—File copy
— Ribbon copy
—Original

SATURN AND ALL-UP FLIGHT TESTING

Historical Note, Saturn History Project

http://heroicrelics.org

by

Mitchell R. Sharpe

January 1974

Saturn and "All-Up" Flight-Testing

With the arrival of Dr. George E. Mueller, on September 3, 1963, as the new Director of the Office of Manned Space Flight for NASA, there also appeared an innovation in the flight-testing of launch vehicles being developed for the Apollo program. The "all-up" concept was received at MSFC with something less than enthusiasm, but it was founded on sound experience that Mueller had accrued during his first few years in the aerospace industry.

"All-up," with reference to Apollo, was, in Mueller's words, flying on each vehicle those systems that will eventually be used in landing on the Moon. That does not mean that each vehicle has all of the systems involved that are going to be used in landing on the Moon. But insofar as possible, there will be as many of them as is economically justified." *

---

* NASA Authorizations for Fiscal Year 1965, Hearings Before the Committee on Aeronautical and Space Sciences United States Senate Eighty-eighthCongress Second Session on S. 2446, March 4, 5, 6, 9, 16 and 18, 1964, Part II, Program Detail, p. 504.

Mueller had become familiar with the concept at Space Technology Laboratories, Redondo CA, where he had been in charge of technical operations. In this capacity, he had been responsible to the US Air Force for the design, development, and testing of systems and components for the Thor, Atlas, Titan, and Minuteman ballistic missiles. The "all-up" concept had first been specified by STL for the Titan II missile, being developed by The Martin Company, Denver, Colorado, just as Mueller was preparing to leave STL for NASA. At the same time, the development plan for the Minuteman intercontinental ballistic missile specified. "All flight tests will be accomplished with an operational three-stage configuration and will utilize closed-loop guidance." * Admittedly, the missile consisted of three solid propellant stages and was hence simpler and more reliable than the complex liquid propellant, multi-stage missiles.

---

* Minuteman Ballistic Missile Development Plan, Test Annex, Tab 5, 25 November 1958. Inglewood, CA: US Air Force Ballistic Missiles Division, p. 1-5-3.

Thus, it offered a better risk from the viewpoint of a successful first mission in the "all-up" mode.

This early association and familiarity with the concept provided Mueller the confidence to institute it in NASA. In the following spring, he would reply to Frank C. Di Luzio, staff director of the Senate Committee on Aeronautical and Space Sciences, who questioned him on whether or not it was a good gamble with space launch vehicles: "On the contrary, the ballistic missiles program indicates it is a very good gamble. In fact, we have learned more once we adopted the all-up testing concept in ballistic missiles per flight than we did prior to that time. We feel it is a very good gamble and one that we should take." *

---

* NASA Authorization for Fiscal Year 1965, Hearings Before the Committee on Aeronautical and Space Sciences, United States Senate, Eighty-eighth Congress, Second Session on S. 2446, March 4, 5, 6, 9, 16, 17 and 18, 1964, Part 2 Program Detail, p. 504.

In practice, however, the concept can be traced back to even earlier missile programs of the then expanding US aerospace industry.

Following the cancellation of aircraft orders from the government in October, 1945, the Consolidated Vultee Aircraft Corp., San Diego, decided to enter the challenging field of guided missiles. In June, 1945, it was selected by the US Navy to produce the Lark antiaircraft missile, a liquid propellant weapon with both command and semi-active homing guidance systems. Four months later, the US Air Force asked for proposals from *

Frederick I. Ordway III and Ronald C. Wakeford, International Missile and Spacecraft Guide. New York: McGraw-Hill, 1960, p. 100.

American industry for an intercontinental ballistic missile with a proposed range of 5,800 miles. The company received a study contract and later built and test flew, in 1948, an experimental missile MX-774, which incorporated several design features to be utilized in the Atlas, which the company developed and flew for the first time a decade later.

The MX-774 was a single-stage, clustered-engine rocket; and the Atlas was a stage and a half missile. Since the half-stage had to be separated from the main stage during flight, it was for mechanical purposes a multi-stage rocket. In the flight-testing of both these rockets, the "all-up" concept was used for a very simple reason. Its engineers were following a test philosophy that had developed over the years in which they had built such aircraft as the Vultee V-11, the Vanguard P-66, and the Vengeance V-72. The philosophy stated in basic terms was that as complete a vehicle as possible would be flown for the first time.

Thus, when the company undertook its first space launch vehicle, the "all-up" testing concept was presumed.* The program was transferred

---

Telephone conversation, not recorded, between Deane Davis, Convair, San Diego, CA, and Mitchell R. Sharpe, MSFC, on November 30, 1973.

---

from the US Air Force to NASA in July, 1959, and technical management for it was assigned to MSFC July 1, 1960.

The Centaur project development plan, prepared by the contractor for MSFC, implies an "all-up" flight-testing concept.*

---

* Centaur Project Development Plan, M-L&M-CGD-608, June 11, 1962 [prepared by contractor on May 21, 1961], pp. 4-35 et seq

---

In actuality, however, one cannot make valid comparison in the testing of the Centaur and the Saturn IB and 5. For one thing, the Atlas first stage of the Centaur had considerable flight-testing, albeit without an upper stage. Neither first stage of the Saturns had flown. The Centaur, unlike the Saturns, was designed only for unmanned payloads and could accept a lesser degree of reliability. Furthermore, MSFC did not have full managerial and decision-making responsibility for the Centaur as assigned to it. * Thus, changes to the original Air Force contract, including testing, were not possible.

---

* Interview of Francis E. Evans, former Centaur Project Manager of the Light and Medium Vehicle Office, MSFC, by Mitchell R. Sharpe, MSFC, on January 10, 1974.

When the first Centaur was launched on May 8, 1962, it was not really in an "all-up" mode, by Mueller's definition. It had a ballast payload, and the vehicle was flown through a ballistic trajectory. In addition, only 50% of the liquid hydrogen load was carried. The mission was not a success because the insulation panels of the liquid hydrogen tank tore loose some 55 seconds after launch, causing the tank to rupture. *

---

* Kurt H. Debus, Test Results, Centaur F-1 Vehicle, MTP-LOD-62-2.3, May 31, 1962, Marshall Space Flight Center, p. 6.

By this time, plans for the flight-testing of the Saturn vehicles had been agreed to by Dr. D. Brainerd Holmes, director of Manned Space Flight whom Mueller was to succeed on September 3.

On April 9, he approved a flight-test schedule that remained in effect throughout the summer of the year.* It called for a conservative and thus costly approach to the flight-testing of the Saturn IB and the

---

Apollo Flight Mission Assignments, M-D E 8000.005A, April 9, 1963. Washington, DC: NASA, Office of Manned Space Flight.

Saturn 5. According to Holmes's approved plan, the first Saturn IB would be launched in August, 1965, with a live first stage and live second stage, but utilizing a Saturn I active guidance system in a developmental instrument unit. The second Saturn IB would be launched in November, 1965, in the same configuration. A third would be launched in January, 1966, with the two rocket stages and instrument unit functional but prototype equipment. They were to place in a circular orbit at 105 nautical miles a developmental Apollo command module, service module, developmental lunar module adapter, and production model launch escape system. No recovery of the payload was to be attempted.*

---

* Ibid., p. 5.

The same schedule called for the first Saturn 5 to be launched in March, 1966, with a live prototype first stage, inert second stage, inert third stage, and functional prototype instrument unit. The second vehicle, to be lauched in July, 1966, was to have a live prototype first stage, live prototype second stage, and inert third stage. Again, it would have a functional prototype instrument unit. The payload in both cases would be the same as those for the first three Saturn IBs. * No payload recovery was to be attempted.

---

* Ibid., p. 7.

This situation changed rapidly and radically once Mueller arrived.

After reviewing those Saturn test plans, Mueller saw immediately that budget limitations simply would not permit the conservative and expensive approach to flight-testing that had been followed previously by MSFC. He later recalled: "It was pretty clear that there was no way of getting from where we were to where we wanted to be unless we did some drastically different things, one of which was all-up testing." *

Interview of Dr. George E. Mueller by Tom Ray in Washington, DC, April 21, 1971.

On October 31, a letter signed for Mueller to George M. Low was sent to the three OMSF field centers reporting to him. However, the same information exactly was transmitted by teletype on November 1. In it he proposed new launch dates for the Saturn vehicles and added:

"It is my desire that 'all-up' spacecraft and launch vehicle flights be made as early as possible in the program. To this end, SA-201 [the first Saturn IB] and 501 [the first Saturn 5] should utilize all live stages and should carry complete spacecraft for their respective missions. SA-501 and 502 missions should be reentry tests of the spacecraft at lunar return velocity. . . My goal is to have an official schedule reflecting the philosophy outlined here by November 25, 1963." *

---

* Letter, M-C M9330.186, Subject: Revised Manned Spacecraft Center; Director, Launch Operations Center; Director, Marshall Space Flight Center; October 31, 1963. Same text appears Teletype No. C005/02, received November 1, 1963, 22452.

The teletype was received at MSFC on November 4 and was discussed at von Braun's daily staff luncheon. Those present included Erich Neubert, associate deputy director for R&D; David Newby, associate deputy director for Administration; Hermann Weidner, deputy director for the propulsion & vehicle Engineering Division; Oswald Lange, director of the Saturn Systems Office; and Frank Williams, von Braun's assistant. Plans were made to discuss it in greater detail at a meeting to be held two days later. *

---

* "Daily Journal --Dr. von Braun, Monday, November 4, 1963."

There followed a series of meetings involving both the Saturn program and project managers from Industrial Operations and the laboratory directors from R&D Operations. The first of these occurred on November 6, and the initial reaction to the proposal was predictable in view of the collective experience of the men present. The older heads, most of whom had two decades and some with three decades of experience in rocketry, were incredulous at the boldness of it. To them the risks involved were unthinkable. If the first stage were to fail, then no performance data could be gained from the upper stages and spacecraft. After all, they had been through the missile development cycle not only with the V-2 but also with the Redstone and Jupiter. With the V-2, which saw some 65,000 modifications to the basic design, an estimated 3,000 rockets were fired during the flight-testing phase of the project and certainly not in the "all-up" mode.*

---

* David Irving The Mare's Nest. London: William Kember, 1964, p. 282.

Despite the experience of V-2 and the technical sophistication in rocketry that had accrued since World War II, the same men who had developed V-2 found it necessary to test launch 37 Redstone missiles between August, 1953, and November, 1958 and 29 Jupiter missiles between March, 1957, and February, 1960.*

John W. Bullard, History of the Redstone Missile System, Historical Monograph Project Number AMC 23 M, October 15, 1965. Redstone Arsenal: US Army Missile Command, p. 173. James M. Grimwood and Frances Strowd, History of the Jupiter Missile System, July 27, 1962. Redstone Arsenal: US Army Ordnance Missile Command, p. 8.2

In neither weapon was an "all-up" mode considered. Indeed, 13 of the initial 21 Redstones fired lacked the guidance and control unit, which was not ready at the time. They were flown with LEV-3 autopilots developed for the early V-2 models of a decade earlier and made from the original German drawings by the Ford Instrument Division, Sperry Rand Corporation, Long Island City, NY.

Bullard, op.cit., pp. 71-72.

Among those clearly and vocally opposed were Arthur Rudolph, Saturn V Project manager; Dieter Grau, director of the Quality and Reliability Assurance Laboratory; and Karl Heimburg, director of the Test Laboratory. Von Braun himself had reservations, but he did not voice them. Having explained the Mueller teletype, he then sat back, more or less, to listen to the dialogue that followed.

Grau's position fairly well sums up the opposition. He later recalled: "In any new project for which there is no precedence case, you have to expect some technical difficulties which nobody can foresee. In the Jupiter missile, the designers learned about sloshing and the effect this can have. Only the cautious planning, which provided for two extra vehicles to be launched before Jupiter 1, made it possible to overcome this difficulty and make Jupiter 1 a success." * His point was

---

* Letter from Dieter Grau to Mitchell R. Sharpe, MSFC, December 12, 1973.

---

well taken as later Saturn developments would prove. The "pogo" problem that developed on Saturn 501 and 502 could have manifested in the original test flight program and been subsequently fixed at less cost.

Rudolph was largely concerned from a technical point of view. For one thing, he was worried about the J-2 engine, which at that point still was far from ready to fly. Also, he like the others, felt that the conservative approach was the only sound engineering approach. *

Interview of Arthur Rudolph at MSFC on December 14, 1973, by Mitchell R. Sharpe.

At a later meeting, when Mueller and Robert Seamans, NASA Associate Administrator, visited MSFC on January 3, 1964, Rudolph was still not convinced and sought to illustrate his disapproval graphically. He led Seamans over to a model of the Saturn 5 standing next to a model of the Minuteman to the same scale. After touching upon the obvious simplicity of solid propellant rockets versus the complexity of liquid propellant ones, he said "Now really, Bob!" Seamans got the point and replied, "I see what you mean, Arthur!" Rudolph then maneuvered Mueller over to the same models and went through his monologue again. When he had finished, Mueller replied, simply: "So what?"

Others in the group had no really strong feelings pro or con. Walter Haeussermann, director of Astrionics Laboratory could think of no valid opposition from his viewpoint; however, he observed that there was no way to analyze mathematically the "all-up" concept. How could one assign a probability of failure to a first stage on a first flight? *

----

* Interview of Walter Haeussermann at MSFC on December 14, 1973, by Mitchell R. Sharpe.

However, an attempt to do so was made at the request of Richard Meyers, Mueller's chief of reliability, early in the following year. He asked the Saturn Systems Office to undertake such a study through Arinc Research, Inc., one of its contractors specializing in the field of reliability. The study, completed on June 15, 1964, proposed that the reliability of an "all-up" Saturn 5, with a one-engine out capability in the first and second stages, was 0.682. With no engine-out capability, the figure fell to 0.497. * In other words, based success or failure on

----

* T. T. Jackson, A. D. Tinkelenberg, and D. Van Tijn, Special Technical Report 13, The Reliability of the All-Up Concept. June 15, 1964. Arinc Research Inc., Huntsville AL, p. 10.

----

the data available from previous Saturn I and intercontinental ballistic missile launchings and the mathematical approach taken, Saturn 501 had a 68% chance of success.

Ernst Geissler, director of the Aero-Astrodynamics Laboratory, was of the same opinion. Indeed, he felt that theoretically "all-up" testing was much more realistic from the trajectory viewpoint. In any event, the decision was a management one, not an engineering one. *

---

* Interview of Ernst Geissler at MSFC on December 14, 1973, by Mitchell R. Sharpe.

The debate continued for over an hour; however, a new and conciliatory tone entered it. As discussion grew less emotional, something of a technological Mexican stand-off became apparent. Just as Mueller could not guarantee that the concept would succeed, those present and opposed could not guarantee that it would fail. Someone interjected the opinion that "if we have done our job right, we have nothing to worry about." Someone else pointed out that the real success would depend largely on those who wrote the test procedures and those who carried them out. Furthermore, the Saturn I program with four successful launchings to date of the S-I stage pointed toward a similar success with the Saturn IB. Also, all static firings of the S-IV second stage of the vehicle had been successful.

By this time, von Braun had made up his mind to accept the "all-up" approach, even though he still maintained some reservations about it. However, he realized that Mueller was "the boss" and that his way should

---

* After the successful launching of 501 on November 9, 1967, he turned to Rudolph in the firing room at Kennedy Space Center and told him that he thought it would never have been possible.

---

prevail, particularly so since no one had come up with a really sound argument against it. Then, he firmly announced that the official MSFC position would be one of endorsement of the "all-up" flight-testing of Saturn. There was no further rebuttal, and Williams was given the task of drafting a reply to Mueller's teletype.

Von Braun did not wait for the letter to reach Mueller. On November 8, he called him and went over Williams's draft. Before doing so, von Braun prefaced his remarks by stressing that what he had to say was "very sketchy because we are talking about a multibillion dollar program involving lots of contractors; and it is very difficult, of course, to impact such a radical change in approach and philosophy and schedule and everything in a period of less than a week." Mueller understood the tentative nature of the response but was both relieved and pleased to hear von Braun continue - not quite truthfully: "Our development team here with whom we discussed everything in much detail is solidly behind the all-up flight concept." *

Transcribed telephone conversation appended to "Daily Journal, Dr. von Braun, Friday, November 8, 1963."

However, he pointed out that there were problems inherent in the plan with which Mueller should be aware. One of these would be introduced by using the first two Saturn 5s to obtain reentry data on the Apollo command module.

Previously to Mueller's teletype of November 1, MSFC had been planning on Saturn 5 vehicles 504 and 505 for reentry missions. * Mission 504 was planned for launch in December, 1966, and was to have

----

* Apollo Flight Mission Assignments, M-D E 8000.005A. April 9, 1963. Washington, DC: NASA, Office of Manned Space Flight, p. 6.

----

the command module reenter at a velocity of 36,000 feet per second at an angle that would insure the maximum heat rate. Mission 505, scheduled for launch in February, 1967, would have the command reenter at an angle that provided the maximum total heat load on it.

Earlier in the year, MSFC in conjunction with MSC, had performed a series of studies for using the Saturn 5 to obtain such data. The two centers had identified five possible modes of so doing, of which only two seemed desirable from the viewpoint of the flight mechanics of spacecraft and launch vehicle. They were a so-called non-optimum burn and nominal lunar flight for launch vehicle. *

----

* Rought draft material for presentation, "Subject: Comparison of Mission Profile Modes for Archiving the Launch Vehicle and the Spacecraft Test Objectives on Saturn V missions 504 and 505," September 9, 1963.

Von Braun explained that the most efficient of these from the viewpoint of testing the Saturn 5 entailed having a live Apollo service module available by the proposed launch date. MSC did not want to commit the service module propulsion system that early. Additionally, MSC objected because the Apollo guidance system for the mission would have to be completely automated to do the job, whereas much of the job in an operational mission would be done by the astronauts.

In view of these objections, MSC proposed that MSFC simply plot a trajectory that would permit the S-IVB stage of the Saturn 5 to drive the command module back into the atmosphere at the required velocity and angle.

Von Braun was against this proposal because it would not test the launch vehicle in an environment approximating a lunar mission. To use his term, it would be a "classical case of dead-end testing." Mueller agreed with him on this point. Von Braun had made his point well with Mueller, and Saturn 501 was flown with the Apollo service module live. It performed as programmed and sent the command module back into the atmosphere, providing the data needed.

---

* Saturn V, AS-501 Flight Evaluation, MPR-SAT-FE-68-1, January 15, 1968, p. 23-1.

The logistical problems involved in a recovery mission were also pointed up by von Braun, who recapitulated the problems encountered in the days of Jupiter-C and Jupiter. He cited the numbers of men and ships that could be tied up in the various target areas on a mission that was at the mercy of meteorological conditions at the launch site in Cape Canaveral. Mueller was aware of these, but apparently did not consider them to be of so great a magnitude as the problem of "dead-end" testing.

The letter of November 8 to Mueller went into considerable detail on several points concerning the practical and financial impact of the "all-up" testing and the reentry missions for 501 and 502.

It also contained a suggestion that considerably qualified the concept and intent of "all-up" testing.

"We believe the philosophy of flying live all stages, modules, and systems, beginning with the first R&D launching, to be a worthy objective. There is no fundamental reason why we cannot fly 'all-up' on the first flight. Our practical application of this philosophy should recognize this objective, but with the important reservation that clear, alternative, 'fall back' positions are also formally recognized--for example, backing down to a two-stage mission--should this become necessary as a result of some critical technical, scheduling, or funding consideration arising at a later date." *

---

* Letter dated November 8, 1963, from Wernher von Braun to George E. Mueller.

The letter also went into the important area of funding for the revised flight schedule based upon the new concept and missions.

"To support the proposed schedule, $138 million additional FY64 funds are required... To support the proposed schedule, the MSFC FY65 requirement is $1,753.3 million. This requirement is $48.8 above our September 18 submission and assumes an internal MSFC reprogramming of the $90.7 million resulting from the Saturn I operational termination. Should MSFC receive the FY ceiling of $1,439.4 million, the resulting unfunded requirement is $314 million." Several million dollars were also identified to meet the needs of constructing special test facilities for the J-2 engine and the S-IVB stage.

At this point in the telephone conversation, Mueller was taken back by the turn of the subject. He said that I am still astonished at the FY64 impact, and we are going to have to look at that pretty carefully to see whether we can find that much money."

After von Braun had suggested supplemental funding would be required at MSFC, he added: "Now when I say supplement may be required, maybe I should correct my language here. It doesn't make any difference where the money comes from if it can be scraped up in a program somewhere.... I realize full well that any commitment to get a supplement of this kind on a tight schedule is unrealistic, but on the other hand NASA has a pretty big swimming pool to paddle around in and maybe this money can be located somewhere else." * Mueller agreed that the funding situation

---

* While money had never been a problem at Peenemuende during the developmental days of the V-2, von Braun early became aware of its scarcety in the incipient American missile program. At Fort Bliss, Texas, in 1947, less than a year after arriving in the country, he told reporter Daniel Lang, "Frankly, we were disappointed with what we found in this country during our first year or so. At Peenemuende, we'd been coddled. Here they were counting pennies." Quoted in Daniel Lang, From Hiroshima to the Moon, Chronicles of Life in the Atomic Age. New York: Simon and Schuster, 1959, p. 189.

---

probably could be handled with savings from the rearrangement of other projects.

After considering von Braun's letter of November 8, Mueller replied on November 18. In it he elaborated his definition of "all-up" testing, and he insisted on it as well as the use of 501, at least, to provide reentry data for the Apollo command module.

"The philosophy of 'all-up' testing shall be observed in developing schedules. 'All-up' testing is defined as having all live stages and spacecraft modules as complete as possible for all Saturn IB and V flights. It is recognized that early Saturn IB flights may not include the complete LEM. Every effort must be made to phase the LEM structure and complete LEM into the program as early as practicable. It is also recognized that early launch vehicles may not have the final operational payload capabilities. Again, every effort must be made to reach operational payload capability as quickly as practicable. Subsystems used for early flights should be the same as those used for lunar missions." *

---

* Letter, M-CL 3000.543, Subject: Manned Space Flight Schedule, from George E. Mueller to the Director, Manned Spacecraft Center; Director, Launch Operations Center; Director, Marshall Space Flight Center, dated November 18, 1963.

After reading the letter, von Braun sent it to Robert Young, the newly appointed director of Industrial Operations, with the following hasty note:

"This, of course, means <u>a definite commitment today</u> that we will not fire SA-501 before all subsystems are available is o.k., but makes weakest link in chain determine first Saturn V launch!"

Similarly, on November 23, he returned Geissler's weekly notes to him with the marginal notation: "In view of Mueller's all-up philosophy and his desire to fly reentry missions on 501 and 502, I'd like to have a sober appraisal as to how a method 5' reentry profile would effect (and validate) such flights for Apollo launch vehicle certification. We shall need hard facts to convince Houston that 'method 5' is out and they must provide a dual-burn service module." *

---

* "Method 5", desired by MSC, was a mission that would send the Apollo command module, less service module, into an elliptical Earth orbit using the three stages of the Saturn 5. The trajectory was calculated so that the command module would intersect the atmosphere to produce the heating conditions required.

While MSFC had no objection in principle to the proposed changes, there were problems involving launch vehicle components. The major problem area so far as Saturn 5 was concerned lay in the S-II stage. On December 27, the contract with North American Aviation, Inc., Space and Information Systems Division, was amended because of the recently adopted "all-up" concept. The amendment called for the delivery of a live stage in July instead of an inert one in April of 1966. *

---

* Teletype, Earl H. Eubanks, contracting officer, MSFC, to William F. Parker, S&ID, North American Aviation, Inc., dated December 30, 1963. See also, Saturn V Project Development Plan, April 1, 1963, MSFC Saturn Systems Office, p. 4-48.

In effect, the first reentry mission was being moved forward by one month and second by five months. Such a change only compounded troubles already facing the manufacturer. By the end of June, he had already been six months behind in his delivery date of the originally scheduled inert stage because of engineering problems which included difficulties in forming gore segments of the propellant tanks and difficulty in bonding insulation to the liquid hydrogen tank of the S-II stage. *

---

* MSFC, Saturn Systems Office, Saturn Monthly Progress Report: May 18 - June 17, 1963, p. 9.

By mid-1964, however, "all-up" testing was a *fait accompli* so far as MSFC was concerned. James B. Bramlet, deputy director for operations of the Saturn 5 Project Office, summed up the status at the first annual meeting of the American Institute of Aeronautics and Astronautics, in Washington, on June 29.

"A program conceptual change introduced last fall, after considerable analyses, is the 'all-up' vehicle spacecraft flight development approach that depends a great deal upon a thorough ground test and qualification program. Instead of progressing from inert upper stages to live upper stages is calculated steps, the 'all-up' concept requires all live stages on the first flight vehicle. The scheme has evolved as being a reasonable risk for taking full advantage of early success. To illustrate the flight mission advantage the new concept provides a launch vehicle flight test program coupled with the reentry heat protection qualification capability on either or both of the first two flight tests where the original plan provided this capability only on the fourth vehicle at the earliest. Manned operations could be accomplished by the third flight if sufficient degree of success has been attained by that time. This more aggressive flight development approach is conceived to take advantage of success for the earliest manning of the space vehicle and offers the earliest potential schedule for the lunar operations. In case the initial flight objectives are not met, sufficient flexibility exists for alternate missions."

Mueller himself summed up his reasons for requiring "all-up" testing in the 1965 NASA authorization hearings before the House Committee on Science and Astronautics, on February 6, 1964. He said, "There are several advantages to the 'all-up' approach. It will permit us to land an American astronaut on the Moon, and return him safely to Earth, in accordance with our schedule even though we are operating this year on a reduced budget. It will permit us to capitalize on successful flights. It will also allow us to gather a very large amount of data early in the flight program and thereby provide much needed information to our design organizations. It is planned in the Saturn IB and Saturn V programs to launch a complete unmanned spacecraft on the first flight in an Earth orbital trajectory."*

---

* 1965 NASA Authorization, Hearings before the Committee on Science and Astronautics U. S. House of Representatives, Eighty-eighth Congress, Second Session on H. R. 9641 (Superseded by H. R. 10456), February 4, 5, 6, and 7, 1964 No. 1 Part 1, p. 154.

Additionally, it permitted the subsequent cancellation of six previously scheduled Saturn 1 flights, at an estimated saving of $50 million. Furthermore, it accelerated the Saturn IB program and permitted NASA to stay within its 1964 budget authorization of $5.3 billion.

The subsequent launches the first Saturn IB and Saturn 5 vehicles proved that Mueller had been correct. The risk was not so great as many people had feared, although the second Saturn 5 flight could have been a costly failure. Despite the anomalies that did occur, Saturn 502 vindicated not only Mueller but its designers and builders as well. In considering the "all-up" concept, a manager at MSFC who had reservations about it earlier summed things up: "Of course, history proved us wrong; and in retrospect, I have no doubt that the procedure was correct. Of course, I would add that we were lucky...sometimes you simply have to bet your money and you win or lose."