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Large Engines and Vehicles, 1958

During the mid-1950s, the Air Force sponsored work on the feasibility of building large, single-chamber engines, presumably for boost-glide aircraft or spaceflight. This work provided the basis for fast response when the nation felt the need to catch up with the Russians in launch vehicle capability.

In 1956, the Army's missile development group, under the technical direction of Wernher von Braun, began studies of large launch vehicles. The possibilities opened up by Sputnik accelerated this work and gave the Army an opportunity to bid for the leading role in launch vehicles. The Air Force, however, had the responsibility for the largest ballistic missiles and hence, a ready-made base for extending their capability for spaceflight. One example of this was Centaur, the hydrogen-oxygen upper stage for the Atlas ICBM.

During 1958, actions taken to establish a civilian space agency, and the launch vehicle needs seen by its planners, added a third contender to the space vehicle competition. In this chapter, we will examine these activities during 1958 and how they resulted in the initiation of a large rocket engine and the first large launch vehicle.

Early Air Force Interest in Large Engines and Vehicles

The development of the Atlas intercontinental ballistic missile had hardly begun to accelerate when the Air Force research and development arm began considering larger rocket engines for larger vehicles. In 1955, the Air Force contracted with the Rocketdyne division of North American Aviation to study the feasibility of a single-chamber engine with a thrust of 1.3 to 1.8 meganewtons (300000–400000 lb). Rocketdyne designated this engine the E-1 and the same year announced that a single-chamber engine of 4.5 meganewtons (1 million lb of thrust) was also feasible.[1] There were no specific requirements for these large engines, but presumably the Air Force was looking ahead to the need to carry larger ballistic payloads and perhaps to manned spaceflight or boost-glide hypersonic aircraft concepts such as Dynasoar.

At the November 1956 meeting of the fuels and propulsion panel of the USAF Scientific Advisory Board (p. 189), large rocket engines were considered. The panel recommended that the Air Force study the feasibility of very large rocket engines on the order of 22.3 meganewtons (5 million lb of thrust). This was far larger than any that had been considered; the minutes do not reveal the panel's reasons for such interest.

The Air Force waited over a year before replying to this recommendation. The reply mentioned the work begun at Rocketdyne in 1955 and indicated that future Air Force requirements for thrusts greater than 4.5 meganewtons could probably be met more efficiently by clustering "appropriately-sized" smaller engines. A vehicle requirement for 22.3 meganewtons could be met in the same manner. The Air Force reply left unclear what size engines it was interested in, but the same month Wright Field initiated a design competition for a single-chamber engine of 4.5 meganewtons. The proposals were evaluated and a contract awarded to Rocketdyne in June 1958. The large engine was designated the F-1.[2]

Transfer of Large Engine to NASA

When Abe Silverstein came to NACA headquarters in early 1958 to organize a space program, one of his immediate concerns was increased launch vehicle capability. Consequently, his proposed FY 1960 budget, completed on 19 July 1958, contained $30 million to initiate development of a 4.5 meganewton single-chamber engine and $15 million for clustering existing ICBM engines to achieve the same total thrust (p. 185).

By late July it became obvious that the large engine work sponsored by the Air Force would be transferred to the new space agency. To deal with this and other launch vehicle matters, Silverstein organized an informal propulsion committee in early August (p. 195). At the 14 August meeting of this committee, the Air Force disclosed that its contract with Rocketdyne on the 4.5 meganewton engine would run out of funds in the fall and that $2 million more, to be supplied by NASA, would be needed by 1 October to continue the work for an additional five months. Since contract negotiations took 5 to 8 weeks, a decision by NASA was urgently needed. Silverstein, however, resisted this pressure for NASA to make an immediate commitment.

The problem of developing a large engine was further complicated by the need for facilities to test it. This matter was considered at the 28 August meeting of Silverstein's committee. Air Force representatives revealed that contracts would be let by the end of the month for a test stand at Rocketdyne's test facility capable of handling 4.5 meganewton engines. The Air Force already had a test stand capable of handling this size engine at Edwards Air Force Base, but it was tied up with Atlas missile development. Silverstein and his propulsion assistant, A. O. Tischler, were concerned that the Air Force plans essentially committed the large engine development to Rocketdyne. Silverstein decided at the meeting that any development of a large engine by NASA would be through competitive bidding. Richard Cesaro of ARPA argued that bidding should start immediately, but again NASA officials resisted the pressure to act at that time.

When the Silverstein committee met for the sixth time on 9 October, NASA was formally in business and moving. Tischler, placed in charge of the large engine, announced that requests for competitive bids would be out within two weeks. Five days later, NASA sent invitations to bid to seven contractors and a briefing on what was wanted was held a week later.

The invitations called for a single-chamber engine of either 4.7 or 6.7 meganewtons (1 or 1.5 million lb thrust), but at the contractors' briefing Tischler made it clear that the higher thrust was wanted.* By 24 November, NASA had received proposals and appointed a technical and a management team to evaluate them. On 9 December the two evaluation teams reported to the Source Selection Board; and three days later, the Board recommended to Administrator T. Keith Glennan that Rocketdyne be awarded the development contract.† Glennan approved and the selection was made public the same day. In less than a month (9 January 1959), NASA signed a definitive contract with Rocketdyne for the development of the F-1 engine with a sea-level thrust of 6.7 meganewtons.[3]

The Army's Bid to Develop Large Launch Vehicles

Although the Air Force took the initiative in sponsoring studies of large rocket engines, the Army Ballistic Missile Agency took the lead in proposing specific large vehicles. These began with studies by Wernher von Braun's missile development team in 1956 and led eventually to the Saturn vehicles developed during the 1960s. By the time the first Saturn was authorized by the Advanced Research Projects Agency in 1958 and a decision made about which propellants to use in its upper stages late in 1959, large launch vehicle concepts had undergone a number of changes. Von Braun's team initially opposed the use of hydrogen and oxygen in the second stage of the Saturn. To understand why and to follow the evolution of Saturn in its early phases, a few observations about von Braun and his team are helpful.

In 1930, when 18, Wernher von Braun was working with Germany's rocket pioneer Hermann Oberth, and von Braun's entire subsequent career was devoted to rockets and spaceflight. As technical director at Peenemünde, he was responsible for developing the V-2, the beginning of modern liquid-propellant rocketry. He headed the 120 Germans brought to the United States by the government at the end of World War II. In 1950, the Germans became the core for an expanding organization assigned to the development of Army guided missiles at Redstone Arsenal, Alabama. By 1956, the guided missile development division at Redstone, with von Braun as technical director, numbered over 2000, of whom 350 were Army officers. Over 200 of these officers were graduate engineers who strengthened the civilian staff of engineers and technicians. By 1958 the division (then called development operations) had a complement of over 2800, about 80 percent of the ballistic missile agency.[4]

As head of large engineering organizations both in Germany and the United States for almost a quarter of a century, von Braun managed by committee or group decision. At Redstone, his division consisted of ten laboratories representing various technical aspects of missile development, each headed by a highly competent member of his old German team. He used these men as a council for decision making; at meetings, von Braun assumed the role of chairman or moderator. He knew how to listen, maneuver,

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*Tischler prepared the invitation with only the higher thrust value but included the lower value when Hugh Dryden, NASA's deputy administrator, pointed to prior agreements between NASA and the Air Force. At the bidder's briefing, Tischler made it clear the higher value was preferred and in later negotiations, Silverstein confirmed it. Interview with Tischler, 25 Jan. 1974.

†Silverstein chaired the Board with J. W. Crowley, Abe Hyatt, R. E. Cushman, and R. G. Nunn as members; the author was a member of the technical evaluation team.

and persuade; proposed actions were thoroughly thrashed out until mutual agreement was reached. Thereafter, all united behind the decision to make planned actions a success.

The loyalty and competence of the von Braun team were outstanding. The core of hand-picked German engineers had worked for von Braun in developing the V-2. They had suffered through the Allied air raids together, escaped the advancing Russians in the closing days of the war, and migrated to a new land and new life in 1945. At Fort Bliss, Texas, they were enemy aliens who, though well treated, could not go into El Paso without a military policeman as escort.[5] These experiences tied the group together—loyal to each other and to von Braun as their leader. As excellent engineers, they were determined to prove their worth.

A third observation is about von Braun's ability to sell himself and his ideas. A man with charisma, he knew how to deal with bureaucracy,* how to compromise, and how to maneuver to achieve his objectives. He used his talents to fire the imagination and stimulate interest in spaceflight unabashedly, to gain support for his team and his ideas. The publicity given von Braun seems not to have bothered his German colleagues, who worked as much in obscurity as he did in the limelight. The team understood and appreciated von Braun's ability in public relations and willingly assisted him in building up his reputation and image, because the group shared in the rewards of increased support.

Von Braun was as conservative an engineer in actual design and construction as he was a bold innovator in concepts. The design of the V-2, Redstone, Jupiter, and Saturn all reflect the conservatism of von Braun and his team. They looked askance at such lightweight structural innovations as Bossart's thin-wall, pressurized tanks for the Atlas ICBM, which they jokingly referred to as "blimp" or "inflated competition." They preferred husky, sturdy structures which Krafft Ehricke characterized as "Brooklyn bridge" construction. Their structural designs were sound, if somewhat on the heavy side. This conservative design philosophy mitigated against the use of liquid hydrogen which, more than conventional fuels, depended upon very light structures to help offset the handicap of low density.[6]

The final observation about von Braun and his team stems from their alliances. By fate and by choice, these engineers were aligned with the military in Germany and in the United States; those alliances were both an advantage and a handicap. The advantage lay in pressing military requirements in both countries, which assured the team virtually a blank check in developing rocket missiles. Emphasis was on achieving success rapidly and seldom, if ever, on minimum cost. But the same reasons that gave the team liberal support also restrained them from deviating from the immediate task at hand. This meant little tolerance for indulging in schemes for spaceflight, von Braun's greatest interest. He was arrested and jailed in 1944 for alleged sabotage of the

*At a dinner honoring von Braun at his departure from NASA in 1972, Eberhard Rees, his longtime deputy and associate, spun a yarn about German bureaucracy. Peenemünde purchase requests had to be approved by Army headquarters, and a request for a gold-plated instrument mirror was rejected as insufficiently justified. Rees, attempting to write a technical justification, was stopped by von Braun. Just tell them we want it because a solid gold one would be too expensive, he advised. Rees did and the request was promptly approved. Interview with D. D. Wyatt, Bethesda, MD, 31 Aug. 1975.

A-4 missile he was developing because he was overheard speculating on spaceflight.* At the U.S. Army's Redstone Arsenal, von Braun was under similar restraints, although he soon found a kindred spirit in Maj. Gen. J. B. Medaris, commander of the Army Ballistic Missile Agency.

Von Braun wanted to adapt existing missile equipment to launch a satellite as early as 1954. He lost out to Vanguard in a 1955 bid to launch satellites for the International Geophysical Year, but by 1956 he had assembled equipment capable of launching a satellite. Sputnik I gave him the long-awaited opportunity and he succeeded with Explorer I on 1 February 1958.

Explorer I was the opening gun in the Army's campaign for a strong role in space. Following the initial Russian and American satellites, it became clear that Russian launch capability far exceeded that of the U.S. and the von Braun team was quick to respond to the U.S. outcry for larger launch vehicles. Among those envisioned was one of multiple stages; the first stage, a cluster of 4 engines, would develop a total of 6.7 meganewtons (1.5 million lb of thrust). The report on this study was submitted to the Department of Defense on 10 December 1957: "A National Integrated Missile and Space Development Program." It was the first of several bids for a space role by von Braun and Medaris.

The December 1957 report was updated in March 1958; it described 11 launch vehicles starting with the Navy's Vanguard and Army's Juno I, and continuing to the very large vehicle of 6.7 meganewtons (table 6). Two of the proposed vehicles used high-energy upper stages with hydrogen-oxygen as one of the candidate propellant combinations.[7] One of these was the stage that Krafft Ehricke had proposed in December 1957 (p. 194).

The March 1958 report also recommended the development of 14 propulsion systems including two large engines (table 8, p. 216). One was a cluster of 4 Rocketdyne E-1 engines of 1.8 meganewtons (400000 lb of thrust) each, using kerosene-oxygen; the other, Rocketdyne's F-1 engine of 4.5 to 6.7 meganewtons (1–1.5 million lb of thrust), also using kerosene and oxygen.†

The Army Ballistic Missile Agency proposed that hydrazine be considered as an alternative to kerosene for first-stage engines. Also recommended was an array of upper stages and engines: large-thrust engines using space-storable (non-cryogenic) propellants, hydrazine-fluorine, and nuclear fission; and small-thrust engines using electric or solar power. These advanced engine concepts indicated that the von Braun team was not at all conservative when it came to planning and proposing.

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* Walter Dornberger, former commanding officer of Peenemünde, described the incident in his book, *V-2* (New York: Viking, 1958), pp. 200–207, quoting Field Marshall Keitel: "The sabotage is seen in the fact that these men have been giving all their innermost thoughts to space travel and consequently have not applied their whole energy and ability to production of the A-4 as a weapon of war."

† According to H. C. Wieseneck, Rockwell International, Rocketdyne conducted a series of rocket engine studies during 1957 and 1958 in support of the Juno vehicle studies at ABMA. Among options considered was the use of 8 existing ICBM engines that led to Rocketdyne's H-1 engine, which was used in Saturn I. Wieseneck to M. D. Wright, NASA, 6 Feb. 1976.

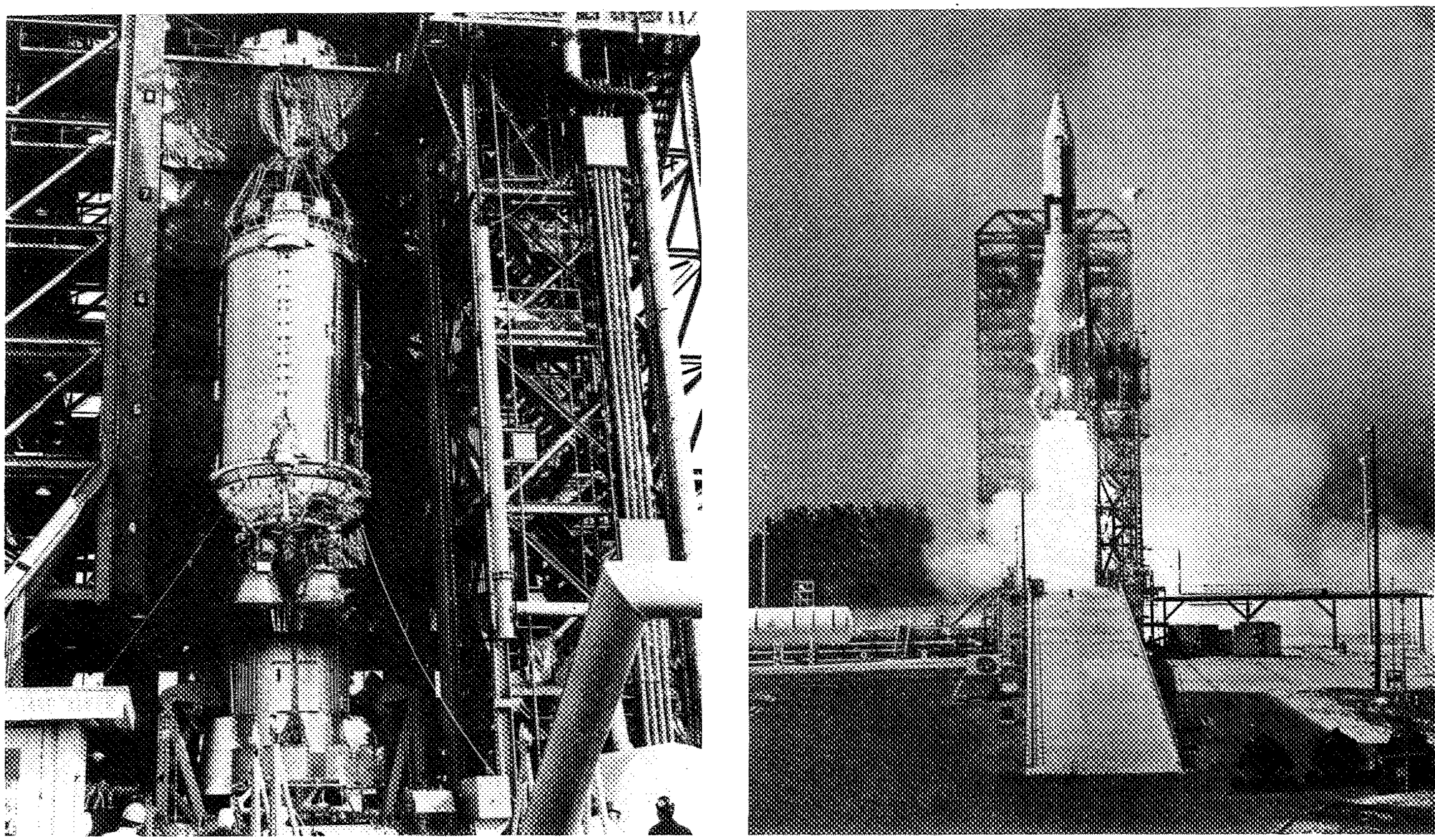

Fig. 53. The Centaur stage (left), 3 m in diameter, was the first to use liquid hydrogen. The Atlas-Centaur (right), 37 m tall, was first flight-tested in 1962 and within a decade 25 flights had been made, 19 of which were successful. The vehicle is still in use, but may be replaced at the end of the 1970s or early 1980s by the shuttle. (1965 and 1967 photographs.)

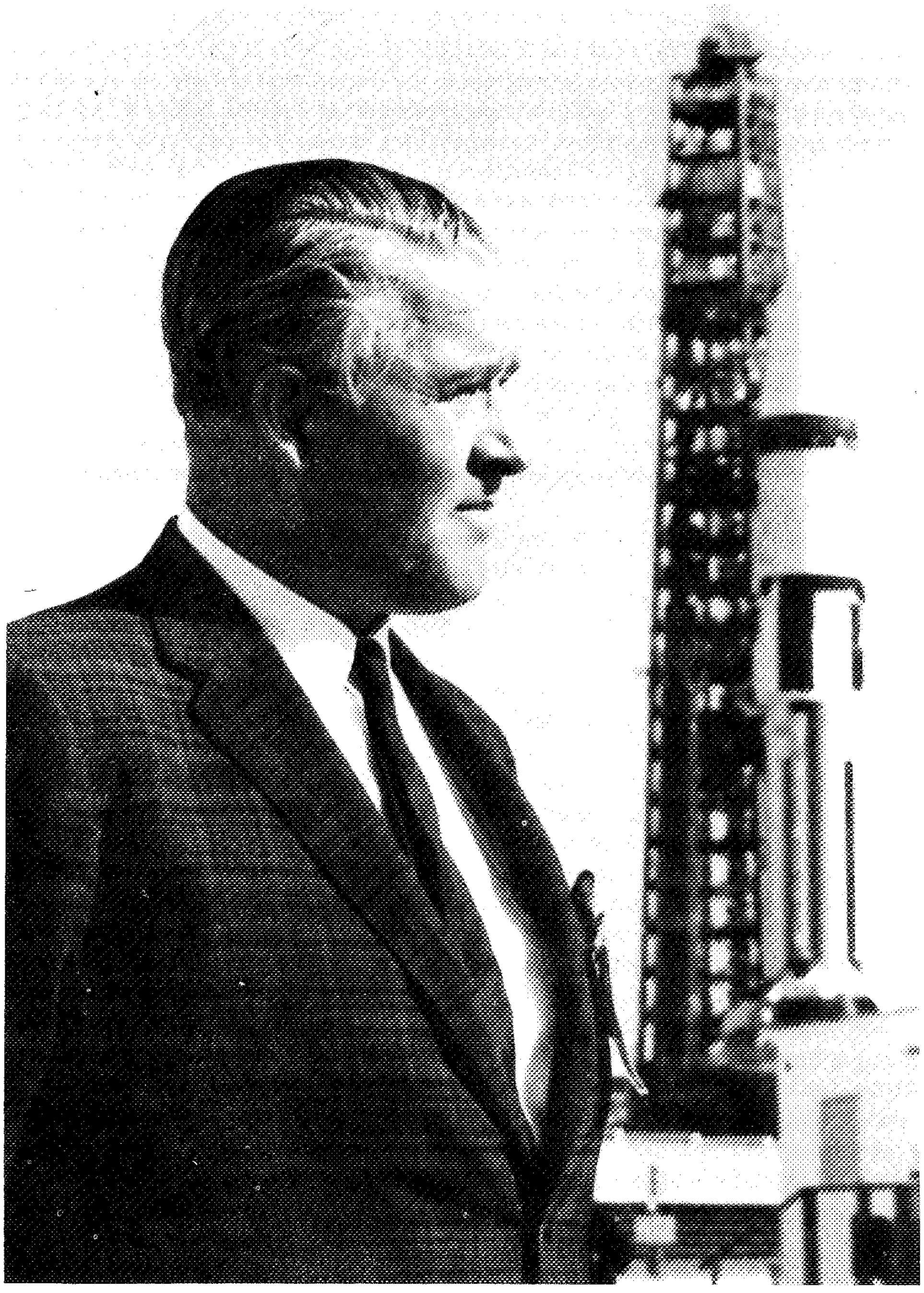

Fig. 54. Wernher von Braun, father of modern rocketry and developer of Saturn launch vehicles. Shown with a Saturn IB, 43 meters tall, used to launch the first flight test of the Apollo lunar module on 22 Jan. 1968.

NACA Working Group on Launch Vehicles

In the first part of 1958, when von Braun and his team were proposing an integrated national missile and space vehicle program to the Department of Defense, von Braun was also participating in a study of space technology for the National Advisory Committee for Aeronautics (NACA) and making similar proposals to it. He was a member of the NACA special committee on space technology chaired by Dr. H. Guyford Stever (p. 181). Von Braun was also chairman of a working group on launch vehicles for the Stever committee. Abe Silverstein and Col. Norman C. Appold were members of the Stever committee and of von Braun's working group.*

During the course of its study, the Stever committee met periodically and heard progress reports from the chairmen of its several working groups, including von Braun. One such meeting was called for Monday, 17 March 1958, at NACA's Ames aeronautical laboratory in California. "I have put a substantial amount of work into the preparation of such a [vehicle] program," von Braun cabled S. K. Hoffman, Abraham Hyatt, Silverstein, and Appold, "but do not wish to present it to the committee without your prior approval." He suggested a meeting at a motel near Ames for Sunday the 16th.[8]

Assisting von Braun on his NACA assignment, but remaining behind the scenes, was Francis L. Williams. He had left Wright Field to join von Braun at the Army Ballistic Missile Agency in February 1958 and was familiar with the December and March proposals that the agency had made to the Department of Defense for an integrated vehicle program. Young and handsome, ambitious and smart, Frank Williams was not content to remain faceless behind the scenes like von Braun's German colleagues. He wanted part of the action, specifically to accompany von Braun to the NASA meetings. Aware of von Braun's work habits, he devised a strategy for the 17 March meeting that worked. He prepared a vehicle program, wrote himself travel orders, stowed his bag nearby, and made an appointment with von Braun before time to depart for California. As expected, time ran out before von Braun had reviewed the program. Williams, of course, was ready to accompany him on the flight to continue the discussion. In California, Williams persuaded von Braun to let him present the program so that von Braun would be free to comment on it like the other members. Von Braun agreed.[9]

The bold plans of the Ballistic Missile Agency delegation evoked plenty of comments at NACA meetings, but this did not deter the proposers. On 1 April 1958, von Braun's group issued a document that astounded the quiet, conservative people in NACA headquarters. Soon all hell broke loose. On the report cover was printed "Interim Report to the National Advisory Committee for Aeronautics, Special Committee on Space Technology: A National Integrated Missile and Space Vehicle Development Program: by the Working Group on Vehicular Program." Inside was the same proposal the Ballistic Missile Agency had made to the Department of Defense. A 23-year spaceflight program was laid out with rows of launch vehicles ranging from small

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*Other members of the vehicle working group: Abraham Hyatt, Navy Bureau of Aeronautics; Louis Ridenour, Lockheed Aircraft; M. W. Hunter, Douglas Aircraft; C. C. Ross, Aerojet-General; Homer J. Stewart, JPL; George S. Trimble, Jr., Martin; Krafft Ehricke, Convair-Astronautics; S. K. Hoffman, Rocketdyne; and W. H. Woodward, NACA, secretary.

to huge. The flight missions included satellites ranging from small unmanned scientific ones to a 50-man permanent satellite with a mass of about 450 metric tons. There were also flights to the moon, interplanetary probes, and expeditions to Mars and Venus. Total cost was estimated at $30 billion.[10]

The bold and imaginative plan was too much for the NACA to swallow, and NACA's director, Hugh Dryden, moved to dissociate his organization from it. The headquarters copy bore a red tag with the notice: "IMPORTANT—that this Interim Report . . . not be allowed outside the NACA headquarters building under any circumstances—unless by specific approval of Dr. Dryden." A staffer attached a comment to the report that the Ballistic Missile Agency was "apparently advertising it rather broadly to get implication of NACA approval for von Braun's pitch."[11]

At Huntsville, Williams received calls for copies of the report and asked NACA headquarters for permission to distribute it. Dryden replied that he had no objection, provided that "A statement should be attached to each copy indicating that the report has not been approved by the NACA Working Group on a Vehicular Program and, therefore, cannot be considered to be an official recommendation of the Working Group or of the NACA Space Technology Committee."[12]

The report contained a number of sound, timely recommendations; among them was "that a development program be initiated immediately for a large engine, in excess of one million pounds thrust [4.5 MN], and the required test facilities with emphasis on early availability of the engine for flight test and operational use." The report was prophetic when it recommended a spaceflight program "with particular emphasis on a manned lunar landing within the next 10 years." Another recommendation was "that long-range vehicle responsibility be assigned to individual development teams without delay under the direction and coordination of a central group." There was little doubt that von Braun had his own team in mind. He was recommending the same vehicle program to the military and civilian sides of the government and courting both to get the vehicle responsibility.

On 18 July 1958, a revised and toned-down version of the earlier interim report was issued by the NACA working group on vehicles. Gone was the recommendation to initiate development of a large engine and in its place was "A development program be initiated immediately for a booster in the 1.5 million pound thrust [6.7 MN] class, with emphasis on early availability."[13] In the months that followed, development of both the large engine and the large booster was initiated—steps which the Stever committee merely endorsed in its final report, without including details that had been submitted by the von Braun working group.[14]

In the time between the April interim and 18 July 1958 final report of the vehicle working group, von Braun had correctly sensed the direction political winds were blowing. The recommendation on vehicle responsibility now read "under the direction and coordination of the NATIONAL AERONAUTICS AND SPACE AGENCY in conjunction with the ADVANCED RESEARCH PROJECTS AGENCY."[15] He was still taking no chances.

The report of the NACA working group recommended 15 vehicles in five generations of development; with some additions and revisions, these were along lines similar to previous recommendations of ABMA as can be seen by comparing tables 6 and 7. The first three generations that NACA recommended comprised 11 vehicles and

TABLE 6.—*ABMA's Proposed National Integrated Missile and Space Development Program, March 1958*

No.	Vehicle	Operational Date	Payload kg
I	Vanguard	1958	2–10
Ia	Juno I	1958	8–16
II	Juno II	58–59	27–45
IIa	Thor + 117L stage	58–59	90–140
III	Juno III	59–62	140–320
IV	Atlas + 117L	61–63	700–900
V	Atlas + H_2-O_2 pressurized stage	61–64	1100–4000
VI	Juno IV	62–64	230–450
VII	Titan	60–80	450–1400
VIII	Titan + Polaris	62–80	1400–2300
IX	Mod Titan (1st stage recoverable; 2d & 3d stages N_2H_4-F_2 or H_2-O_2)	65–80	2300–4500
X	Mod Jupiter (1st: 4 × 1.7 MN, RP-O_2 recov.; 2d: 1 × 1.7 MN, RP-O_2 or H.E. prop.; 3d: 356–445 kN, N_2H_4-F_2)	63–70	11000–16000
XI	Large orbital carrier of 2 recoverable stages (1st: 2×6 MN* N_2H_4-O_2, delta wing; 2d: nuclear with NH_3 or H_2)	69–80	23000

Source: "A National Integrated Missile and Space Vehicle Development Program," 2d ed., report D-R-16, Dev. Oper. Div., ABMA, Redstone Arsenal, AL, 14 Mar. 1958.

*Correction by author of obvious misprint.

were based on current missile developments with high-energy stages added. In the fourth generation, an alternate vehicle was added that used 9 ICBM engines in its first stage, a configuration—favored by the Advanced Research Projects Agency—which was a forerunner of Saturn I. In the fifth generation, vehicles requiring thrusts as high as 27 meganewtons (6 million lb) were recommended for a recoverable first stage. The hand of Silverstein and the 1956 recommendations of the Air Force's Scientific Advisory Board appear to have been at work for this large thrust vehicle, a forerunner of the 5-engine first stage of the expendable Saturn V developed during the 1960s.

The NACA working group also recommended 17 propulsion systems which were essentially a revised and expanded version of the ABMA recommendations, as can be seen by comparing tables 8 and 9. Among the NACA additions was an engine with a thrust of 2.2 meganewtons (500000 lb) using hydrazine-fluorine or a "similar high-energy propellant." This would be a follow-on to a 53-kilonewton (12000-lb-thrust) engine using hydrazine-fluorine, being developed for the Air Force by Bell Aircraft, and the recommended 356–445-kilonewton (80000–100000-lb-thrust) engine using the same propellants. Both ABMA and the NACA working group appeared initially to favor hydrazine-fluorine over hydrogen-oxygen, but this was to be reversed within 18 months.

The day following the issuance of this report, Silverstein, in his spaceflight role at NACA headquarters, completed his FY 1960 budget request, which included funds for a large engine, the clustering of ICBM engines, and high-energy propulsion systems (p. 185). Ten days later, on 29 July 1958, President Eisenhower signed the bill

TABLE 7.—*NACA Working Group's Recommended Space Vehicles, July 1958*

Group	Type	Vehicle	Operational Date	Payload kg
I	IA	Vanguard	1958	2–10
	IB	Juno I	1958	8–16
II	IIA	Juno II	58–59	45–90
	IIB	Thor + 117L stage	58–59	90–180
	IIC	Juno IV	59–80	230–1130
III	IIIA	Atlas + 117L and/or	59–63	900–1400
	IIIB	Titan	60–62	450–1400
	IIIC	Mod. Atlas + 89 kN H_2-O_2 and/or		1400–4100
	IIID	Mod. Titan + 53 kN N_2H_4-F_2	62–64	1400–2700
	IIIE	Uprated Atlas —3 × 668 kN eng. + high-energy upper stage and/or		
	IIIF	Uprated Titan + high-energy upper stage 1st stage recoverable	63–80	2300–4500
IV	IVA	Basic large carrier—(1st: 6.7 MN, recov.; 2d: 2.2 MN; 3d: 356 kN high energy) and/or	63–70	11000–16000
	IVB	1st: 9 × 668 kN Atlas eng.; 2d: 3 × 668 kN; 3d: 178 kN high energy	63–70	11000–
V	VA	Recov. booster (1st: 2 to 4 × 6.7 MN; 2d: 1 × 6.7 MN)	68–80	23000–68000
	VB	Recov. booster (1st: 2 to 4 × 6.7 MN; 2d: nuclear)	68–80	45000–113000

Source: Working Group on Vehicular Program, "Report to the National Advisory Committee for Aeronautics Special Committee on Space Technology," 18 July 1958.

creating the National Aeronautics and Space Administration; and on the next day, he asked Congress for $125 million for NASA operations. Silverstein's spaceflight budget reflected confidence that NASA would develop large engines and launch vehicles for manned flight and high-energy upper stages for unmanned vehicles.

ARPA Initiates First Large Launch Vehicle

The Advanced Research Projects Agency (ARPA), established since February 1958 and having a budget, could have acted immediately on the large launch vehicles proposed by the Ballistic Missile Agency in the December 1957 and March 1958 proposals to the Department of Defense, but did not. Instead, on 17 April 1958, ARPA requested that the Army Ordnance Missile Command study an advanced satellite carrier vehicle patterned after Juno III.* The new vehicle, designated Juno IV, was

*Juno I was a modified Redstone with three upper stages of solid propellant rockets. Juno II was a modified Jupiter IRBM with the same upper stages as Juno I. In Juno III, the solid propellant rockets in the upper stages were slightly larger. Juno I launched the first U.S. satellite (Explorer I) and two others (Explorers III and IV). Juno II launched two space probes (Pioneers III and IV) and two satellites (Explorers VII and VIII). Juno III was not built.

TABLE 8.—*ABMA's Recommended Engine Developments, 1958*

No.	Thrust N(lb)	Propellants	R&D
1	1.8 MN (400000 lb) sea level	RP-O_2	1956–61
2	Cluster, 4 × 1.8 MN, SL	RP-O_2	1958–63
3	356–445 kN (80000–100000 lb) in vacuum of space	N_2H_4-F_2	1957–61
4	2.2 MN (500000 lb), vac.	N_2H_4-F_2 or similar	
5	45-90 kN (10000–20000 lb), vac.	space storable (non-cryogenic)	1957–61
6	134 kN (30000 lb), vac., pressurized tanks	H_2-O_2	1958–60
7	4.5–6.7 MN (1–1.5 million lb), SL	RP or N_2H_4-O_2	1960–66
8	445 kN, vac.	space storable	1960–65
9	2.2 MN, vac.	space storable	1960–65
10	1.3 MN (300000 lb), vac.	nuclear fission	1957–65
11	4 N (1 lb), vac.	ion*	1957–66
12	45 N (10 lb), vac.	solar power	1957–64
13	0.9–2.2 MN (200000–500000 lb), vac.	arc-thermodynamic*	1958–?
14	0.9–2.2 MN, vac.	magnetohydro-dynamic*	1958–?

Source: "A National Integrated Missile and Space Vehicle Development Program," 2d ed., report D-R-16, Dev. Oper. Div., ABMA, Redstone Arsenal, AL, 14 Mar. 1958.

*Requires electric power source.

based on a modified Jupiter IRBM as the first stage with the addition of upper stages.[16] ARPA earmarked $46 million for the project.

In the months following the Juno IV order, interest at ARPA shifted to alternative vehicles. During this period David Young, Richard Canright, and Richard Cesaro began discussing larger launch vehicles based on using a cluster of existing engines for the first stage. Canright, on loan from Douglas Aircraft, had examined the desirability of using multiple rocket engines in launch vehicles for redundancy and reliability, following much the same philosophy used for large aircraft. He was, therefore, an instant and strong advocate for a large launch vehicle using a cluster of engines. He differed from the Ballistic Missile Agency, however, in that he wanted to use existing engines—the tried and proven rocket engines powering the Atlas ICBM and Thor IRBM. Each of these produced a thrust of 670 kilonewtons (150000 lb), but both were capable of a 25 percent increase in thrust. This meant that a cluster of 8 or 9 could produce a total thrust of 6.7 meganewtons (1.5 million lb). Cesaro, a former NACA propulsion researcher at the Lewis laboratory, also favored large launch vehicles using multiple engines.[17]

In addition to large vehicles, Canright also began to consider smaller launch vehicles that could use existing missiles as first stages. In these studies, it is not surprising that he favored the Douglas-built Thor over the Chrysler-built Jupiter. He argued that Thor not only had the capability of the Jupiter, but cost much less. Word of his considerations of Thor reached ABMA, home of Jupiter, where naturally there was some unhappiness over the turn of events. ABMA was also well aware of Air Force interest in large vehicles, evidenced by a June 1958 contract with Rocketdyne for a

TABLE 9.—*NACA Working Group's Recommended Engine Developments, 1958*

No.	Thrust N(lb)	Propellants	R&D
1	1.7 MN (380000 lb), sea level	RP-O_2	1956–61
2	Cluster, 4 × 1.7 MN, SL	RP-O_2	1956–64
3	6.67 MN (1.5 million lb), SL	RP or N_2H_4-O_2	1960–64
4	Cluster, 2 or 4 × 6.67 MN, SL	RP or N_2H_4-O_2	1960–65
5	27 kN (6000 lb) in vacuum of space; vernier	space storable (non-cryogenic)	1958–59
6	200 kN (45000 lb), vac., pressurized tanks	N_2H_4-N_2O_4	1958–61
7	445 kN (100000 lb), vac.	space storable	1960–63
8	2.2 MN (500000 lb), vac.	space storable	1960–66
9	53 kN (12000 lb), vac.	N_2H_4-F_2	1958–63†
10	89 kN (20000 lb), vac.	H_2-O_2	1959–60
11	356–445 kN (80000–100000 lb), vac.	N_2H_4-F_2	1958–63
12	2.2 MN, vac.	N_2H_4-F_2 or similar	1960–65
13	2.2–4.5 MN (0.5–1 million lb)	nuclear with hydrogen	1957–66
14	4–4450 N (1–1000 lb), vac.	ion*	1957–?
15	4–4450 N, vac.	arc-thermo-dynamic*	1958–?
16	4–4450 N, vac.	magnetohydro-dynamic*	1958–?
17	4–4450 N, vac.	thermonuclear	1958–?

Source: Working Group on Vehicular Program, "Report to the NACA Special Committee on Space Technology," 18 July 1958.

*Requires electric power source.
†Under development at Bell Aircraft for the Air Force.

study of large engines. There was plenty of competition building up over who would be responsible for developing launch vehicles.

One day in mid-1958, Roy Johnson, ARPA's director, sent Canright to represent him at a meeting in the office of Wilbur Brucker, Secretary of the Army. Involved were Brucker, Maj. Gen. J. B. Medaris of ABMA, ARPA chief scientist Herbert York, David Young, and others. Brucker, a blunt, outspoken Michigan attorney and vigorous proponent for the Army, lost no time in coming to the point: ARPA had sold out completely to the Air Force, ignoring the Army's superb missile team at Huntsville, as well as the equally superb missile, Jupiter. Canright attempted to state the reasons for selecting Thor over Jupiter, but Brucker interrupted and in colorful language made it amply clear that the Army's capability should not be ignored. After the meeting, Medaris told York and Canright that von Braun's operations required about $90 million a year and if ARPA would pay half that amount, the Army would be satisfied. Canright was incensed over the Army's pressure tactics, but York apparently saw little else that could be done. Years later Canright believed that this meeting was a major factor in the assignment of ABMA to develop a large launch vehicle.[18]

The meeting with Brucker did not resolve the issue of the configuration for the large launch vehicle. Canright went to Huntsville and told von Braun and his associates what ARPA wanted: 7 or 8 Rocketdyne H-1 engines in a cluster for the first-stage propulsion system. At the time, von Braun still favored the Juno V configuration using a cluster of 4 larger engines, the E-1, still on the drawing board. Canright recalls Medaris taking him into his office along with von Braun and saying, in effect, that trying to make 8 engines of such complexity work together was totally impractical. Canright, however, remained firm; he cited the favorable reaction of the National Security Council's panel and indicated that if ABMA was not willing to cluster the engines, a contractor could be found who would. The meeting left von Braun still unsatisfied with the 8-engine cluster, and he continued to argue for the use of fewer and larger engines.[19]

The planning of Silverstein at NACA and the Air Force's June 1958 contract with Rocketdyne for feasibility studies of a 4.5-meganewton engine increased the pressure for ARPA and ABMA to resolve the stalemate over using the cluster of existing ICBM engines for a large vehicle. According to Richard Cesaro, a crucial meeting occurred at the Pentagon in mid-1958. Medaris and von Braun represented ABMA, and Roy Johnson, David Young, and Cesaro represented ARPA. With control of the purse strings, the ARPA men laid their views on the line in forceful language and had their way. They also made it clear that ARPA was not going to serve merely as a money conduit, but intended to manage the work, a far cry from the blank check approach that ABMA had enjoyed in the past.[20]

Competition from another direction faced ARPA: civilian space planning led by NACA's Silverstein. When Silverstein organized his propulsion and vehicle coordinating committee (p. 195) with its first meeting on 7 August 1958, the ARPA men sprang into action. The day of the committee meeting, Young and Canright went to Huntsville to discuss the possibility of von Braun's starting immediately on the cluster engine. They proposed using some Juno IV funds for this as an expediency. Eight days after Young and Canright returned to Washington, Johnson signed ARPA order 14-59. It directed the Army Ordnance Missile Command and ABMA to provide a development and funding plan for a large launch vehicle and to demonstrate its feasibility in a full-scale, captive test by the end of 1959. Initial funding was $5 million; the same day, Johnson signed ARPA orders 15 and 16 for Juno IV development under reduced funding.[21]

ARPA order 14-59, 15 August 1958, was the start of the first U.S. large launch vehicle, which would later be named Saturn. With ABMA assigned to build a large launch vehicle, Medaris and von Braun began to escalate the funding needed. By the end of August, ARPA agreed to triple the funding, although this was not formalized until December. The name of the new vehicle was changed from Juno IV to Juno V, because the former had been widely identified with the cluster of four E-1 engines.

In September, a member of von Braun's staff made a tactical error. The team was accustomed to thinking big, and in a briefing to visiting NASA administrator T. Keith Glennan, a cost analysis was shown which used the firing of a hundred Juno Vs as a mission model. It was only an arbitrary assumption for a cost analysis, but on learning about it, Johnson of ARPA grew very concerned that the ambitious von Braun was getting out of hand and that the whole program might be cancelled as too costly before it was well started. The President's National Aeronautics and Space Council was meeting on 24 September, and Johnson summoned Medaris to Washington the day before in order to reach an understanding about the project. After a two-hour meeting, the two agreed upon $13.4 million for FY 1959 and $20.3 million for FY 1960 for research and development. An additional $1.6 million to modify a Huntsville test stand and $7 million for Atlantic Missile Range facilities brought the FY 1959 funding to $22 million—quadrupling the initial $5 million in five weeks. This was still prior to ABMA's submission of a development and funding plan.

In October 1958, the September agreement hit a snag. On 10 October, ABMA submitted a formal request for the $1.6 million to alter its test stand. It moved through government channels smoothly until it reached the Bureau of the Budget. On 1 October, NASA was formally in operation and on 14 October, Glennan requested the Department of Defense to transfer the Jet Propulsion Laboratory and the space activities of ABMA to NASA. The Bureau of the Budget was a party to this request, so when it received the ABMA request for $1.6 million for the test stand, it withheld approval until the Juno V project was clarified as to its scope and the responsible agency.

The enterprising staff at ARPA took the Bureau of Budget disapproval as only a momentary setback. An analysis was prepared showing that Juno IV was really not needed and its funds could be diverted to support Juno V. Johnson cancelled Juno IV and ordered a maximum recovery of those funds from ABMA. The ARPA staff was confident that the recovered funds, some $8 million, could be switched to support the clustered engine project, Juno V. Young and Canright hurried to Huntsville to see if the amount was sufficient to cover the proposed work, which included upper-stage design studies, additional component testing, and purchase of long-lead-time equipment. Von Braun's engineers convinced them that more money was needed and submitted two plans: one at $17 million and the other at $11 million. ARPA considered these and decided to allocate the $8 million for design studies, component testing, and testing another "battleship" (non-flightweight) first stage. An additional $3.4 million was allocated for purchasing equipment with long delivery times. It was now the end of October and the promised funding for Juno V in FY 1959 had climbed to $33 million. In planning for the next fiscal year, ARPA requested $40 million for Juno V work at ABMA and $14 million for guidance equipment.

Both ABMA and ARPA must have been pleased with the upward trend of funding, but on 13 November they got a shock. During that week, the Bureau of Budget had found that both ARPA and NASA had requested funding for a large launch vehicle in FY 1960. Clearly the problem of who does what needed resolution. On the 13th, James Killian, the President's science advisor, met with DoD, ARPA, and NASA officials to discuss, among other things, deleting Juno V funds from the ARPA budget. The question of transferring the large launch vehicle from ARPA to NASA was raised, but Glennan was noncommittal, so the issue remained unresolved. On 19 November, Secretary of Defense McElroy and his deputy, Donald Quarles, agreed to include $50 million in the DoD budget for the clustered engine stage, subject to further discussions with Killian and the Bureau of the Budget. This remained intact through the budget review and was in the FY 1960 budget submitted to Congress in January 1959.

The ARPA men were elated over the McElroy-Quarles action and two days later amended order 14-59 to increase the funding to $13 million, as promised in September. The same day Johnson urged Quarles to help in securing Bureau of Budget approval for the $1.6 million for the Huntsville test stand. Also the same day, ABMA submitted a proposal to ARPA for increasing FY 1959 funding for the clustered engine project to $32.9 million, in accordance with the development plan, which included one vehicle for static firing and four more for test flights. The funding for FY 1960 was estimated at $60 million—$10 million more than McElroy and Quarles had agreed to include only two days earlier.

Quarles tabled the $1.6 million request for the Huntsville test stand until the FY 1960 budget was clarified. This occurred on 3 December and Quarles told Johnson that the DoD budget would contain $50 million for the clustered engine stage. Soon after, the Bureau of the Budget released the held-up funding for the test stand. Both ARPA and ABMA had reason to rejoice on another matter resolved on 3 December. An agreement of that date left ABMA with the Army but "immediately, directly, and continuously responsive to NASA requirements."[22]

Summary

During the mid-1950s, the Air Force contracted with the Rocketdyne Division of North American Aviation to study rocket engines larger than those in intercontinental ballistic missiles. This began with the E-1, about three times larger than an ICBM engine, but Rocketdyne believed that an engine with a thrust of 4.5 meganewtons (1 million lb)—over six times larger than an ICBM engine—was feasible. In late 1956, the Air Force's Scientific Advisory Board was even bolder and recommended studies of engines up to 22 meganewtons (5 million lb of thrust). The Air Force, however, believed that such a large thrust was best attained by clustering smaller engines. In mid-1958, the Air Force contracted with Rocketdyne for design studies of the F-1 engine, with a thrust of 4.5 meganewtons. Shortly thereafter, responsibility for developing a large engine was transferred to NASA; in October, NASA opened the competition to other contractors and indicated a preference for 6.7 meganewtons (1.5 million lb of thrust). Rocketdyne won the competition and a development contract was signed early in 1959.

It was the Army, however, which took the initiative in proposing large launch vehicles using E-1 and F-1 engines, beginning with studies in the mid-1950s. In late 1957, the Army missile development team, under the technical direction of Wernher von Braun, submitted a national integrated missile and space development program to the Department of Defense. Included was a vehicle with a thrust of 6.7 meganewtons. In early 1958, the National Advisory Committee for Aeronautics formed a vehicle working group as part of a space technology committee. The working group was headed by von Braun and included Abe Silverstein, soon to become the chief planner at the new civilian space agency. The NACA group modified and extended the Army's recommended vehicles and propulsion systems. The favored high-energy propellant combination in both the Army and NACA plans appeared to be hydrazine-fluorine, a choice influenced by an Air Force development contract with Bell Aircraft for a small engine using this combination. In August 1958, the Advanced Research Projects Agency, responsible for planning and coordinating military space missions, ordered the Army to devise a development and funding plan for a large launch vehicle with a first stage using a cluster of existing ICBM engines; this was later to become Saturn I. NASA's request for the transfer of both the large vehicle and the Army's development team met with strong opposition; an agreement in December 1958 left the Army team intact but responsive to NASA needs.