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Learning from the past:

Birth, Life and Death of the Saturn Launch Vehicles

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Abstract
The SATURN launch vehicle family is the classical story of the evolution and life cycle of a space transportation system. Its official history is well documented by historians or journalists. The author, in his function of Chief, Preliminary Design Branch, U.S.Army Ballistic Missile Agency, and after joining NASA, as Director, Future Projects Office, has had a key position during the years of developing this transportation system in the Huntsville team headed by Dr.Wernher von Braun. However, this was several decades ago and in retrospect, it may be useful now to reflect on this historical development with respect to the lessons learned. The evolution of the development from the JUNO 5 booster, to the SATURN I, IB and finally SATURN V is discussed in some detail from the viewpoint of the author. Excerpts of the autors weekly notes to Dr.v.Braun shed some light on the gyrations and problems the development team had to overcome. The life cycle of the SATURN's began in 1958, production stop was ordered in 1968, and it ended with the last launch of a SATURN IB in 1975.
This report comprises 2 tables, 12 figures, 26 references on 38 pages.

Key words: SATURN, launch vehicles, space transportation systems lifecycle

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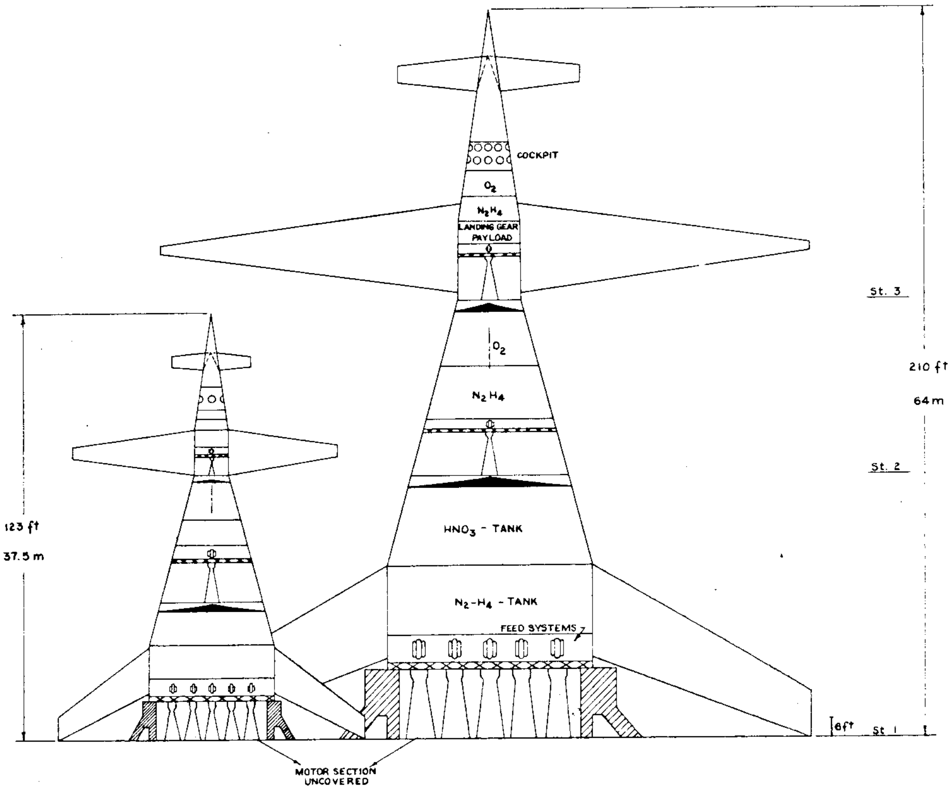
1.Introduction

The history of the development, operation and elimination of the SATURN launch vehicles is a classical story that will probably not be repeated again. It is a case story well to be remembered, proving again that there is no substitute for experience. Thus it appears worthwhile to look back and see how this dramatic development unfolded.

To present the historical picture, one has to go back several decades. After the end of WW II the Russians continued the development of long-term rockets without interruption and improved the German A-4 rocket. Dr.Wernher von Braun, and more than one hundred of his associates were invited to the United States[26]. Their first job was to assemble and flight test captured A-4 missiles at Fort Bliss and in Florida. That kept them busy for a few years and then they were waiting for a new assignment.

In this waiting period, i.e. the years of 1949/51 W.v.Braun, supported by some of his colleagues, took up an old dream and conceived a manned expedition to Mars. In this process he designed a satellite ship that was capable to put the elements of his Mars ships into an Earth departure orbit[1]. He published this concept in the magazine COLLIERS and made a big splash in the public, which was fairly exited about this adventure. Thus, Wernher von Braun and his team became the first rocket designers to study large reusable launch vehicles in 1949/51 period in connection with his MARS Project[1].

Figure 1: Concepts of W.v.Braun and K.A.Ehricke on orbital carriers and satellite ships.



He demonstrated that a partly reusable launch vehicle, employing technology that could be expected t0 be within reach, was in the position to transport 25 to 40 metric tons (t) of payload into a low Earth orbit with a launch mass of 6,400 t, having a growth factor of 160 to 250 tons launch mass per ton payload.

K.A.Ehricke, extending this analysis, studied various sizes of launch vehicles and published two different sizes of a heavy lift launch vehicle in the proceedings of the 3rd International Astronautical Congress in 1953(3) at Stuttgart[4]. He compared a big satellite ship with a launch mass of 4,884 t and a payload of 25 t with a growth factor of 195, with a smaller vehicle that could orbit about 5 tons. All of these vehicles had practically the same features, their configurations and dimensions are illustrated in figure 1.

In these years the Soviets improved the A-4 and achieved ranges of nearly 1000 km. That encouraged them to think about intercontinental rockets for their nuclear bomb then under development. When the Korean conflict came along, demonstrating that Russia has evolved from an ally during WW II to a political opponent, action was required. This prompted the U.S. to take up the development of military rockets, and the U.S.ARMY was ordered to develop quickly a rocket for transporting a 6000 lb conventional or nuclear warhead over 300 miles with a high target accuracy of a few hundred feet to be achieved by terminal guidance. Thus the short range REDSTONE missile was born. In the year of 1950 nobody could foresee that this rocket would be a satellite launcher in 1958!

Recognizing that long-range nuclear missiles would be a dangerous threat, the U.S.AIRFORCE was ordered in 1952 to develop an intercontinental missile, the ATLAS. This long-range missile had a launch mass of about 200 t and was sized to a payload capability compatible with the weight of a nuclear warhead to be expected in production in the year of missile deployment some five to six years later.

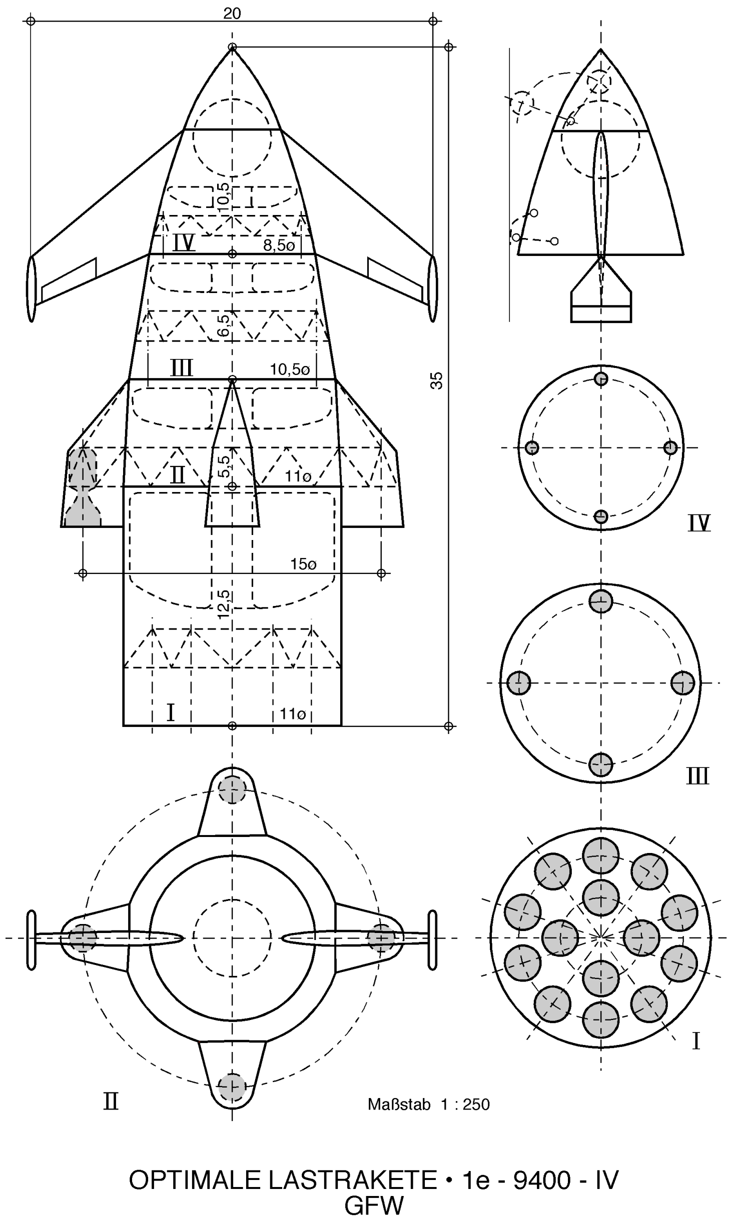
It was in these years that the author, a student at the Technical University of Stuttgart, revived the former "Society for Space Research"(GfW) in January of 1948. This society attempted to rekindle the sprit of the old German Society for space travel, which existed during the years of 1927 through 1934 with offices at Berlin. This group did build a rocket test range at Reinickendorf in 1931/32, where Winkler, Nebel, Riedel, Oberth and von Braun launched their first small rockets.

The newly founded society had a difficult start three years after a terrible war. They had to start from scratch. Some primitive publications and articles in the newspapers were the tools to get the message to space proponents that there is a new beginning. Meetings took place mostly at Stuttgart in the beginning. Within a few years a few hundred members signed up. Some working groups were established to collect information and relevant material in areas of interest. One of the working groups started to make design studies of space launchers.

The author, heading this group, was supported by a former Peenemuender structures engineer Helmut Hoeppner, and assisted by a few other enthusiasts of the German Society for Space Research. This was the only other known activity designing launch vehicles for future manned space travel at that time[2,3].

During the years 1950/53, the author was working towards his masters degree in the field of mechanical engineering, and in this process he performed the preliminary design of a four stage orbital rocket carrier with a launch mass of 872 t and a cargo payload of 3.5 t, or alternatively a manned capsule (figure 2). This activity included also the design of a pump-fed hydrazine/oxygen rocket engine with a thrust of 100 metric tons by the author. 14 engines of this type were clustered in the first stage and four of the same in the second stage of launch vehicle conceived.

Figure 2: GfW Launch vehicle concept



This conservative launcher concept had a growth factor of 250! The concepts described above represented the state-of-the-art in launcher vehicle design in the early fifties. Ten years later it was possible to design launch vehicle of this size with a growth factor of 25, which was an improvement by one order of magnitude! This was possible, because the relevant technologies were pushed by the development of intercontinental missiles. This major development effort was initiated in East and West during the years of 1951/53!

During the following years some studies were published on orbital carrier vehicles, emphasizing the use of modified military long range rockets with launch masses around two hundred tons. These studies were proposals on how to close the recognized booster gap between the Soviet Union and the United States of America, eventually resulting in the JUNO 5 effort, initiated by ARPA as discussed below. The JUNO 5 booster became the satellite launcher that was destined to overcome the initial lead of the Soviet Union in lifting capability.

2. Precursers

In the year 1955, it became clear that the Russians were ahead of the USA in developing intercontinental rockets capable of threatening the US with a nuclear attack. The U.S. responded with a crash program comprised of the concurrent development of two intermediate range ballistic missiles (IRBM) with a range of 1,500 miles, named JUPITER (by the Army) and THOR (by the AIRFORCE), and taking no chances, the TITAN intercontinental missile, as a back-up ICBM, using a different design approach, because the progress with the ATLAS development was not quite satisfactory.

In July of 1955, upon the recommendation of several scientific bodies, supported by the military-industrial complex, the Eisenhower Administration announced the development of a scientific satellite for the *International Geophysical Year* planned for 1957. The U.S.ARMY well prepared offered to launch a satellite using its REDSTONE booster, the largest rocket available for flights at that time. However, the US Navy received the job to develop a "civilian VANGUARD launch vehicle". It was obvious to the rocket designers at Huntsville, that it was only a matter of time, that the Russians would launch their satellite, which was announced by Prof. Sedov at the fifth International Congress at Copenhagen in fall of 1955. Thus the Huntsville team did their best to be prepared for a backup role[26].

This was the situation as the Soviet Union surprised the World with the launch of their first satellite SPUTNIK I in October of 1957 to be followed by STUTNIK II later that year. The booster gap was apparent! The satellite was more than ten times heavier than anything the US could have launched. The US Congress got into action, concentrated all military space projects within the Department of Defense in a new agency, called "Advanced Research Projects Agency (ARPA)", and all civilian space activities in the "National Aeronautics and Space Administration (NASA)".

The eager U.S.Congress passed the Space Act of 1958 providing a legal and administrative frame of reference for a new space program. The booster gap became now a major issue and the American public demanded action to catch up with the Russians. With these actions, the U.S. was organized within a few months after the Sputnik shock, to take up the challenge.

While loosing the bid for launching the first American satellite, the Army team at Huntsville began preparations for using their REDSTONE booster to launch a satellite in case they would be called upon. Joining in this effort was the Jet Propulsion Laboratory, an Army contractor, the developer of high performance solid rocket engines,. A three-stage spinning cluster of 6" Sergeant rockets was placed on top of the REDSTONE booster. It was to be launched into space at the moment the REDSTONE rocket would reach the summit of its trajectory.

Missiles 27 and 29 were officially prepared for "high speed entry tests" of a nose cone model planned for the JUPITER missile. At that time the reentry problem was yet to be solved. These vehicles were designated "Jupiter C", and thus sharing its high DX priority. Aside from the design and development of the JUPITER missile, the preparation of a satellite launch had the highest priority at ABMA in Huntsville during the year 1957[26]. In late October 1957 in the aftermath of the Sputnik shock, ABMA was authorized to launch a Satellite as quickly as possible. Dr.von Braun promised to do this within 90 days! In the last days of January 1958 the first American satellite EXPLORER I was launched successfully into orbit!

Launching EXPLORER I, however, was not the only space activity of the Huntsville team. The Army Ballistic Missile Agency(ABMA) contributed also to a major effort drafting a National Booster Program. The team was ambitious enough not to be satisfied with the JUNO 1 and JUNO 2 launch vehicles used to launch the early satellites, since they were limited to launch satellites up to 40 pounds (EXPLORER) and space probes of 10 pounds (PIONEER). Bigger things were in the mill. How the big booster development started requires to take a look what was initiated about ten years earlier and how the historical developments evolved.

3. JUNO 5 Booster

Three months before President Eisenhower announced plans in July 1955 to launch an artificial satellite, the author had arrived at Huntsville, joining the team of Dr.von Braun. That was perfect timing. He began as an assistant of the Chief Designer Dr.Raithel. After receiving the clearance for access to classified information, he was appointed Chief of the Preliminary Design Section. First priority in this position was to acquaint himself with the existing state-of-the-art in the United States primarily in Huntsville, Florida and California. Then, in April of 1957 he took up his old dream to design a rocket big enough to get people into orbit. He was convinced the time would come when the United States would need more lift capability than available or planned in 1955 to beat the Russians.

As reported above, the priority job of the Huntsville team in the year 1957 was to develop a quick satellite capability. The Preliminary Design Section was a major contributor to achieve this objective, it had a major responsibility in trajectory shaping, configuration and performance control.

But that was not the only activity at that time. There were other studies for the U.S.ARMY on short and medium range missiles, satellite defense systems and the like. In addition, preliminary design of advanced carrier rockets was assigned to this small group. In this process a family of JUNO rockets was conceived[26]:

- The JUNO-1 vehicle was the satellite carrier version of the JUPITER C missile, which was used for testing scaled reentry nose cones required for the JUPITER IRBM. Both ware based on the REDSTONE booster.
- The JUNO-2 vehicle was a satellite carrier employed the JUPITER booster and the upper stages of the JUNO-I, increasing the payload capability from about 10 pounds to 40 pounds.
- The JUNO-3 was a design modification of the LUNO II booster stage with a heavier cluster of solid rocket motors, but this design was not approved.
- The JUNO-4 was a competitive bid for an optimized three stage liquid propellant launcher with the THOR or JUPITER as the first stage, having a payload capability of over 200 lb. The THOR team won this competition, because they used VAMGUARD upper stages.
- The JUNO-5 was a booster design in the million pound thrust size to make a big jump in lifting capability, the goal was 10 tons to low orbit or more.

The initial studies of a big booster began in April 1957, six month before the first Russian satellite went up! These studies were kept tightly within the Preliminary Design Section for the first few months. Even Dr.von Braun was not informed, because I was not sure whether he would have liked it at that time where all attention was concentrated on the JUNO 1. But I was sure to follow his basic philosophy. Using tanks of the REDSTONE and Jupiter rockets, and E-1 engines proposed by ROCKETDYNE, a big booster was designed.

The work on this satellite launch vehicle concept began with performance calculations, using some simple and practical calculation methods on rocket trajectories and performance on their IBM computers. The analytical tool for the conceptual design of satellite rockets we used for this purpose was developed by the author previously in Stuttgart and his co-workers (particularly Dr.H.G.L.Krause) under contract with the U.S.AIRFORCE, between 1952 and 1955. The Huntsville team at that time did not have yet the capability of running trajectories of three stage satellite rockets, so our analytical tools came in handy.

As soon as the propellant loadings of the stages were determined, a 1:10 scale drawing of the big booster was made by Fritz Pauli of the PD Section and put into a drawer for use at the right time. It turned out that this was timely advanced planning for a situation expected to develop in the near future. The first design of the booster was based on usingE-1 engines at 330K sea level thrust. This engine was under component development at ROCKETDYNE.) Our fairly detailed design of a big booster convinced ourselves that we could handle this size of a rocket at Huntsville on our rocket test tower.

This capability was brought to the attention of ARPA in July 1958 when R.Canright and D.Young of ARPA were visiting Dr.von Braun. They came to Huntsville, because 10 million dollars were left in the ARPA budget. They wanted to obligate these funds in the current fiscal year. The next year the big launch vehicle development would be a responsibility of NASA. These two engineers suggested to use eight JUPITER engines instead of the E-1 cluster, in order to start development and save about $ 50 M engine development money, not available in the budget[8,9,12]. We accepted this change of the engine cluster concept and in doing so, our proposal was apparently convincing.

Within four weeks the authorization and funds were sent to ABMA to demonstrate the feasibility of a big clustered booster. It was initially named JUNO 5 (ARPA Order 14-59, August 15, 1958). We went to work right away to order hardware and prepare our facilities to get the job done. The JUNO 5 booster was renamed officially to SATURN[25] as proposed by Dr.von Braun, in February of 1959 by an ARPA memorandum.

This way, our efforts to close the booster gap to the Soviet Union became an element of the National Booster Program. This project was initially assigned to the U.S.ARMY with the tentative objective to use a three-stage vehicle to launch a geostationary communication satellite. But already in Sept. 1959, the Director of Research and Engineering, Department of Defense, Dr. Herbert York decided that the Army should get out of the space business, because he could not find a military requirement for rocket boosters of this size.

Consequently, the Department of Defense offered this booster program to the newly created NASA for consideration. After some deliberations within the Government and Congressional Committees, the President of the U.S., Dwight Eisenhower, signed an order transferring the Development Operations Division of the Army Ballistic Missile Agency (ABMA) and the SATURN launch vehicle project to NASA on November 1959[25].

After a presentation of the SATURN launcher and its growth capabilities in Washington in September 1958 to the NASA Administrator Dr. Keith Glennan and his Deputy Dr. Hugh L. Dryden by Dr. W. von Braun and the author, a go-ahead was given by ARPA/NASA in November 1958 to build four flight vehicles so that long lead time hardware could be ordered. One item in this presentation was a cost estimate I had to make for the development of the SATURN I, including the hardware for 15 vehicles. When I reported to Dr.Rees, Deputy to Dr.von Braun, that the cost estimate came out close to 1.1 billion dollars, he changed this arbitrarily to 880 million dollars, because he said "we simply can not make a proposal over one billion dollars!".

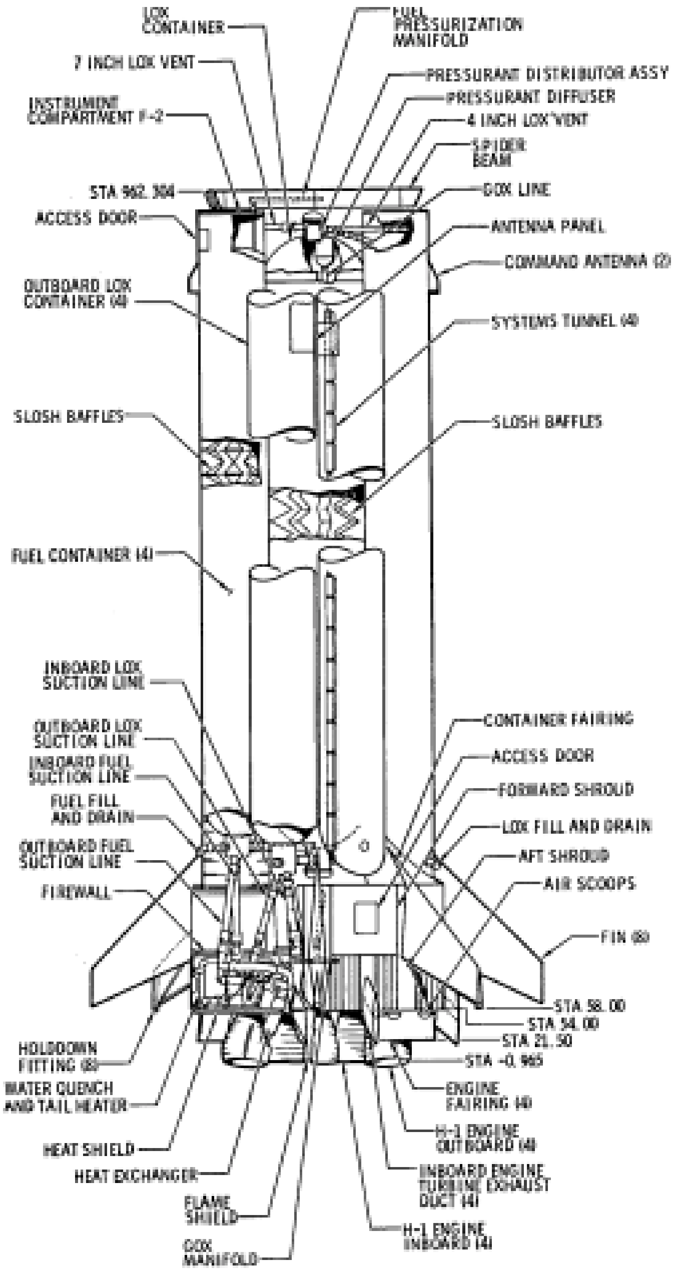


Figure 3: JUNO 5 Booster

He was probably right, because our presentation went over quite well and NASA decided to accept the responsibility for the SATURN development[14]. Meanwhile, the von Braun team prepared itself to be transferred to NASA on July 1960. The JUPITER IRBM development was coming to an end, the production of this vehicle was contracted to the Chrysler Corporation. The PERSHING missile development, approved as a substitute for the REDSTONE missile a few months before, was contracted with MARTIN Co. at Orlando.

4. SATURN I and IB

Meanwhile, the aerospace industry was not sleeping. They wanted to get a part of this new business. Space minded engineers in the Aerospace industry were eager to demonstrate competence in launch vehicle design. Preparatory studies on bigger boosters were made in the late fifties to get the "foot into the door". One of the conceptual designs performed in industry by S.B.Kramer and R.A.Byers was published (fig. 4)[10].

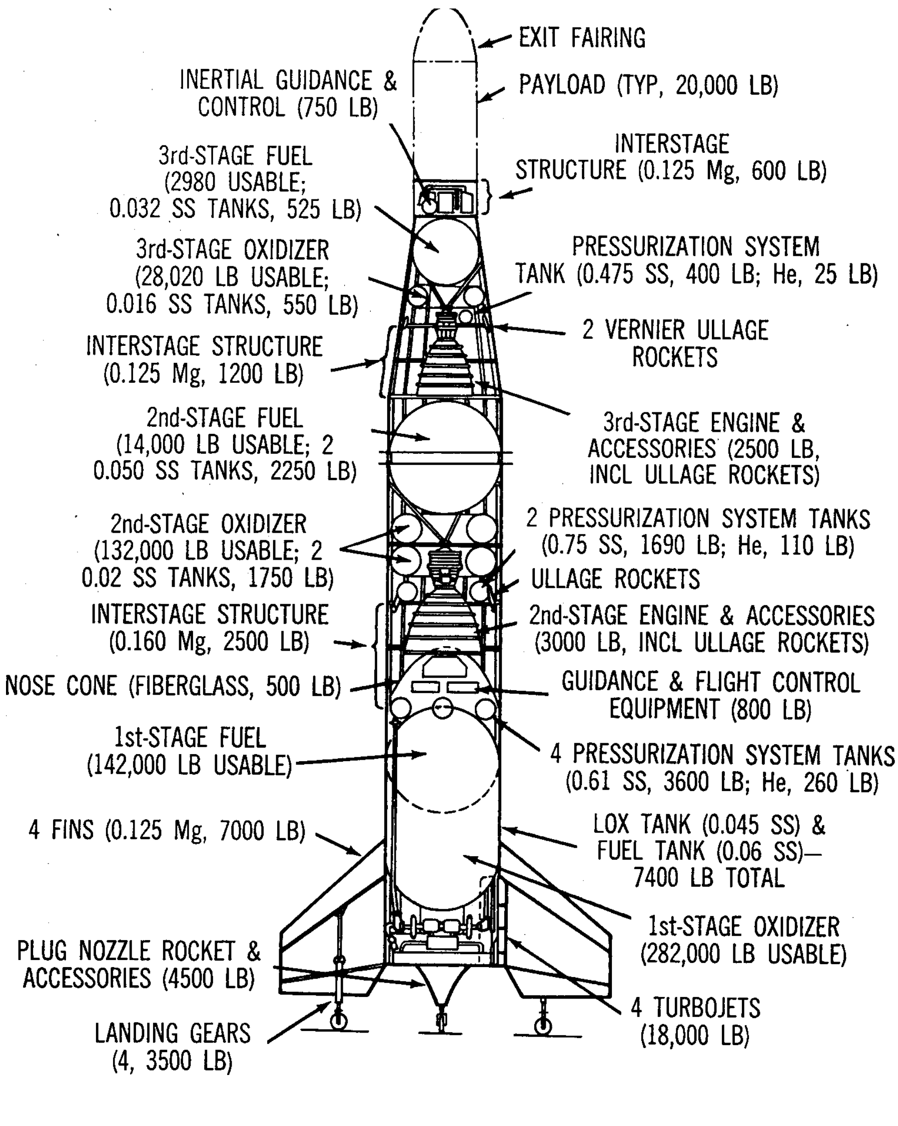


Figure 4: Three-stage launch vehicle for a 20,000 lb satellite (Kramer/Beyers)
Gross weight 214 t, payload 9 t, growth ratio = 24

The gross weight of their vehicle was 700,000 lb. Payload weight was estimated to be 20,000 lb. This was a fairly advanced and optimistic design, but it did have some similar features as the SATURN I under development at ABMA. It had a more ambitious single engine with 1,160,000 pound thrust, featuring a plug nozzle in the recoverable first stage, but in contrast to the SATURN I this was a paper engine! Meanwhile, the first big booster was in the making at ABMA in Huntsville.

After it became clear that NASA would take responsibility of the non-military big launch vehicle development for space applications in the U.S.A., SATURN vehicle configuration studies were intensified. Before that, less ambitious initial vehicle preliminary design studies by the Huntsville team during the Eisenhower Administration assumed a modified TITAN booster as the second stage and the second TITAN stage or a hydrogen/oxygen Centaur vehicle as the third stage (SATURN A configurations). Alternative configurations of a high-energy second stage on the same booster (SATURN B) originally studied for the Lunar Outpost logistic operation, did not find many supporters. The performance limits of the initial SATURN A and B concepts configuration were 33,500 pounds into a 300 mile orbit or to soft land 2,700 pounds on the Moon depending on the upper stages used. With manned lunar flights in the offing, this was not enough.

To prepare for the transfer of the SATURN to NASA, a study group was formed by the NASA for the purpose of preparing recommendations for guidance of development and, especially for selection of upper stage configurations. The seven members of this study group were Dr.A.Silverstein, Col.N.Appold, A.Hyatt, C.T.Muse, G.P.Sutton, Dr. W.v.Braun and E.Hall. This group made recommendations already in December 1959, giving the direction in which the development of the SATURN vehicle was to proceed.

It was at this point, that the decision was taken to use hydrogen/oxygen propellants in all upper stages of SATURN. Some of us felt that this was a risky step. In this step of the design process all possible configurations using the ROCKETDYNE F-1 engines and high-energy upper stages were designated SATURN "C" concepts.

It is interesting to note, that the recommendations listed in the recommendation mentioned already as one of the possible missions *"a manned lunar landing by rendevouz in earth orbit techniques, using no more fueling flights than can be launched in six months to refuel an escape vehicle capable of soft landing 50,000 pounds on the Moon exclusive of the landing propulsion weight."*

The recommendations of the Silverstein Committee cleared the way to the final approval of an extended SATURN launch vehicle development program by NASA and request of the necessary funds in the budgets of the years 1960 and 1961. The SATURN Project was confirmed on January 18,1960, as a program of the highest national priority (DX rating).

The configuration that was approved and developed is shown on the illustration below and can be described as follows:

A fact sheet prepared by NASA, dated 31 March 1960 contained the latest data about the SATURN I development as seen at that time:

- Booster is made up of a cluster of liquid fueled H-1 rocket engines, each developing 188,000 pounds of thrust, a total of 1,5000,000 pounds an equivalent of 30 million horsepower at cut-off. Second stage is powered by four liquid hydrogen fueled RL10 engines with 20,000 pounds thrust each. Third stage will have two engines of the same size as the second stage.

- Booster was designed for engine out capability in case one of the eight engines should malfunction. The possibility to recover the booster by employing parachutes and retro rockets was studied.
- On satellite missions, this configuration, standing nearly 200 feet high, will orbit payloads of from 23,000 to 25,000 pounds.
- Funding level proposed to congress for fiscal years 1960 and 1961 were 63 and 276 million dollars respectively.

- 10 development flights were scheduled, beginning in 1961, the first four to test the booster only with dummy upper stages. The first operational flight was planned for 1964. The development of the SATURN I was actually concluded after 10 successful flights on July 30,1965.

Effective July 1,1960 the Huntsville Group became the "George C.Marshall Space Flight Center (MSFC)" of NASA[26]. It was one of several centers, but the only one to be responsible for launch vehicle development.

The next surprise of the Soviet Union was the launch of the first human, Jury Gagarian, into orbit and to return him safely to Earth on March 12, 1961. He circumnavigated the Earth only once, but it was an impressive accomplishment making a big impact on World opinion. This was a blow for the newly elected President J.F.Kennedy who has expounded on the booster gap during his campaign. Quick action was required. He asked his staff to compile proposals on what can be done to surpass the Russians. After only two month of deliberations, coordinated by Vice-President Johnson, with inputs of Dr.von Braun and others, the decision was taken on May 26,1961 to put a man on the Moon and return him safely to Earth within the decade. This was quite a challenge, but we did know it could be done.

After the transfer of the Huntsville Group to NASA, and even more so after the Gagarien flight, the SATURN I (earlier referred to as SATURN C-1 configuration) development gathered speed[15,16,17]. The detailed engineering of the vehicle led to several changes in the vehicle configuration. By August 1961 it was concluded that the second stage was underpowered resulting in an undesirable trajectory. The tanks of the first stage, S-I, were elongated to allow a longer burning time, beginning with the fifth flight. Two more RL-10 engines were added to the cluster of four in the second stage, designated S-IV delivering a total of 90,000 pounds thrust. This helped somewhat but even a more powerful engine was desirable.

The successful launch of the first SATURN I booster and two more flights in the year 1962 increased the reputation of the team and the confidence that the team was on the right track. The first SATURN I, with a dummy upper stage, was launched successfully on October 27, 1961, only 38 months after program approval. This was certainly a crash program, but one in which no risks were taken.

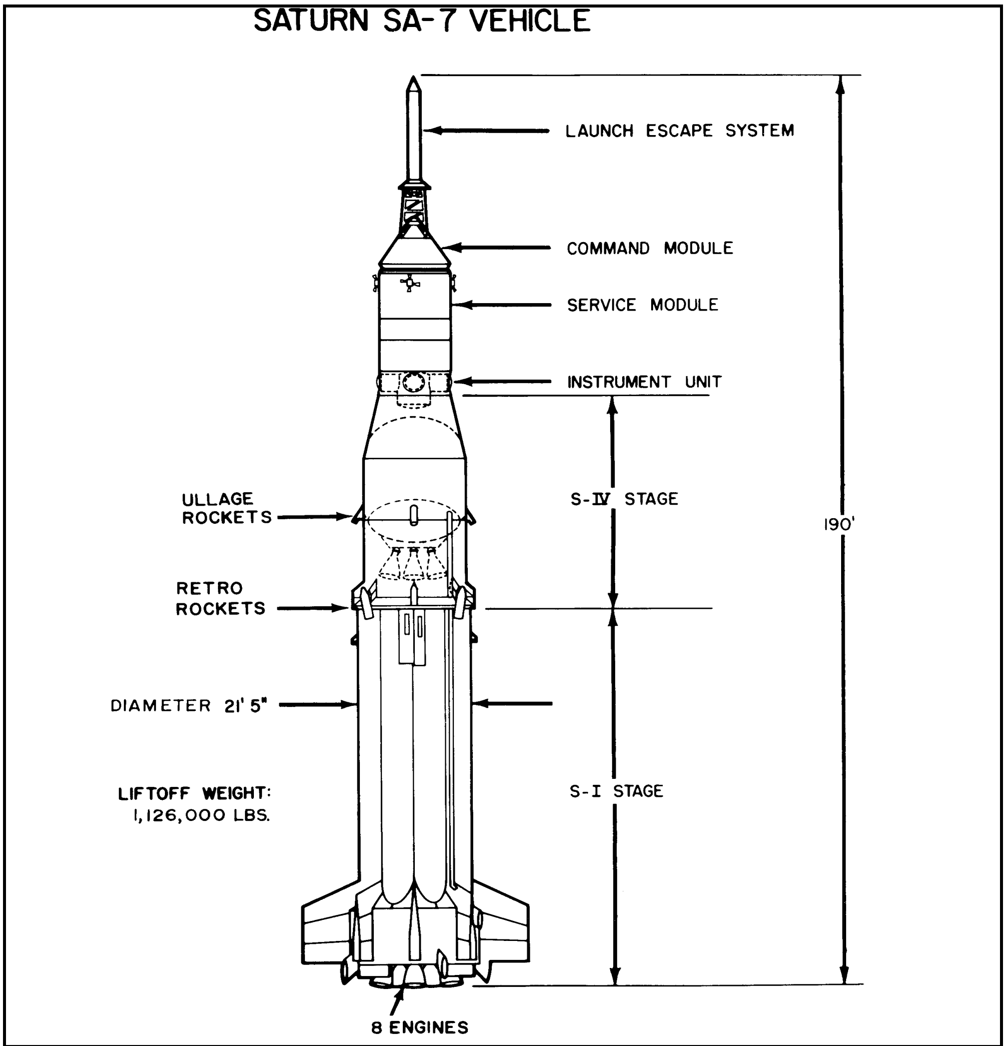


Figure 5: SATURN I (SA-7 Vehicle)
Take-off mass = 512 metric tons, LEO payload 9 t,
Growth ratio = 57

The launch weight of this vehicle was 927,000 pounds, sea level thrust 1.296 million pounds, regular burning time was 115 seconds. Including the free flight portion the full mission took 484 seconds. The empty booster crashed a few hundred miles downrange in the sea as planned. More experience was gained in the following flights with the objective to achieve an orbital capability and demonstrate this to the public. Since it became clear, that a hydrogen-fueled engine would be developed, advanced configurations were studied and optimized. Production unit SA-5, the first of the Block II vehicles, carried a live second stage and was launched on January 1964. The vehicle mass arriving in orbit including the empty second stage was 37,700 pounds, a new record, the first time beating the Russians in lifting capability!

Improvements in the SATURN I were incorporated step by step. The last four flights of the 10 test flights approved received assignments to support the APOLLO program flying early models of the Apollo spacecraft. After replacing the RL-10 engine cluster by a single J-2 engine in the second stage (S-IVB), it was possible to increase the performance and reliability considerably. With this modification, the SATURN IB was able to place the three-man Apollo spacecraft with 20 tons into a low Earth orbit[18].

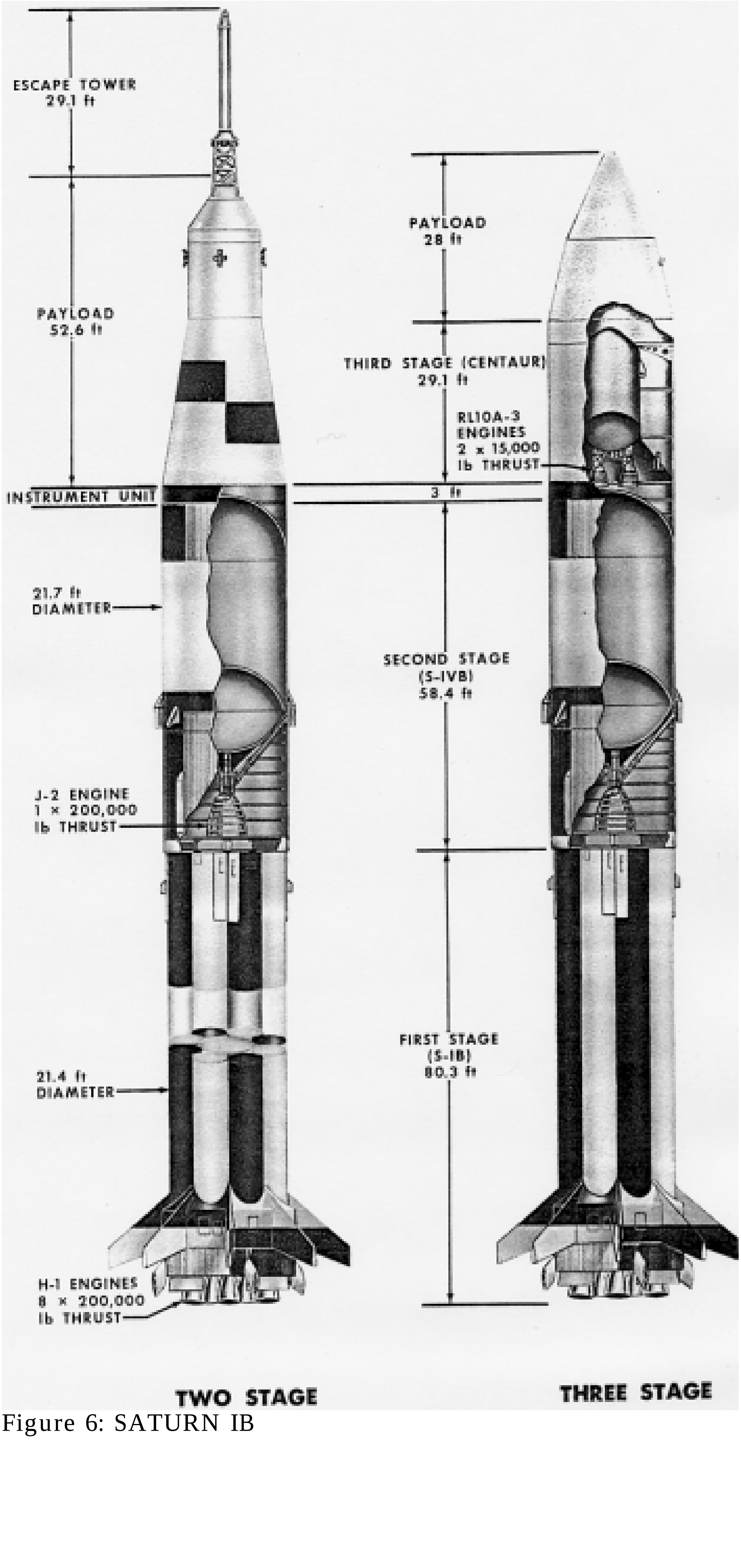


Figure 6: SATURN IB

5. SATURN V

The SATURN V has its own story. It began soon after NASA was organized. Milt Rosen, the former Head of the Vanguard program and his team was transferred to NASA with other organizations. They continued to think about the national booster program. It took several months before the interested people got together and formed a planning committee.

Beginning in summer of 1959 alternative approaches were discussed within this group. Using the platform of an International Astronautical Congress, M.Rosen and C.Schwenk (members of the respective committee) proposed an expendable launch vehicle concept, called NOVA, to demonstrate the requirements of a manned flight to the Moon[11].
This was a very ambitious design concept based on the new F-1 engine, which was contracted for in January 1959 with R)CKETDYNE to close the booster gap. This vehicle was a four-stage expendable rocket to the lunar surface with high energy propellants in the upper two stages. Its diameter was 48 feet and its height about 220 feet. Only crude mass and performance analysis could be made at that time, a preliminary design was not performed. The launch mass of this vehicle was estimated to be 3,015 t, placing a 16.2 t return vehicle (5th stage) on the lunar surface (growth factor of 189).

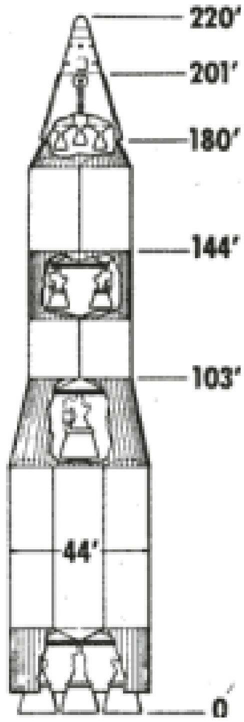


Figure 7:The NOVA launcher concept

This publication was the beginning of the search for a rocket that could land people on the Moon. However, these efforts were started during the Eisenhower Administration, which was rather reluctant to support such a project. It was not accepted as an official proposal of NASA at that point. An other push came from the U.S.ARMY. The Ordnance Corps wanted to get an assignment in this area based on their experience in the construction of polar stations. After a 3-month crash study in spring of 1959, the U.S.ARMY proposed already the construction of a lunar outpost (Project HORIZON).

Nevertheless, the NOVA proposal for a direct landing on the Moon, led a few months later to a detailed analysis of a manned lunar landing. Thus it became one of the alternative concepts to reach the Moon. This evaluation was performed by the "Low" and "Fleming" Committees, in which the author participated as a member representing the Huntsville group[24,25].

At the time the Kennedy Administration took office in January 1961, a more powerful configuration than the SATURN I was under study at ABMA, the SATURN C-3. It was featuring a new booster using 2 F-1 engines, which were already developed for the Apollo program. A second stage (S-II) was designed

to use a cluster of 4 J-2 engines with 200,000 pounds of thrust each. The 3rd stage was nearly identical with the S-IV stage, employed with the SATURN C-1.
With these changes the payload capability was expected to increase from 40,000 to 80,000 pounds for low Earth orbits. An initial contract for the S-II was placed with North American Aviation at Los Angeles a few months later in order to speed up the APOLLO program. Several other concepts were derived in the first months after the APOLLO program was announced, and optimized with respect to performance, schedule and reliability.

While there was first a preference to play it safe and go in two steps, comprised of a lunar circumnavigation using a SATURN C-3 configuration and follow this by a direct landing with a 8 F-1 engine cluster in a NOVA vehicle[11], the detailed planning showed that this would be a very tight schedule and quite costly. A vehicle concept, using a four engine F-1 cluster in the booster, and employing orbital rendevouz techniques was finally recommended as the launch vehicle to accomplish the planned mission.

Setting the course for the Development of the SATURN V

One important event in which the recommendation to proceed with the SATURN V development evolved, took place at the NASA Marshall Space Flight Center on August 7, 1961, only four months after the announcement of the Lunar Landing Program. The Memorandum for Record prepared by Mr. E.Neubert, Associated Deputy Director of MSFC reveals the details:

SUBJECT: MSFC's Position on Advanced Launch Vehicles in the SATURN and NOVA Class.

1. A meeting was held in Dr.von Braun's office on August 7, 1961 from 10:15 to 5:00 p.m. concerning the question of MSFC's position on SATURN C-3, C-4 and NOVA.
2. The meeting was attended by: Dr.v.Braun, Dr.Rees, Mr.Morris, Mr.Neubert, Mr.Maus, Mr.Mrazek, Dr.Lange, Mr.Schramm, Dr.Debus, Dr.McCall and Mr.Koelle.
3. The discussion was opened by a briefing of Mr.Schramm on the activities of the GOLOVIN Committee in Washington. He discussed the objectives and the schedule of this Committee. He reported about a strong recommendation by STG for the development of a unitized 160-inch single solid rocket engine and about a JPL presentation concerning a launch vehicle using solid propellants only, for lunar missions and lunar surface assembly operations using solid rocket engines for the lunar launch vehicle. He stated that an attempt would be made by the committee to review the entire national booster program, based on NASA and Department of Defense requirements.
4. Mr.Koelle gave a presentation and distributed a handout of 21 pages on comparative data for an early lunar landing with particular emphasis on SATURN C-3 (2 F-1 engines), C-4 (4 F-1 engines) and NOVA (8 F-1 engines), various modes of operation, weight requirements for the lunar launch and orbit launch vehicle, performance mission reliability and typical schedules.

5. Dr.v.Braun discussed general philosophy in this particular area related to launch vehicles and manned lunar missions in some detail. At the end of the discussion, he requested from each person attending his personal recommendation what his choice would be in case he would have to make a decision.

These recommendations can be summarized as follows:
a. Mr.Schramm:
(1) Wants to be very conservative.
(2) Recommends direct capability regardless of time and funding level.
(3) Feels that NOVA should be priority approach with SATURN C-3 and Orbital Operations as a backup.
(4) Prefers the development of a large hydrogen engine, however, this could be the pacing item for the NOVA development.
(5) These disadvantages for a selection of the C-3 configuration must be compared with the disadvantages of both the direct approach and orbital operations.
(6) Continue with the development of large solids for application in vehicles up to SATURN C-3 size.
b.Mr.Koelle:
(1) Recommends high-energy propellants for the upper stages with storable propellants as a backup.
(2) Recommends development of rendevouz and docking techniques in orbit.
(3) Recommends aggressive development of the NERVA engine for growth potential.
(4) Recommends modification of the SATURN C-1 by substituting a single J-2 engine for the RL 10 cluster.
(5) Recommends the SATURN C-4 configuration for development.
(6) Recommends the incorporation of a nuclear upper stage into the NOVA concept.
(7) Recommends to push the state-of-the-art of large solids and decide later where their place is in launch vehicles, as experimental data becomes available.
c. Mr.Maus:
(1) Expresses the opinion that it will not be easy to sell the costly large NOVA vehicle.
(2) States that the C-3 will have a schedule advantage of about one-half year.
(3) Prefers high-energy propellants for the return vehicle.
(4) Recommends that MSFC take another look at all launch vehicles for the next few weeks before making a recommendation.
(5) States that his personal choice at this time would be the C-4 configuration.
d.Dr.Lange:
(1) Prefers a re-optimization of the SATURN C-1 when the J-2 engine becomes available.
(2) Recommends to proceed with the C-3 configuration without delay.
(3) Recommends to develop a direct flight capability at a later time after another look at the NOVA configuration.
e.Mr.Mrazek:
(1) Points out that the base-heating problem of the four-engine cluster is more serious than that of a two-engine cluster.
(2) Recommends to proceed with the C-3 without delay.
(3) Recommends the development of a large hydrogen / oxygen engine.
(4) Recommends a NOVA vehicle with a clustered tank booster or a solid rocket engine cluster in the first stage.
(5) Favors product improvements in the SATURN C-1 configuration during development.
(6) Take more time to study the NOVA configuration
(7) Recommends the development of orbital rendevouz techniques and high-energy return propulsion.
Mr.Morris:
(1) States that he feels the President is solidly committed for a Man on the Moon program that will have first priority.

(2) He feels that the resources available will not permit a parallel development of SATURN C-3 and NOVA.
(3) He recommends the development of the C-4 configuration.
(4) Has high confidence that nuclear propulsion will be developed in an aggressive manner and become available at the end of this decade and therefore should be incorporated in any advanced large vehicle design.
Dr.Rees:
(1) He states firmly that he does not believe that we have any chance to beat the Russians to the Moon.
(2) He expects the Russians to establish a strong hold on the Moon and possibly not permit us to get a hold on the lunar surface.
(3) Therefore, he thinks that we should adopt a crash program on a war-like basis and ask for unlimited funding.
(4) He favors the most simple propulsion system for the lunar launch vehicle such as solids.
(5) He states that we have to take greater chances in our development program.
(6) He likes to be conservative with weight and performance assumptions.
(7) He favors a single J-2 engine in the SATURN C-1 configuration, replacing the S-IV stage.
(8) He recommends the development of the SATURN C-3 configuration without delay.
(9) He favors the development of a large NOVA vehicle with transfer of the crew on early flights to the Moon in the waiting orbit.
(10) He strongly recommends that MSFC should emphasize the development of solid boosters initially for the SATURN C-3, and eventually for NOVA. He would like to build up our in-house capabilities for solid rocket engines.
(11) States that he eventually would like to see the development of a larger hydrogen / oxygen engine.
Dr.Debus:
(1) Recommends the development of a solid booster for the SATURN C-1 configuration.
(2) Points out that NASA and DOD must pool their resources in order to be capable to pursue a diversified launch vehicle development program.
((3) He favors the development of solid and liquid boosters at the same time, but prefers the solid booster systems due to their simplicity. This offers operational advantages.
(4) He favors the development of the SATURN C-3 without delay.
(5) He favors a strong follow-up program to first lunar landing which might not be critical.
(6) He recommends that the development of orbital operations be funded by the DOD.
(7) He would like to proceed with the NOVA at a later date after another detailed investigation of various configurations.
Mr.Neubert:
(1) He is of the opinion that we have to limit ourselves to chemical liquid propellant systems if we want to land a man on the Moon in 1967.
(2) He feels that we can afford to wait another three months if it takes this time to sell the SATURN C-4 configuration which he favors due to the limited resources available.
(3) He points out that no new facilities for the SATURN C-4 will be needed neither in the area of fabrication or static test facilities.

Dr.von Braun:

(1) Expressed his personal preference for the SATURN C-4, because it would make it possible to concentrate the available resources on one vehicle.
(2) He would like to pursue the development of orbital operations with the docking of the C-4, because he does not have high hopes for a direct capability with the C-4 configuration.

6. A detailed discussion of the divided opinions followed and a compromise was offered which was finally adopted as the current MSFC party line. This can be formulated as follows:

We recommend to pursue the approval for developing the SATURN C-3 configuration at the earliest possible time, and study the very attractive SATURN C-4 and NOVA configurations for another four to five months, before an MSFC opinion will be formulated with the best approach for accomplishing the manned lunar landing mission. The possibility of using a nuclear upper stage in these configurations should be studied.

7. It was agreed at the conclusion of the meeting that in future weight and performance figures shall not be quoted outside of MSFC without approval of a weight performance review board consisting of Mr.Mrazek, Dr.Geisler and Mr.Koelle, a memorandum will be prepared by Mr.Koelle for Dr.von Braun's signature. This arrangement is determined necessary because of the confusion resulting from the different quotations and opinions concerning the degree of conservatism in various NASA committees and working groups.

The first signal of the new position went out by directing North American Aviation to redesign the S-II stage to incorporate five J-2 engines, providing a total of 1,000,000 lb thrust. In addition, the foundation of the booster test stand at MSFC, already under construction, was enlarged to take the thrust of 4 F-1 engines. In December of 1961 NASA selected the Boeing Company as the possible contractor for the first stage of the new heavy lift SATURN vehicle.

As documented above, the author, responsible to develop the vehicle alternatives, presented his recommendation for this C-4 configuration in this milestone meeting. Dr.von Braun and some other key people concurred in this recommendation and in so doing, the course was practically set towards the final choice of the Moon rocket, the SATURN C-4 vehicle configuration by the end of the year for the job of transporting the first American astronauts to the Moon.

6. The Final Decision on the Moon rocket

The final MSFC recommendation of developing the SATURN C-4, instead of a combination of the C-3 and NOVA, was officially approved by the NASA Management, after coordination with the U.S.AIRFORCE in the GOLOVIN committee, on January 10, 1962. In this finalization process, a fifth F-1 engine was added in the booster stage to alleviate the base-heating problem, and to increase the margin for error[26].

With the decision of the final launch vehicle configuration the development responsibility was transferred to the SATURN Program Office, supervising all elements and milestones of the approved program.

The SATURN V, now the final designation, was designed to place about 120 tons into Earth orbit and sending the APOLLO spacecraft with a mass of about 48 tons to the vicinity of the Moon. The Rocket launch mass was eventually 2,920 metric tons at liftoff. This was a growth ratio of 60 for escape missions.

The LEO payload capability was up to 120 t, e.g. a growth ratio of 24. Initially it was planned to use the SATURN V also for flight testing nuclear upper stages, which determined the size of the assembly building at the Cape, however, the nuclear stage never materialized. The problems of operating nuclear rockets were recognized soon, leading to dropping this alternative concept. The SIC stage was quickly put under contract with the Boeing Company, the S-II stage with the North American Aviation and the third stage S-IVB was already under development at the Douglas Company.

The Program Offices at NASA Headquarters and at MSFC engaged in rapid decision-making and contracting, with a speed the Russians were unlikely to duplicate.

Some important milestones of the successful SATURN I, IB & V Program were as follows[18,19,20,21,23]:

April 1957	Begin of preliminary design of JUNO 5 booster
Aug. 1958	ARPA authorizes life booster test of JUNO 5
Nov. 1958	NASA authorizes four SATURN 1 flight vehicles
18 Jan. 1960	DX priority for the SATURN program
Jan. 1961	First proposals to NASA for SATURN C-2 and NOVA
25 May 1961	President Kennedy announces the APOLLO Program
20 July 1961	SATURN C-4 proposal sent to GOLOVIN Committee
24 Aug. 1961	Atlantic Missile Range selected for launch site
7 Sept. 1961	Michoud Facility selected for SATURN production
11 Sept. 1961	North American Aviation selected for S-II development
25 Oct. 1961	Missisippi Test Facility selected for vehicle stage testing
27 Oct. 1961	First launch of SATURN I, first stage
17 Nov. 1961	Chrysler Company selected for SATURN C-1 production
15 Dec. 1961	Boeing Company selected for SATURN V, S-I stage development
20 Dec. 1961	Douglas Co. selected for S IVB stage development
22 Dec. 1961	SATURN C-5 configuration finally approved for APOLLO
22 Jan. 1963	Original NOVA concept dropped in favor of advanced concepts
29 Jan. 1964	First launch of 2-stage SATURN I
26 Feb. 1966	First launch of SATURN IB
Nov. 1967	First SATURN V Launch successful
Oct. 1968	First manned orbital flight of SATURN IB
Dec. 1968	First manned flight around the Moon
July 1969	First manned landing on the Moon
Dec. 1972	Seventh and last manned flight of SATURN V to the Moon

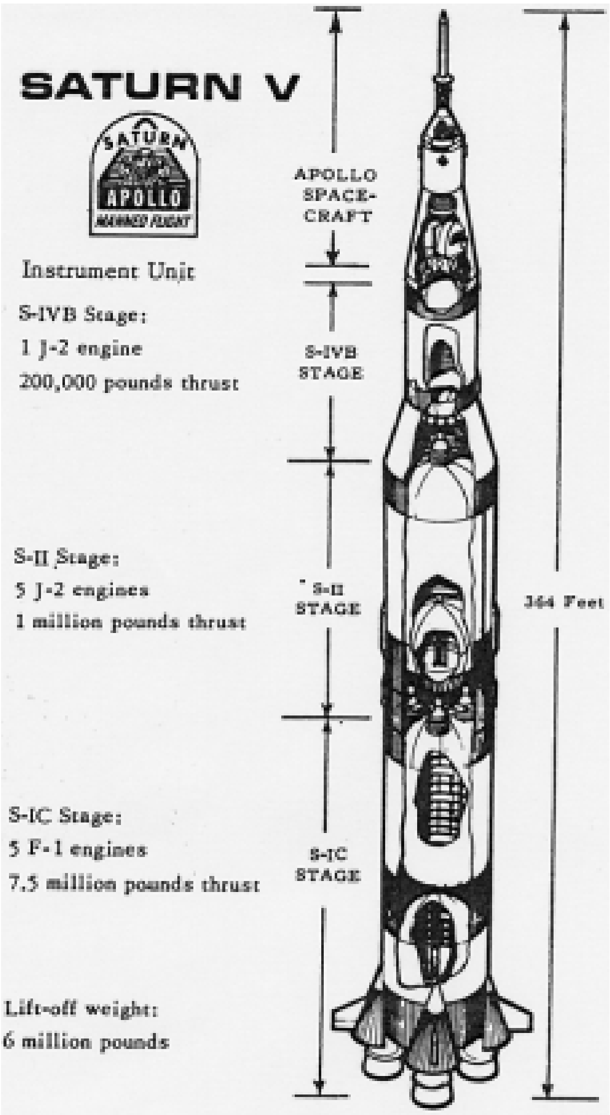
The NASA "players" of the SATURN development were:

- NASA Headquarters with APOLLO Program Management
- Marshall Space Flight Center Huntsville for SATURN development

- Manned Spacecraft Center Houston for Spacecraft development
- Kennedy Space Center Florida for Launch Operation

The cooperation between these team members was quite good, sometimes painful and different opinions had to be ironed out in a very large number of meetings and conferences. The degree and kind of experience was not the same of those people who had a say, particularly at Headquarters where many new people who were imported from industry wanted to run the show. In a letter of September 4, 1962 Dr.von Braun in a letter to his boss, D.Brainerd Holmes, Director Office of Manned Space Flight, made it very clear under which philosophy he intended to develop the launch vehicles for the Moon program.
He did send him a position paper that probably explains better than anything else the success of the SATURN development:

Figure 8:
SATURN V launch vehicle,
Three-stage expendable lunar rocket
Designed for the APOLLO landing and return mission



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MSFC's Ground Rules and basic Philosophy for Time Scheduling

"Historically, military guided missile boosters such as Atlas, Thor, Jupiter, Titan, Minuteman, Polaris etc., were developed on a crash schedule, and the corresponding high risks were accepted. In case of catastrophic failures, damage to launching sites and dangers to the public were relatively small; and the damage could be repaired fairly quickly and cheaply. The relatively small cost of the vehicle made it possible to afford these losses because each flight attempt brought valuable results for the continuation of the development. Furthermore, these programs were very well funded; and the development effort therefore included a large number of R & D launchings. Finally, publicity of results of launchings was limited due to the classified nature of these weapons systems; thus, failures did little damage to the programs in the eyes of the public and to the prestige abroad. This made unrealistic planning and subsequent reprogramming more acceptable.

In contrast to the weapons systems, the launch vehicles for manned space flight of the C-1, C-5 and NOVA classes are huge in size and contain from 10 to 100 times as much propellant (now including highest energy propellants). The cost per launch is to be multiplied by approximately the same scale factor. Perhaps most significant at all is the fact that the first few manned flights will still be in the R & D stage of development. A catastrophic failure close to the launching site can cause excessive damage to launch facilities and equipment resulting in time delays for repair of many months or even years. An erratic flight will endanger human life and private property to an extent not comparable with guided missiles. Since space flight, especially the manned lunar undertaking, stands in the limelight of worldwide attention, any failure even during early booster launchings will be witnessed all over the world, this will set back the program, will result in congressional and other Washington investigations, and will cause loss of prestige to the U.S. in addition to the monetary losses and perhaps even the loss of human life.

<u>Catastrophic failures, therefore, must be avoided by all means; and the chance of any failure during development and operational flights must be minimized.</u>

A vital factor to accomplish this is the establishment of a <u>realistic</u> and <u>reasonable</u> time schedule as a principle basis for proper management of the program. This time schedule must take into account the conditions mentioned above, and the limitations inherent in the NASA and Federal Government management systems. It must clearly acknowledge that the Manned Lunar Landing Program, under present ground rules and funding levels, is definitely not a crash program.

MSFC, in its attempt to achieve a successful program in the shortest possible time, therefore wants to follow certain concepts and ground rules as established below:

1. The time schedule must be made in consonance with the resources on hand or reasonably anticipated. If resources in the proper amount, especially money, cannot be made available on schedule, then the development and launch schedules will slip of necessity. We should be honest with ourselves and accept this as a fact.

2. One of the basics of successful accomplishment of a launch vehicle program is extensive testing of components, sub-systems, and total systems both by the manufacturer and the government in-house. This has been demonstrated by MSFC for years and is the foundation of any reliability program. <u>No test in the launch vehicle program, considered necessary by MSFC, should be eliminated for the sake of shortening the time schedule.</u>

3. The "high risk concept" should be banished from our philosophy entirely in making time schedule in favor of a more conservative and realistic approach, which will finally lead to a more economic and successful program, and a shorter over- all time schedule in the end.

4. Especially for the early launchings of the big boosters, ample time should be allowed in order <u>to arrive at a "mature" design with possible alternate solutions to be explored</u>. By "mature" design I mean one which is thoroughly investigated, well planned and based on proven design concepts with ample margins of safety; in addition, it means limiting the design goals for the first few vehicles to a more simplified version with the full expectation of bringing the more refined design features into a "block II" or even a "block III" design after some flight experience has been acquired. Principle mistakes in early design concepts and designs are hard to overcome later on, and a basic redesign after the program is far down the road will cause extensive time delays and cost large amounts of money.

5. No launching should be attempted unless great (though not absolute) confidence exists by all parties involved that it will be successful. To achieve this confidence, each and every component and sub-system must be carried through a Qualification Test Program, all systems tests must be made and evaluated, and painstaking inspection, including in-process inspection, must be performed.

6. Development tests such as wind tunnel investigations, structural tests, dynamic tests, static, battleship, all systems tests (long duration), etc. have to be performed according to a definite plan before first launching.

7. In the early phase of a program, no funds should be taken away from necessary development effort and allotted to, for example, long lead time hardware in an attempt to accommodate an earlier time schedule. This hardware will be immature and the program will later on pay dearly in higher costs, time delays, failures, and loss of prestige. This is typical of the kind of trouble created by optimistic, unrealistically short time schedules.

8. No stage should arrive at Cape Canaveral, as a rule, which is not complete and entirely check out in the home plant to the satisfaction of the Government. Neglecting this rule will show earlier delivery date to the Cape, which many people favor because they assume this also means an early and successful launch. Experience, however, (CENTAUR!!) has shown that this is fictitious and even has the reverse effect on the launch date. Developing

difficulties, including mating problems, should be straightened out in the home plant as far as possible and not at the Cape. Of course, there have to be exceptions to this rule, especially in the integration and automatic checkout area, but the basic rule should stand.
9. In programs like the manned Lunar Landing, the time schedule has to be ambitious -- very ambitious. However, the time compression should not go beyond reality, lest it erode the spirit and the morale of the people involved: nothing is gained if the people at the working level believe that a schedule is unrealistic anyway and therefore meaningless. It has been our long-standing experience that impossible deadlines and milestones are not taken seriously and only serve to undermine the sense of responsibility of the individual and his respect for those responsible for either making or accepting such schedules.
10. Under the impact of short time schedules, very frequently wrong financial, administrative, managerial, and technical decisions are made, which are later in the program almost impossible to correct. This should always be borne in mind (see Centaur program among others).
11. Allocation of funds for expansion (or over-expansion) of industrial production capability should be especially avoided at times when funds are badly needed for fundamental development.
12. Time schedules that are established must be compatible with Government management capabilities, policies, procedures, controls, limitations, evaluations, re-evaluations, etc. A crash program or accelerated schedule makes sense only if it is in tune with the funding level appropriated by Congress. Moreover, accelerated programs also require certain relaxation in laws, regulations and practices in fields such as procurement, funding, facility planning, civil service personnel ceiling control, etc. "

These ground rules had been violated by the Russians, the first four attempts of launching their Moon rocket N-1 were failures. That was the reason to loose the race to the Moon! - Also, if these ground rules had been observed in 1986, the Challenger mishap would have been avoided! Since new launch vehicles are likely to be developed it would be very wise to follow the philosophy applied by the von Braun team at Peenemuende and Huntsville.

The details of the actual SATURN development have been documented in various publications and are thus not discussed in this report. This report has been compiled with emphasis on those facts and aspects the author has personal knowledge of.

After the transfer of the Huntsville Group to NASA the Center Director introduced the "Weekly Notes" as a management tool. All people reporting to him directly had to turn in a single page report about the events and problems surfacing during the week. The Director of the Future Projects Office (FPO) was one of them.

These notes contain very valuable information about the evolving SATURN / APOLLO program. Here are some relevant excerpts:

Weekly Notes to Dr.von Braun on SATURN and APOLLO planning

10-16-61:
1. LLVGP Support (Golovin Committee on large launch vehicles)
Discussions were held with Thiokol, Aerojet, and United Technology Corp. to gain information pertaining to past and proposed solid performance programs. All data are being evaluated to assist the LLVPG in defining realistic schedules and reliabilities.
2. LLVPG Thinking
Emphasis is being placed on a 240" solid motor for C-1, C-4, and possibly NOVA application. The solid propellant enthusiasts are pushing for a solid vehicle backup to the liquid C-4. This week the funding picture will be studied in detail, since the worst solution would be two under-funded programs. *(Dr.v.B.comment: Counldn't agree more!)*
10-23-61:
LUNAR LANDUNG STAGE
Max Faget told me last Friday that they are now drafting the specs for the lunar landing stage. Should we not try to get in on it at this time? If the answer is yes, I suggest you call Mr.Gilruth and make proper arrangements.
10-30-61:
PRESENT CONTRACT ACTIVITIES
The following contracts are presently implemented (with termination dates):
a. Launch Vehicle Size and Cost Analysis Study (Nov.61)
b. Study of Large Launch Vehicle Utilizing Solid Propellants (Dec.61)
c. Earth-Planetary Transportation System Study (Apr.62)
d. Earth-Lunar Transportation System Study (Nov.62)
e. Orbital Launch Operations Study (Jan.62)
f. Analysis of Medium Class Launch Vehicle Systems (Jan.62)
g. SATURN C-3 Launch Facility Study (Nov.61)
h. SATURN D Design Study (Dec.61)
We are presently negotiating an extension of the Martin contract (item d.) for a very detailed study on the storability of propellants on the lunar surface.
11-6-61:
ENVIRONMENTAL TEST FACILITIES
Large space environmental test facilities for checkout of orbital launch vehicles, orbital launch facilities and other orbital equipment are a real critical problem in preparing for orbital launch operations.
11-20-61:
NOVA PRELIMINARY DESIGN
Work has been started to prepare a composite plan leading to the definition of NOVA. The Plan will include in-house, as well as contractor effort, and will be coordinated with the Divisions. After finalization, it will be sent to you for forwarding to Mr.Holmes so we can get the 2.3 million for NOVA presently in the financial operating plan.
The effect of a nine-month delay in a NOVA decision on the first launch date was studied for the LLVPP and the results forwarded for inclusion into the final report. For the 8xF-1 plus 8xJ-2 configuration a nine month delay in program approval caused a four month delay of first flight.
1-15-62:
NOVA
We are now preparing an action plan concerning NOVA efforts (spending approximately two million dollars in the next eight months) in order to produce a firm NOVA configuration and development plan. We should be ready to present our proposal to a special "Technical Board Meeting" on or about January 22 in the hope that this meeting will produce a Marshall position, which you could present to the next Management Council meeting in Washington late in January.
2-12-62:
LUNAR ORBITAL OPERATIONS
With lunar orbital operations getting more momentum, I feel we have to make a special effort to control our C-5 weight and performance picture in order to stay competitive. There seems to be a trend that too many people try to put their own safety margins in. This results in one reserve on top of many others, and the performance deteriorates rapidly. I am trying to get together with Mr.Mrazek and Dr.Geisler in our Performance Review Board. An occasional encouraging word from your side might help. *(Dr.v.B.comment: Agree. You have my full blessing!)*
2-26-62:

POSITION PAPER ON "SOLIDS versus LIQUIDS"
The status report on "solids", which you requested as preparation for Congressional hearings, is now undergoing the third iteration process. Next Monday we will have a clean draft ready for review by you and the Division Directors. At present time it is about 20 triple-spaced typewritten pages.
(Dr.v.B.comments: Suggest to crank into this paper the class 9/class 2 argument. My position (backed by Seamans) .We want no part of C-5 or NOVA solids unless they are officially accepted as class 2 hazzard in presence of dewars. Suggest you check also of LOD re siting problems in new cape
4-2-62:
NOVA
A memo concerning the number of engines for NOVA is on the way to you with the recommendation that 10+2+1 configuration should be selected for detailed preliminary design in our contractor effort. If you like this recommendation, please, forward to Mr.Rosen for comments.
4-9-62
C-5 DIRECT CAPABILITY
I will organize a small effort to results in a precise determination of the "margin for error" for this mode. This would be a fifth working group within Dr.Geissler's overall effort.
CONTRACTOR SELECTION ON 10-TON REUSABLE CARRIER STUDY CONTRACT. - One of our new studies is a follow on to the C-1 for the early 1970's. We have specified 10 men plus a crew of 2 or 10 tons of useful cargo as performance capability. We have also specified low maximum accelerations and reuse of both stages. The evaluation committee has selected NAA and Lockheed proposals as the best.
4-23-62:
APOLLO MISSION - PROBABILITY OF SUCCESS
A few months ago we did a detailed study in this area of all modes that might be applied. We first broke down each mission into forty to fifty steps, and gave each step a probably value, and a lower and upper limit. Then we employed Monte Carlo techniques to determine the relationship of confidence level in the first success versus time. We have the following data available:
a. Number of attempts required for one or more successes.
b. Time to first success.
c. Launch vehicles expended.
d. S-IVB stages expended
e. Spacecraft expended.
The following modes were considered: Docking mode and lox refueling-mode with and without spares, lunar orbital operations, C-5 direct mode, C-5 nuclear direct mode and NOVA. These estimates are based on presently assumed schedules. While we have concentrated on developing the method, we believe that the results are already quite interesting. However, the assumptions can stand more refinement.
7-30-62:
LUNAR LOGISTICS PROGRAM
We should try to narrow down the large number of possibilities in the very near future. Firstly, we have to make a choice between ballistic flight with near vertical decent and decent through lunar orbit. In the first case, we would want a 100 to 200Klb thrust level in the braking stage; in the second case we would want 2 or 3 RL-10 engines. If the latter case is the adopted solution, we probably can make use of the same stage as a third stage for C-1B escape missions. There are more angles to it and I would appreciate if we could set up a meeting to discuss major problem areas and alternatives.*(Dr.v.B.comment: Please, see me on this. We had a long discussion on this subject in the Management Council. B. -7-31)*
1-21-63:
JUSTIFICATION OF LUNAR LOGISTIC SYSTEM
We will, as you requested, spend more time in the next few months studying the impact of the selection of a particular type lunar logistics vehicle on the immediate APOLLO follow on-activities on the Moon. We already have an analog model operational on a 7090 computer that will assist us in studying all the possibilities in an efficient manner. We are now in the process of incorporating the money aspects into this model.
4-8-63:
NOVA REDIRECTION

As a result of our discussion on Wednesday, April 4 and your directives, we are now reorienting our study efforts in the direction of unconventional reusable NOVA concepts. We will issue new guidelines to the contractors this week along the following lines:
A. Sixty percent or more of the total study effort will be applied in the area of operations analysis and conceptual design leading to and approaching the greatest practical extent of an "ideal NOVA" as defined below.
(1) NOVA must have a multiple mission capability, preferably in all of the following areas:
- Earth to low orbit heavy cargo delivery,
- Earth to orbit cargo delivery in connection with doglegging into high orbit inclinations and / or inter-orbital transfer to high altitude orbits,
- Global logistic transport for cargo and personnel,
- Lunar logistic transport for mixed cargo and personnel,
- Planetary logistics for cargo and / or personnel,
- High velocity space probes.
(2) The "ideal" NOVA concept might have most of the following features:
- single stage configuration, land and sea recovery, design lifetime of 1000 flights, terminal guidance, wide payload range capability, acceptable acceleration limits in case of personnel transport, compatibility with nuclear upper stages.
B. The rest of the effort will be used to up-date conventional expendable or partially reusable NOVA vehicles, in the latter case with first stage recovery as a minimum goal. This data will be used to evaluate the advantages offered and price to be paid by various "ideal NOVA's" we hope to come up with.
9-21-64:
S-II ORBITAL FUELING TEST PROGRAM
Last Friday we had a full day planning meeting with Dr.Dixon, Director for Manned Planetary Studies under Ed Gray. One of the subjects discussed was an orbital fueling test program in the early 1970's as a first development phase toward achieving a manned planetary flight capability for reconnaissance missions in the mid seventies. Dr.Dixon was very receptive to such a program proposal and we will draft and coordinate a letter for your consideration from you to Dr.Mueller or Ed Gray, suggesting a feasibility study on this subject during FY 1965.
2-8-65:
BOOSTER RECOVERY for S-IC
Boeing has recently completed a study on simple recovery systems for the first stage of SATURN V. They have cone up with a concept which is simple enough that it might even work and cheap enough that we can afford it (development cost are estimated $ 50 million). It has a chance to pay off after a very few flights.

The final product resulting from this development effort, the SATURN V comprised the following features:

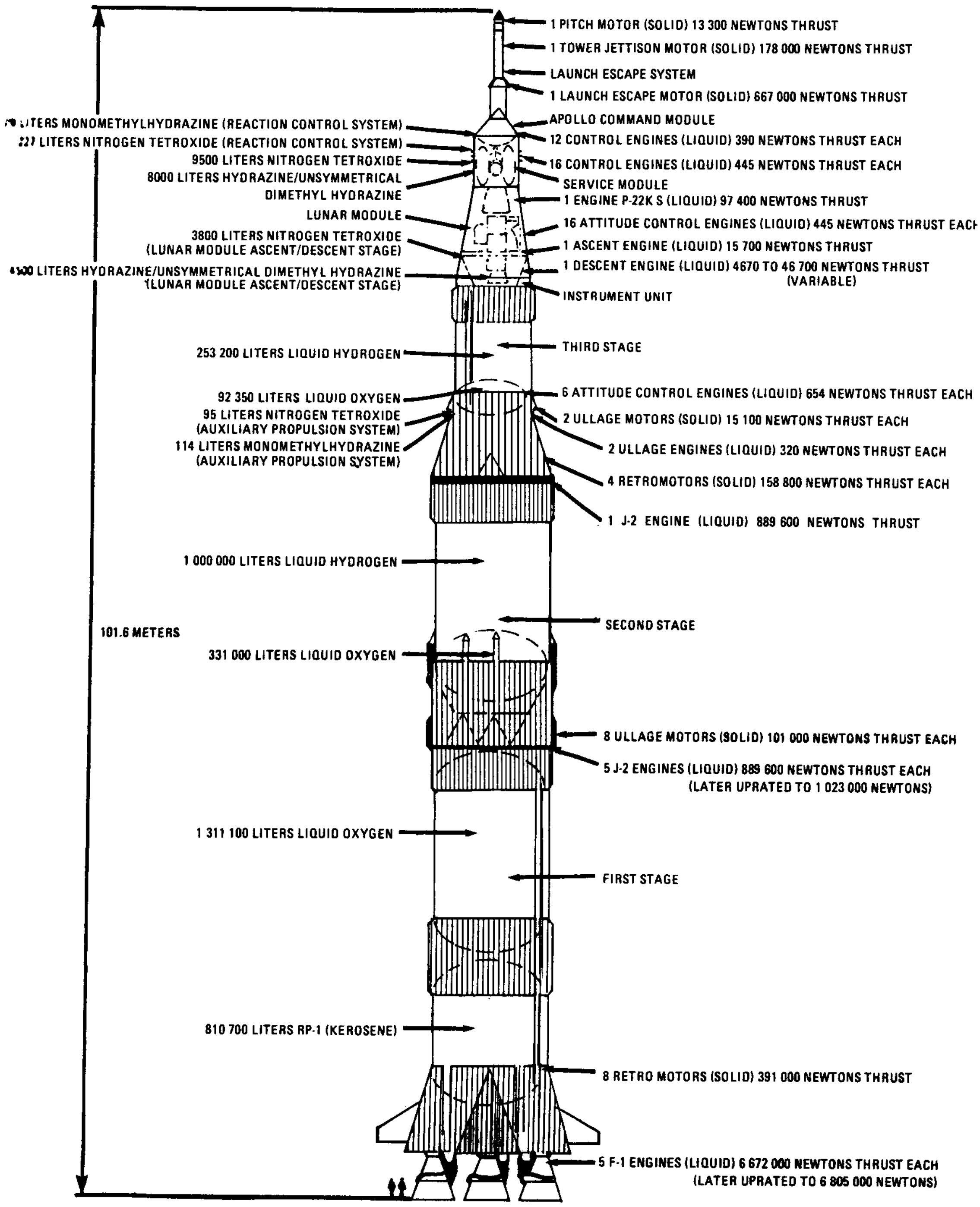


Figure 9: The final product: SATURN V Launch Vehicle

The SATURN V was designed for transporting the APOLLO spacecraft to the vicinity of the Moon, more precisely to accelerate the space vehicle to escape velocity in the direction to the Moon. However, this vehicle had more capabilities and the next task was to find further interesting missions to keep this vehicle program alive.

7. Looking for the heavy Lift Launch Vehicle Market after Apollo

After selection of the SATURN V configuration as the backbone of the future space program in December of 1962, the Future Projects Office continued in the search for the final mission architecture, the mission mode decision was yet to be selected. This effort lasted a few months and is reported elsewhere. After that the primary effort was to find applications for other missions than the APOLLO program. Below, a few examples are quoted from the Weekly Notes of the Director, Future Projects Office, to Dr.v.Braun.

6-11-62:
SPACE STATION
We are presently compiling all available data useful for a preliminary development plan (PDP). Our proposal is based on the modification of a S-IC lox tank as the basic structure. We are studying the use of TITAN II-GEMINI, SATURN C-1B and the TITAN III as a basic supply vehicle. This effort is in support of MSC.
10-8-62:
EARLY MANNED PLANETARY FLIGHTS
I just returned from the mid-term reviews of our planetary study contracts at GD/A, Aeronutronic and Lockheed. These are important for NOVA size and timing. One thing comes out loud and clear: We are in a box! This is not yet a crisis, but soon may become one. There is a definite launch window for Mars in the early seventies (1973, may be 1975), as the energy requirements will go up rapidly in the early seventies due to the eccentricity of the Mars orbit. The solar flare minimum is in the years 1972/74. On the other hand, we need a high thrust nuclear engine (about 700K) to make a fast (1- 1/2 year) roundtrip, which takes 10 years to develop. If we do not get a decision next year for the facilities for this engine, we will probably not make the 1973 launch date. For the 1975 date we need a 900 sec Ispec. 30Klb thrust tungsten reactor that has a lead-time of about 12 years. If we miss this launch window (1973/75) we might have to wait 14 years (!) for another chance. By next April we should be able to come up with clear-cut alternatives for NOVA, as well as the early manned planetary exploration.
(Dr.v.B.comment: Interesting. Suggest, rather than just ringing alarm, you prepare several alternate package proposals, none over ten pages thick. Should be geared to whatever NOVA we'll come up with of course. - B.)
2-4-63:
LARGER MANNED SPACRAFT
MSC has contracted studies on three larger spacecraft for SATURN IB:
a. A five-man APOLLO modification for Earth orbital flights.
b. A scaled up APOLLO for 12 men.
c. A 12 men spacecraft with new configuration permitting larger L/D and thus reducing maximum accelerations.
All these studies are being carried out in connection with the space station project.
We will probably also have to look into possible "product improvements" for SATURN IB, such as a larger nozzle expansion ratio in the S-IVB stage, to squeeze out some more performance. This vehicle will be needed in the years from 1967 through about 1975. A space station project would be our best customer for SATURN I-B's.
5-6-63:
SATURN V PLANETARY CAPABILITIES
You asked the question "what is being done in the area of SATURN V manned planetary capabilities. Here is a short summary:
a. Lockheed is performing a study on minimum energy profiles for Venus and Mars flyby-missions that can be performed with a few SATURN V flights and orbital operations.
b. We have a study with Chance Vought entitled "Advanced Orbital Operations" in which we will identify and define individual development problems and packages, whereby the SATURN V refueling and docking operation will play a primary role.
c. We are presently trying to initiate a small in-house study that will attempt to describe such a manned SATURM V planetary mission in enough detail that we can evaluate its problems, timing and cost.

6-24-63:
SPACE LABORATORY REVIEW
We have a small study going on to familiarize ourselves with the problem of a laboratory as one of the possible payloads for SATURN IB and SATURN V. Our concepts fall in between the Langley configuration and the large Houston concept. It appears that one SATURN IB will not satisfy the requirement for artificial gravity for several months. One of our concepts consists of two IB launch vehicles and a crew of three for a lifetime of about four months. The other concept is on SATURN V plus one IB with a crew of six and a lifetime of one year. The latter looks more attractive. We talk about a 1968 operational time period or later. The main purpose of the study is to find out the alternatives with emphasis on what MSFC can or should contribute.

1-13-64:
POST-APOLLO SATURN IB MARKET
During Ed Gray's visit last week, I had an opportunity to inform him that now is the time to plan for missions of the SATURN IB for the post-APOLLO time period. In my opinion there is a great probability that we will not have a large enough market to keep the SATURN IB production line going. New payloads of a complex nature for 1968 and 1969 are almost out of question due to lack of resources. Further, we have the competition of TITAN III to expect and we should not forget that the SATURN V is around also. With a firing rate of 2 per year (which could be all we might be able to sell for 1868/69/70) the cost of the IB might be more than the SATURN V. I am greatly concerned about the prospects in this area and am trying to get some joint activity started among OMSF, MSC, and MSFC to complement the contractor effort, which just resulted in their first report.

9-21-64:
MARKETING
There is growing evidence that we will have difficulties in the years to come to sustain public support we enjoyed in the last years. This suggests - and I know that you have preached along these lines quite often recently - that we at MSFC should make an organized effort to come up with a better utilization of our space flight capabilities and take great care to justify, in a better way, the use of newly developed hardware and new projects; e.g. the "why" of space flight. Up to now we have concentrated almost exclusively on the "how" of space flight. This no longer seems to be the crucial issue. I would suggest a special brain storming session in which we discuss how our MSFC talents can be brought to bear more on the problem of space flight marketing. I am thinking of increasing our present effort (which is a few hundred man-hours per year) by at least two orders of magnitude. This might require an organizational change or shift of some manpower. I am thinking of a group of 5 to 10 professional people doing nothing but to compile potential applications and develop the uses of space flight in an aggressive manner within NASA policies and in conjunction with other organizations. Many avenues of approach offer themselves in accomplishing such an objective.

6-14-65:
LUNAR STUDIES
We have received authority to proceed with four lunar system studies that are designed to assist in defining the interface between the lunar AES program (as presently envisioned with a maximum 14 day stay time) and any follow-on lunar exploration program. The resources allocated to these industry studies are as follows:
a. Mobility Systems (follow-on to MOLAB studies) $ 500,000
b. Lunar Shelter Concepts $ 200,000
c. Lunar Exploration Modes (total system evolution including logistic support) $ 900,000
d. Scientific Lunar Missions $ 200,000.
Headquarters considers these studies as an essential complement to the AES program definition.

8. The Death Knell (20)

After the expenditure peak for the SATURN / APOLLO program was reached in 1966 the question of the continuation of this program had to be answered. During the discussions of the FY 1967 budget it was clear that there would be no room for financing major APOLLO applications projects. These were in the planning stage for several years intended to fill in the years to follow the planned lunar landing.

A first signal of what had to be expected was a NASA order to the Boeing Company terminating procurement of ten S-1C stages, nos. 16 through 25, several months before the first human crew reached the vicinity of the Moon. This was in response to Boeing proposals to purchase long lead-time items for the next batch of boosters.

Originally, in its proposal for FY 1969 NASA had requested funds for follow-on utilization of the Apollo capabilities beyond the manned lunar landing. This request was made to receive guidance on future programs after achieving the APOLLO mission. However, in mid 1968 it was obvious that the Vietnam conflict required all available national resources in an attempt to win the undeclared war, putting pressure on all other programs. Escalating social unrest at some Universities and in some big cities added to this trend. The President, an ardent supporter of the space program, had to set new priorities.

One of the decisions taken by President Johnson was to put severe limitations on the NASA 1969 budget. After a program review in the early **August** days of **1968** the NASA Administrator Mr.James E.Webb, facing a budget limit of $ 3.8 billion for FY 1969, was forced to make painful decisions, one was a particularly difficult one, namely to discontinue production of SATURN I launch vehicles No.215 and No.216, and SATURN 5 launch vehicles 516 and 517. Tanks and engines of those vehicles were completed at that time, but clustering had not begun. They had no specific mission assignments at the time of decision, but were tentatively scheduled for roles in the APOLLO application program, then in the planning stage[22,24,25,26].

The first Apollo mission was performed in **December 1958,** with a flight around the Moon by Col.Frank Borman and his crew, in spite of all these problems. Half a year later, in **July of 1969,** the original goal set by President Kennedy, to put a man on the Moon and return him safely to the Earth, was achieved by Neil Armstrong and his crew.

A press release of NASA (No.70-162) of **August 17,1970** stated: "Manufacture of the fifteenth and final SATURN V booster stage (S-IC-15) has been completed by its builder, the Boeing Co., at the NASA-Marshall Center's Michoud Assembly Facility at New Orleans. ... S-IC-15 is scheduled to boost the APOLLO 19 Moon landing mission in 1974."
-Unfortunately, this never happened and the last vehicle stage ended up on display at one of the NASA Centers.

The NASA Press release No.75-150 of **July 9,1975** included the sad note:

"When the SATURN IB launch vehicle blasts off its Florida launch pad on July 15 to begin the joint U.S.-Soviet Apollo-Soyuz Test Project (ASTP), it will signify the end of an era.

The 32nd and final SATURN-class vehicle scheduled for launch, it will close the era of NASA's large expendable launch vehicles. Americans will not go into space until the reusable Space Shuttle comes into use in 1979.
All previous launches of SATURN I, SATURN IB and SATURN V vehicle have performed their missions successfully.
...
As it closes one era, the last of the SATURN's -- in its APOLLO-SOJUS mission -- may be helping to open an other: that of greater international cooperation in space."

In summary it appears justified to list all SATURN flights during the lifetime of this historical family of space launch vehicles:

Table 1: SATURN flight history

Launch vehicle	Launch date	Name	Mission
SA-1	10-27-61	-	Dummy 2nd stage
SA-2	4-25-62	-	Highwater
SA-3	11-16-62	-	Highwater
SA-4	3-28-63	-	Engine-out test
SA-5	1-29-64	-	1st 2nd stage flight
SA-6	5-28-64	-	Aerodynamic test
SA-7	9-18-64	-	LES jettison test
SA-8	5-25-65	PEGASUS II	Meteoroid test
SA-9	2-16-65	PEGASUS I	Meteoroid test
SA-10	7-30-65	PEGASUS III	Meteoroid test
SA-201	2-26-66	AS-201 / CSM-009	Re-entry test
SA-202	8-25-66	AS-202 / CSM-011	Re-entry test
SA-203	7-5-66	SAT IB	Hydrogen test
SA-204	1-22-68	Apollo 5	LM-1 orbital test
SA-205	10-11-68	Apollo 7	1st orbital manned flight test
SA-206	5-25-73	SL-2 / CSM 116	SKYLAB repair
SA-207	7-23-73	SL-3 / CSM-117	SKYLAB support
SA-208	11-16-73	SL-4 / CSM-118	SKYLAB support
SA-209	Back-up	- CSM-119	Rescue capability for crew
SA-210	7-15-75	ASTP / CSM-111	SOYUS docking flight
SA-501	11-9-67	Apollo 4	CM entry at lunar speed
SA-502	4-4-68	Apollo 6	Vehicle & system test
SA-503	12-21-68	Apollo 8	Manned lunar circumnavigation
SA-504	3-3-69	Apollo 9	Lunar orbit rendevouz test
SA-505	5-18-69	Apollo 10	Simulated lunar landing
SA-506	7-16-69	Apollo 11	1st manned lunar landing
SA-507	11-14-69	Apollo 12	2nd lunar landing
SA-508	4-11-70	Apollo 13	Accident, rescue of crew
SA-509	1-31-71	Apollo 14	3rd lunar landing
SA-510	7-26-71	Apollo 15	4th lunar landing

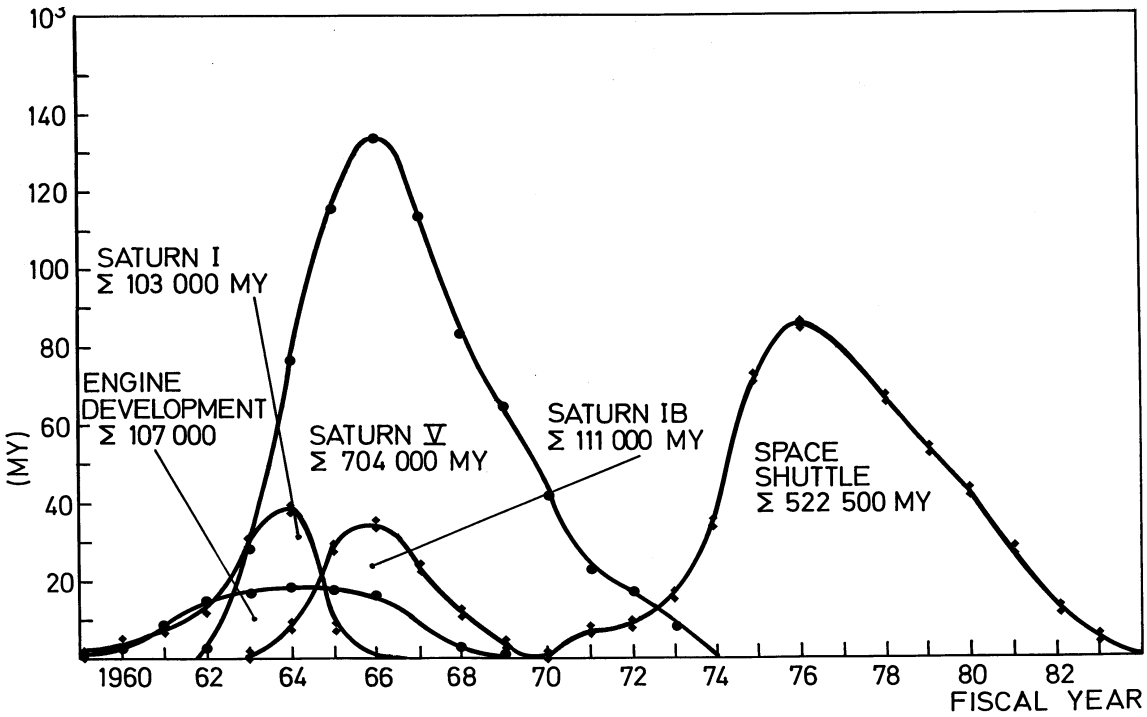
SA-511	4-16-72	Apollo 16	5th lunar landing
SA-512	12-6-72	Apollo 17	6th lunar landing
SA-513	5-14-73	SL-1	Orbiting SKYLAB

The left over hardware in the pipelines found a place at various exhibitions at Huntsville, Houston and Cape Canaveral to be inspected by the taxpayers and visitors from all over the World. Before discussing the accomplishments and returns of this program it is in order to list the respective expenditures.

Table 2: Cost of the SATURN Program (million current dollars)[25]

	Million current $	Equivalent engineering man-years
SATURN I	838	103 000
SATURN IB	1002	111 000
SATURN V	6540	704 000
Engine development	900	107 000
Launch operations	4	40
Lunar rover	39	330
Total	9323	1 025 370

Figure 12: Distribution of labor years (equivalent direct engineering man-years, if converted at current dollar values) versus time for SATURN I, SATURN V and SPACE SHUTTLE in comparison.



9. Program results

What was accomplished?

Politically:

- The United States of America prove to the World that it has not lost its pioneering spirit in conquering the frontiers of human existence.
- The United States of America demonstrated to the World that its social system and their technology was superior to that of the Soviet Union.
- Self-respect of the American people, suffering after the glorious successes of the Soviets at the beginning of the space race, was re-established.
- Military stature of the United States of America was improved, and in this way, keeping peace. The cold war did not turn into a hot war.
  Europe's freedom was strengthened.
- Looking at our home planet from the distance of the Moon demonstrated the uniqueness of spaceship Earth and showed the fragility of our Biosphere. The environmental movement received a big push.

Economically:

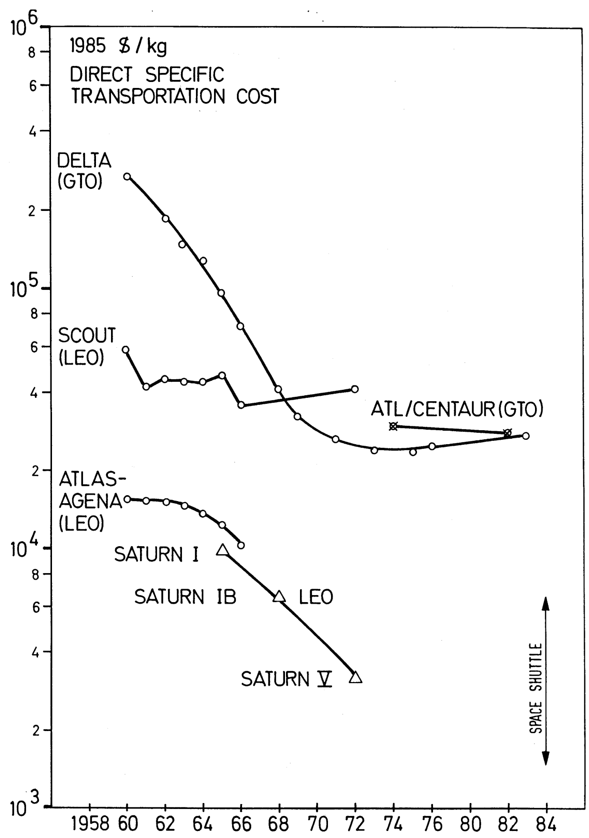
- The United States of America proved that the planet Earth is not a closed system, extraterrestrial resources would be available in case of need.
- Superior American products were exported at an increasing rate. The United States of America confirmed its dominating position in world trade. Aerospace products had no real competition abroad.
- An increasing number of American patents were registered, and sales of licenses to users in other countries increased rapidly.
- The American economy boomed for more than a decade

Science:

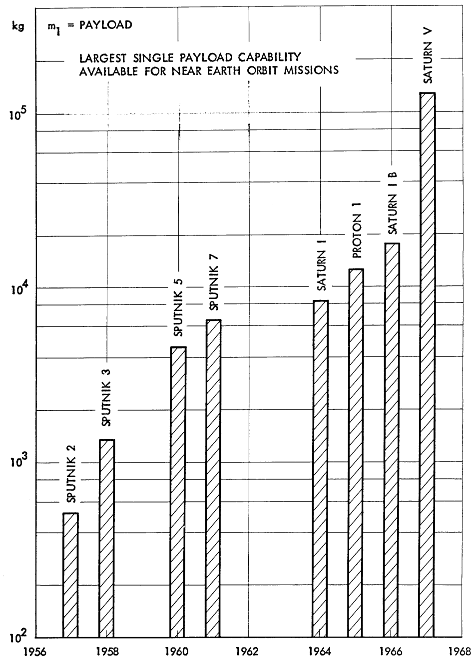
- The United States of America accepted the leadership in the field of space science and technology worldwide.
- Knowledge of the Moon was greatly enhanced. Nearly 400 kg of lunar materials were brought back to the Earth for analysis.
- Knowledge about the former and current state of the Earth and near space environment was considerably extended.
- Functioning and performance of human beings outside its home planet, in space environment, and on other celestial bodies was tested and confirmed.
- The science basis was broadened in many areas due to direct and indirect support resulting from research and development activities of the SATURN / APOLLO program.

Technology:

- An advanced space transportation systems were developed that cut the specific transportation cost to Earth orbit by an order of magnitude.
- In many areas the aerospace products and their many derivatives developed in the process of getting people to the Moon, particularly in the areas of materials, micro-electronics, energy systems, quality control equipment, medical equipment, made a quantum jump and secured the American leadership in technology for a long time to come.



- The United States of America regained the superiority in lifting capability from the Soviet Union in the mid sixties and retained it ever since.



What did we learn?

- If the goal is clear and visible to everybody, and the resolve of the national leadership is maintained, almost anything becomes possible.
- It pays off to think ahead of things to come, and be prepared to make a competent bid for a new project when it suddenly appears over the horizon due to unexpected socio-political developments.
- That it is people, not robots and computer who are the life blood of a program, and thus competent leaders are required to complete a program successfully.
- Plan early, but start late cutting hardware.
- Painstaking care must be applied to all elements of a demanding program, particularly when it comes to testing the flight hardware.
- Avoid the labor driftwood arriving on the scene struggling to get on the pay role of a new program that is promising good pay for a long period.
- Cost overruns are difficult to avoid in a program of high complexity and priority. The stability of the top management personnel plays a major role in this context.

- Lasting public support is essential for continued financial support of a program and must be carefully nurtured.

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