical problems began to compete for attention. Efforts to resolve them were coming up against a crucial disparity between Air Force and NASA goals in Titan II development.

This was only three days after the crash of the second half-scale paraglider test vehicle. The conjunction of the newly revealed impact of Titan II problems and the latest in the series of paraglider mishaps suggested that Project Gemini was in deep technical trouble. To make matters worse, Gemini had new money worries. The reprogramming effort of the last quarter of 1962 had slowed the rate at which Gemini was spending money but at the expense of stretching out the program. In the nature of things, a longer program was liable to cost more overall; when Holmes reported, early in February, that Gemini's total cost would reach $834.1 million, the figure was not too disturbing. That was about $60 million over the lowest estimate in September 1962 but well short of the $925 million that had then appeared to be a possibility.[39]

Just a month later, however, on B March 1963, MSC's revised preliminary budget for fiscal year 1964 reached NASA Headquarters, and it was a shock. Gemini's estimated total had shot over the billion-dollar mark. The new figures was nearly twice the cost first approved in December 1961 and almost $200 million higher than the figures Seamans and other NASA officials had been using as the basis for NASA's fiscal year 1964 budget request, most recently in House hearings earlier that week.[40] So large an increase, coming on the heels of what had seemed to be a resolution of Gemini's funding problems, took NASA Headquarters by complete surprise. Chamberlin, as manager of Gemini on the field level, knew what was happening. But, waiting for an opportune moment to break the news, he was overtaken by events.

Unexplained cost increases combined with seemingly critical problems in paraglider and Titan II development to bring Chamberlin's tenure to an abrupt end.[41] On 19 March, Gilruth relieved Chamberlin of his duties as project manager and assigned him to the post of Senior Engineering Advisor to the Director, cutting him off from any

These were the arguments that NASA spokesmen used to explain the higher costs that Gemini had incurred in the past fiscal year and to defend their budget request for fiscal year 1964 to congressmen growing restive in the face of soaring NASA needs. Gemini, Holmes told the House Subcommittee on Manned Space Flight, was "much more than a big, overgrown Mercury."[52] It had, said Webb, "what I would characterize as the potential for the first workhorse of the Western space world in very much the same way that the DC-3 airplane became a great workhorse of aviation for many, many purposes."[53]

How much of this was merely after-the-fact rationalization may be open to question, but whatever hopes NASA officials might have for using Gemini or helping Apollo depended on solving some urgent problems. Development of the new technology that was to transform Gemini was lagging. The most advanced spacecraft systems - propulsion, escape, and fuel cell - were running into trouble; the paraglider program had faltered; and, worst of all, the Titan II launch vehicle posed a question mark for manned space flight. Maybe Gemini would become a workhorse, and maybe that prospect was good reason to delay the flight program. But the many technical problems, Gemini's new acting manager admitted when interviewed by a leading trade journal, had already wrecked the old schedule.[54]

Attacking Paraglider and Titan II Problems

The most pressing worry when Mathews took charge of the project in mid-March 1963 was what to do about the trouble-plagued paraglider development program. Back-to-back failures, as North American tried to deploy the wing in flight, had destroyed both half-scale test vehicles. GPO had been funding paraglider on an interim basis since February, little money was left, and North American was ready to quit unless it got new directions. With neither time nor money enough to replace the two lost test vehicles, GPO had to work out a new test program with North American, using the hardware still on hand or almost ready - the two full-scale test vehicles slated for deployment tests, [133] the half-scale boilerplate left over from emergency parachute system qualification, and the paraglider trainer that North American was building.[55]

Spokesmen for North American and MSC met in Houston 27-28 March to discuss the options. Telephones in GPO, in the Gemini Procurement Office, and in North American were busy over the next two weeks as the main features of a revised test program were argued, talked out, and settled. The key decision was to divide the flight sequence in half and work through the problems of each phase separately before trying to demonstrate a complete flight from deployment through landing.[56]

Spreading the wing in flight was still the crucial problem, and it was to be tackled with the two full-scale test vehicles. The new test plan, however, was simpler than the old. As the vehicle dropped from a high-flying aircraft, its wing would inflate and deploy to convert its fall into a glide down to 3,000 meters. That ended the test sequence. Explosive charges would sever the cables that suspended the test vehicle from the wing, and the now wingless vehicle would descend to Earth beneath a large parachute. The rest of the flight sequence, gliding from 3,000 meters to a landing, was to be studied with two tow-test vehicles, modified versions of the paraglider trainer. Towed by a helicopter to the proper altitude and then released, this vehicle would be flown by a pilot down to the California desert. In the final stage of the program, Gemini static articles would be fitted with standard paraglider gear and flown through the complete flight sequence from deployment to landing.[57]

If everything went according to plan, the paraglider landing system could be ready for the seventh Gemini spacecraft. By the time McDonnell started building the tenth spacecraft, paraglider gear could be installed at the proper place on the production line.[58]

On 12 April 1963, Mathews outlined for North American what had to be done at once to put the new program into effect. The company was to stop all work on landing gear for the full-scale test vehicle, since it would now land via parachute, and to forget about trying to convert the half-scale boilerplate into a half-scale test vehicle. Instead, the boilerplate would be used as a tow-test vehicle to work out takeoff techniques needed later for manned flights. North American also had to qualify the new full-scale parachute system, which differed substantially from the emergency system - using three Mercury-type parachutes - that North American had tried hard to qualify, without much success, during the summer and fall of 1962. By the end of April 1963, North American had shifted gears and was working along the lines laid out earlier that month.[59]

The reoriented paraglider program was formalized in a new contract between North American and NASA on 5 May 1963 that also [134] closed out the earlier contracts. MSC and the contractor agreed on a year-long program (to May 1964) more tightly focused on the basic design of a workable paraglider system than the old had been, with such matters as flight training and production postponed until the design had been proved.[60] NASA settled the earlier contracts with North American for $7.8

million and negotiated a $20-million price for the new effort that was intended to save paraglider landing for Gemini.[61]

Although doing something about paraglider was the most pressing problem Mathews faced when he took over Gemini, Titan II was the greater concern for the program as a whole. So far, Air Force efforts toward clearing up the troubles had been limited to what was needed to make its missile work. Nothing extra was yet being done to see that Titan II met Gemini's needs, although Bernard Schriever had assured Holmes that any Titan II problems that threatened Gemini would be taken care of.[62] Pogo seemed to Mathews, as it had to Chamberlin, the most urgent, and Mathews, like Chamberlin, insisted that ±0.25g at the spacecraft was the highest level of vibration that NASA could accept. BSD, however, professed to be content with the g-level of ±0.6g already achieved, well below earlier levels as high as 5g. That was low enough for the missile, and BSD firmly refused to spend any more of its money to lower it further.[63]

GPO could do little to change BSD's stand, but Schriever, whose command embraced BSD, did have something to say about it. He ordered top officials of both BSD and SSD to his headquarters at Andrews Air Force Base in Maryland on 29 March 1963 to present a status report on Titan II problems related to its role as Gemini launch vehicle. Spokesmen for the major Titan II contractors - Martin, Aerojet, Aerospace, and Space Technology Laboratories - were on hand to discuss their efforts. What Holmes and the other NASA representatives Schriever had invited to the meeting heard was far from reassuring.

Paraglider on the Wane

Work on the reoriented paraglider program of May 1963 got off to a quick start. Before the end of the month, North American Aviation was working out techniques for launching a tow-test vehicle from the ground. This preliminary effort, which involved first a car-towed half-scale vehicle and then one towed by helicopter, was designed to show what the paraglider would do during towing and liftoff and to work out proper towing techniques, all this to prepare for that part of the new test program in which a pilot would fly the test vehicle from an altitude of 3,000 meters to a landing. NASA's Flight Research Center also conducted a series of tow tests, the whole effort being completed in mid-October 1963.[21]

May 1963 also saw North American begin work on the other phase of the new test program, testing the deployment sequence with the full-scale test vehicle. Since this phase of testing called for the test vehicle to land by parachute, the first step was to qualify a parachute recovery system, one standard Gemini parachute backed up by a second. North American got off to a smooth start. Two drops of a small bomblike test vehicle on 22 May and 3 June showed that the system's two small stabilization parachutes worked. The contractor quickly began testing the full system on a boilerplate test vehicle. A minor malfunction marred the first drop on 24 June, but three good tests followed in July, with only one more needed to prove the system. What was to have been the final drop, on 30 July, brought a crucial setback. Both main and backup parachutes failed, and the boilerplate crashed.[22]

The company wanted to get on to the next phase of testing and argued that the failure could be safely ignored, partly because North American believed it knew how to correct the problem partly because further tests would require a new boilerplate and mean a delay in the program. The logic was sound enough, but GPO feared that, although the immediate problem might be easily corrected, its root cause - the instability of the vehicle - might produce other, and worse, problems. [146] GPO and North American agreed on two further drop tests. McDonnell furnished the new boilerplate, which North American, on the basis of spin-tunnel tests, modified to provide a more stable suspension system. That took time; over three months elapsed before the next drop, on 12 November 1963. Everything worked, and another test three weeks later confirmed the result; the parachute recovery system was at last qualified for full-scale vehicle deployment tests.[23]

Proving the parachute system was not the only source of delay. Design engineering inspections of the full-scale test vehicle on 1 August and the tow-test vehicle on 27 September produced the normal share of required changes. Wind tunnel tests of North American's first full-scale prototype wing at Ames Research Center in October yielded too little data and had to be repeated in early December. So it was late November before the contractor could deliver the first tow-test vehicle to Edwards Air Force Base to begin its manned program and mid-December before the two full-scale vehicles arrived.[24] With almost two thirds of the time available under the new contract exhausted, North American had yet to begin the major flight-testing portion of the program.

By the fall of 1963, the status of paraglider in Gemini was once more in jeopardy only partly because of North American's troubles. The inflated frame used in the paraglider design was being challenged by advocates of what seemed to be a viable alternative - an all-flexible gliding parachute, the so-called parasail. This device offered a lift-to-drag ratio ranging from 0.9 to 1.2, lower than paraglider's but still enough to provide worthwhile range and control. It was further handicapped by its relatively high rate of descent, which required landing rockets to cushion impact with the ground. But, overall, parasails matched conventional parachutes closely enough to promise a reasonably quick and relative cheap development of a reliable device for land landing.

The gliding parachute had, in fact, competed with the inflated-frame paraglider design back in 1961, when the choice of a land-landing technique for what was then the Mercury Mark II project was being made. Although rejected for Mark II, the concept persisted as the subject of a modest research and development program at MSC.[25] As paraglider faltered, parasail seemed more attractive. Project Gemini's new manager, Charles Mathews, was more receptive to parasail - or less committed to paraglider - than James Chamberlin had been. Supported by MSC Director Gilruth, Mathews called on GPO for another look at parasail. In April 1963, after the second half-scale test vehicle had crashed but before the future of the paraglider program was decided, he asked McDonnell to study changing Gemini's landing system from paraglider to parasail.[26]

While McDonnell pursued its study, MSC's Flight Operations Division [147] and Systems Evaluation Division continued testing a parasail system and pressing for its adoption. Paraglider still had highly vocal backers, however, who denied that its problems involved anything more than sequential details that would have to be ironed out for any recovery device, even conventional parachutes. Claiming that paraglider development had been known from the first to be a hard task, they objected to dropping it after so much of the work had already been done.[27] The lines were drawn here they had been in 1961: Flight Operations Division and the Engineering and Development Directorate still opposed paraglider; most of the project office and the prospective pilots, supported by Flight Crew Operations, favored it.

When McDonnell finished its study early in September 1963, the issue was carried to NASA Headquarters. The company's informed guess at the cost of a parasail and landing-rocket system for the Gemini spacecraft was $15.7 million, with a good chance to be ready for Spacecraft 7. When the parasail proposal was informally presented to NASA Headquarters on 6 September, it was rejected. Dropping paraglider on the verge of flight testing, leaving nothing to show for all the time, money, and effort already spent, was out of the question. The alternative, going ahead with parasail development as something to fall back on if paraglider failed, was ruled out for lack of funds to support both tasks at once.[28]

Although reprieved, the paraglider program did not come through unscathed. High-level talks between MSC and NASA Headquarters produced still another reorientation of the program.* The paraglider landing system program was stripped of all other objectives, leaving as its only goal proving paraglider's technical feasibility - which meant primarily showing that the wing could be inflated and deployed in flight to achieve a stable glide - with the accent on staying within the $16.1 million budgeted for fiscal year 1964. Until that goal had been met, there was to be no further work on a prototype system for Gemini, much less on production. Gilruth insisted on a clear understanding that paraglider might still fly on Gemini if the flight tests succeeded, that paraglider's future in Gemini had not been foreclosed.[29] The implication of foreclosure was nonetheless there.

Under orders from MSC, North American ceased its efforts to keep the full-scale test vehicle fitted with the latest Gemini equipment. MSC also directed McDonnell to stop all testing related to installing the paraglider, to design parachute versions of all Gemini spacecraft, and to plan on putting paraglider in the last three, the last two, or [148] only the last spacecraft. Nothing of paraglider was to remain in the spacecraft except the option to put everything back if the flight testing succeeded. Parachutes had, by late 1963, displaced paragliders as the planned means of recovery through the ninth mission. Paraglider landing was still listed for the last three Gemini flights, but some planners, SSD Commander Ben Funk among them, assumed paraglider would not be included in the tenth mission, either, "and probably will not be carried on any of the twelve flights."[30] The very fact of paraglider's doubtful status had already begun to close off any real chance to fly in Gemini, whether it proved itself or not.

A common feature of spacecraft development, and always a matter of concern, seems to be an innate tendency toward weight growth. Gemini was no exception. A complete paraglider landing system weighed almost 360 kilograms more than a conventional parachute recovery system. Once paraglider's place had been questioned, that difference was seen as a bonus and was simply used up. Experiments, for instance, began to encroach on as yet unfilled space allotted to paraglider, especially after January 1964, when the Manned Space Flight Experiments Board was formed. Gemini's planners were beginning to look on paraglider as an extra demand on the payload budget, already pushing the limits set by the booster. If paraglider were to be restored, some other mission objectives would have to give way.[31] In other words, even if North American succeeded in showing that paraglider worked, that could no longer guarantee an attempt to fly the system in Gemini. Everything rested on the outcome of North American's upcoming effort to deploy the wing on the full-scale test vehicle in flight; although success could not ensure a place for paraglider, failure would surely bar it.

Titan II Makes the Grade, But Not Paraglider

The striking vindication of Titan II in the final months of 1963 had no parallel in the paraglider program. Paraglider's only chance to regain a place in Gemini hinged on the outcome of North American's new series of deployment flight tests with the full-scale vehicle. A full-scale wing was to be uncased and inflated in midair, to prove it could support the vehicle in stable gliding and maneuvering under radio control. Each of the planned 20 tests was to end with the wing cut loose at 3,000 meters and the test vehicle landing by parachute. The parachute system was qualified on 3 December 1963, clearing the way for flight testing of the full-scale vehicle to begin on 22 January 1964. The first test did nothing to dispel doubts about paraglider; the second test, on 18 February, was also a failure.[12]

That same day, George Mueller told the House Subcommittee on Manned Space Flight that the paraglider "is not presently scheduled on the . . . Gemini spacecraft."

"Will it be used at all in the Gemini program?" one of the Representatives wanted to know.

Mueller replied, "That will depend upon the development status of the paraglider which we will evaluate next spring. It will also depend upon the needs for a paraglider for precise landing of the Gemini spacecraft which we are developing now with the Air Force."

Further probing revealed that paraglider could be ready for the tenth Gemini mission, particularly if the Department of Defense lent [171] its support - this from George Low. But, he added, "we have no money included [in] 1965 or beyond for the paraglider under the assumption we will not go into production."[13]

NASA's public position was that, while land recovery appeared to be both desirable and feasible, it was riskier than water landing. Crew safety, the paramount concern, dictated the proven mode of safer landing for all 12 Gemini flights.[14] The risks of land recovery were real enough, needless to say, but they had been just as real in 1961 when NASA decided to adopt land landing as a major Gemini objective. Toward the end of winter in early 1964, however, the means to that end, a paraglider landing system, had yet to achieve a level of performance great enough to rely on. After nearly three years of work, there was still no certain answer to the key paraglider problem - how to unship and inflate the wing from a two-tonne spacecraft plunging downward through the atmosphere. The risk that loomed so large early in 1964 was perhaps not so much land landing as paraglider landing.

Paraglider still had ardent defenders in NASA, and the decision to strike it from Gemini was not yet final.[15] But NASA was ready to drop the paraglider, the more so since the system might still fly in another version of Gemini. In the spring of 1963, under the auspices of the Gemini Program Planning Board, the Air Force had begun laying the groundwork for its own Gemini program. Gemini B/Manned Orbital Laboratory (Gemini B/MOL). The Air Force X-20 orbital glider, still often called by its former name, Dyna-Soar, had been canceled in December 1963, a victim of low priorities and lagging development. Some X-20 funds were diverted to the new MOL program, which projected two men in a modified Gemini spacecraft launched by a Titan III. In orbit, the crew would transfer to a separately launched laboratory for two to four weeks, after which they would return in their spacecraft.[16]

Air Force planning had progressed far enough by January 1964 to require a formal agreement between NASA and the Air Force in the form of a memorandum signed by Seamans for NASA and Harold Brown for the Air Force.[17] Although Gemini B/MOL would not be officially approved until August 1965 and design work was only beginning, NASA saw a chance to save paraglider. On 17 March 1964, George Mueller asked the Air Force for "an expression of the DOD interest in this capability," whether for Gemini B/MOL or any other program. Six weeks later, having concluded that paraglider development had too many problems to warrant putting it in the new program, the Air Force discounted any prospect of joining in paraglider development and threw the problem back to NASA: "Should the NASA qualify and demonstrate the paraglider in the NASA Gemini program, consideration would be given to its application to the Gemini B/MOL."[18] By then, however, it was too late.

[172] North American's further efforts to fly the full-scale test vehicle produced a string of failures, each distinct in detail but united in a single root cause, "an inability to adequately predict the wing loads of flexible structure[s]." The fifth failure in a row, on 22 April, was the last straw. The next day, William Schneider, NASA Headquarters Gemini chief, informed George Mueller that he planned to transfer what was left of the paraglider program to Flight Research Center and to spend no more Gemini money. A week later, the program office in Houston began cutting back paraglider work and phasing the program out of Gemini. Early in May, GPO and North American agreed to run the rest of the flight-test program with the equipment and money already committed. Paraglider was dead as far as Gemini was concerned, although a public statement of its demise waited until 10 August.[19]

Ironically, North American achieved its first full-scale test vehicle success on 30 April, the day after phasing it out of Gemini began. In fact, the worst was over. Before the end of 1964, North American flew 19 more tests for a total of 25, 5 more than originally planned. By July, the deployment sequence was no longer giving much trouble, although a stable glide after the wing inflated was harder to manage. The last three flights, however, displayed the complete sequence without flaw.[20]

The last full-scale test vehicle flight was on 1 December 1964. Two days later, NASA told North American there would be no more money for flight testing, but equipment on hand might be used, if the company cared to spend its own money. North

American seized the chance to complete the other major portion of the May 1963 program - working out landing techniques with a piloted tow-test vehicle. Tow-testing had begun during the summer. On 29 July, a helicopter had towed the vehicle up to a height of a few hundred meters, around the test area, and back to a safe landing. A free flight followed on 7 August, but the vehicle went into a series of uncontrolled turns, forcing the pilot to bail out. North American attacked the problem with dispatch and came up with an altered wing design. On 19 December, a pilot flew the tow-test vehicle through the complete test to a safe landing.[21]

NASA had long since decided to dispense with paraglider for Gemini, however, and that was irrevocable.** [22] [173] The system's shortcomings, or at least North American's slowness in coming up with answers, account chiefly for paraglider's failure to survive in Gemini. But the immediate reason for the abrupt action in the last week of April 1964 to kill what remained of the Gemini paraglider may have had more to do with money than with technology.

Ironically, at the same time that Mathews was urging SSD to get Lockheed under control, the contractor was finding that it needed still another $2.5 million in 1964 funds, a request that was duly passed along to GPO on 4 April. Lieutenant Colonel Mark E. Rivers, Jr., who had just replaced Major Charles Wurster as chief of Gemini-Agena engineering for SSD, saw signs of sloppy management in the new Lockheed request, which appeared to be based on small changes that had piled up unnoticed over several months.[28]

This, then, was the setting in April 1964 when North American, for the fifth time in a row, failed to deploy the paraglider wing in flight. Mounting costs in all phases of Gemini development had stretched the 1964 budget to the breaking point, and the trend was still upward. Paraglider had been budgeted for $16.4 million in 1964, but that would be the last of the money. Keeping paraglider meant finding new funding or cutting back other parts of the program. In the money budget as in the weight budget, once paraglider's status became doubtful, its place was preempted. Against this confluence of forces - technical, operational, and budgetary - paraglider could not stand.

Whether the target vehicle program could survive was also a question. In late April, budget pressures forced Mathews to discuss with his staff some desperate measures. Paraglider, Atlas-Agena, and even one of the planned Gemini missions were on the chopping block. Once again, however, MSC was able to reprogram funds to save the full 12-flight program and, via Agena, the rendezvous objective, if not paraglider and land landing.[29] One of the factors that may have made Agena's place in Gemini shaky in April 1964 was a new round of technical problems that had cropped up earlier in the month.