"The History of America's Giant Rockets"

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At the beginning of the Space Age, the payload capability of American launch vehicles lagged far behind those of the Soviet Union. While the first American satellites typically weighed just tens of kilograms, their Soviet counterparts had masses that exceeded a metric ton. And within a couple of years, Soviet engineers had built rockets capable of lofting almost five tons into orbit. Despite the initial lag, the technology needed to build giant rockets capable of lifting tens of tons into Earth orbit and beyond was already under development in the US.

Starting in 1956, a team of engineers lead by German rocket pioneer Wernher von Braun at the Army Ballistic Missile Agency (ABMA) began studies of a launch vehicle with a ten metric ton payload capability known as Saturn. With the availability of large engines still years away, von Braun and his team decided to cluster eight Rocketdyne H-1 engines burning kerosene and liquid oxygen (LOX) to generate almost 6,700 kilonewtons. To save time and money, the ABMA team extended the clustering concept to the first stage structure. They clustered eight stretched propellant tanks from their Redstone rocket around a single lengthened propellant tank from the Jupiter IRBM.

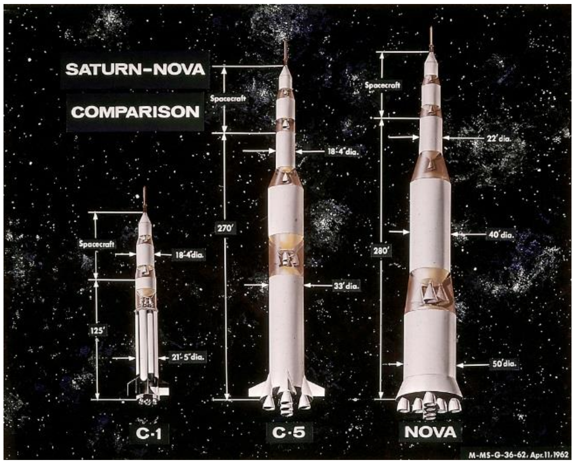
In 1960, when the Saturn program was officially transferred to NASA, the configuration of the Saturn I was finally settled. Its second stage would use a cluster of six Pratt & Whitney RL-10 engines burning the high energy combination of liquid hydrogen and LOX to produce 400 kilonewtons of thrust. In its original configuration, which was never flown, the Saturn I would be topped by the high performance Centaur upper stage sporting a pair of RL-10 engines.

The first orbital launch of the Saturn I, SA-5 on January 29, 1964, was America's first heavy lift rocket launch. The inert second stage and its ballast had a record orbital mass of 17,100 kilograms. (NASA)

For its first four test flights starting in 1961, the Saturn I was launched with dummy upper stages. The next six flights in 1964 and 1965 used live second stages with the last five orbiting boilerplate Apollo spacecraft. In the end, all ten flights of the Saturn I were successful and generated the knowledge necessary to build still larger rockets.

Heading to the Moon

As work began in earnest on the Saturn I, von Braun and his team had already begun looking ahead to the next goal for manned spaceflight - the Moon. Four successively larger versions of the Saturn were studied that would rely on not only the H-1 and RL-10 but also on various combinations of new more powerful rocket engines. The largest was Rocketdyne's F-1 which burned kerosene and LOX to produce 6,672 kilonewtons. As with the Saturn I, the upper stages of the advance Saturns would also use high energy cryogenic propellants. Rocketdyne got the contract to develop the J-2 engine which produced 890 kilonewtons of thrust for the larger upper stages.



NASA studied a variety of super-rockets to send the first manned spacecraft to the Moon. The largest, the Nova, is shown in comparison to the Saturn I and V. (NASA)

NASA also began to study a rocket, called Nova, that could launch a simple direct ascent lunar landing mission in one shot. While many configurations were examined, the preferred designs would cluster eight F-1 engines in the first stage to produce an astounding 53,400 kilonewtons of thrust at lift off. Depending on the exact configuration of the upper stages, the Nova would have been capable of orbiting about 200 metric tons of payload.

But in the end this leviathan was never built. It was too expensive and take too long to develop in time to meet the 1970 deadline set by President Kennedy for the first manned Moon landing. In the end the US decided to use the LOR or "Lunar Orbit Rendezvous" option where a small, purpose built lunar vehicle would perform the actual landing leaving the return capsule in orbit. The payload required for this option was just small enough to launch on a single rocket - the Saturn V.

Even though the Saturn V was smaller than Nova, it would still be the largest rocket ever built by the US. The first stage would use a cluster of five F-1 engines generating over 33,000 kilonewtons at liftoff. The cryogenic second stage used a cluster of five J-2 engines while the third stage, which would provide the final boost towards the Moon, had a single J-2. Standing 111 meters tall with the Apollo mounted on top, the Saturn V could orbit 100 metric tons or send 35 tons towards the Moon.

In addition to the Saturn V, a launch vehicle more capable than the Saturn I was needed to support Apollo flights in Earth orbit. Called the Saturn IB, it incorporated many upgrades in the first stage based on lessons learned during the Saturn I development flights including uprated H-1 engines that now provided 7,300 kilonewtons at liftoff. The original second stage was also replaced with a modified third stage from the Saturn V. This new launch vehicle would now be capable of lifting a payload of 15 metric tons into Earth orbit. Its maiden flight, AS-201, orbited the first unmanned Apollo spacecraft in 1966 and the Apollo 7 manned flight in October of 1968.


The final Saturn IB launched the successful ASTP mission in July of 1975. After the retirement of the Saturn, NASA would rely on the Space Shuttle. (NASA)

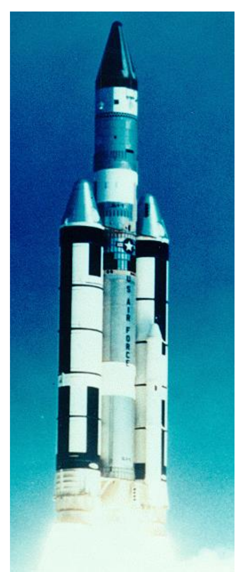
Meanwhile development of the Saturn V proceeded steadily throughout the 1960s. In November of 1967, the first test flight of the Saturn V was launched. Unlike the conservative approach used in the development of earlier launch vehicles, the unmanned flight of Apollo 4 would be an "all up" test with three live stages. This flight along with the subsequent Apollo 6 unmanned test flight were not only successful but also provided the first flight test of the Apollo spacecraft under conditions it would encounter during its return from the Moon. The first manned flight of the Saturn V, Apollo 8 launched in December of 1968, sent the first humans into lunar orbit. And after another pair of manned flights to test all the components of the Apollo spacecraft and the Lunar Module, the sixth Saturn V successfully sent Apollo 11 on its historic mission to land on the Moon.

The first Saturn V, shown here before its launch on November 9, 1967, was a bold test flight with three live stages. It successfully sent the unmanned Apollo 4 on its mission and flew without failure another dozen times before it was retired in 1973. (NASA)

Over the following three years, the Saturn V successfully launched another half dozen lunar expeditions. The last flight of the Saturn V in May of 1973 used a two-stage version to orbit America's first true space station, Skylab. Over the next year, three crews would visit Skylab flying modified Apollo spacecraft launched into orbit on the Saturn IB. The last flight of the Saturn family was for the ASTP mission in July of 1975 when a Saturn IB launched the last Apollo into orbit to dock with a Soviet Soyuz spacecraft. During a decade and a half of flights, all nine Saturn IB and 13 Saturn V launches were successful - a record unequaled by any other family of launch vehicles to this day. NASA now planned to rely on military launch vehicles and the Space Shuttle for its future heavy lift needs.

Military Heavy Lift

After the development of Saturn started, in 1959 the USAF decided to build a heavy lift launch vehicle based on their Titan II ICBM to meet their anticipated requirements. A pair of five-segment, three-meter in diameter strap-on solid rocket motors generating a total of 10,500 kilonewtons lifted the Titan II core off the ground. After these giant motors burned out, the liquid fueled core would ignite at altitude and continue the ascent. A restartable third stage called the Transtage, designed to maneuver the payload into its final orbit, finished off the stack. Called the Titan IIIC, it could lift 13 metric tons into low Earth orbit - comparable to NASA's Saturn I.



The USAF decided to develop its own heavy lift capability based on its Titan II ICBM. Here we see the first test flight of the Titan IIIC on June 18, 1965 which would remain in service until 1982. (USAF)

The first flight of the Titan IIIC took place in June of 1965 lifting the Transtage and lead ballast into orbit. Even though its low orbit capability was never used operationally, the Titan IIIC did launch a variety of military communications, early warning, and technology test satellites into high Earth orbits for almost two decades. When a low orbit heavy lift capability was finally needed in 1970 to launch the latest generation of reconnaissance satellites, the USAF introduced the Titan IIID. Essentially a Titan IIIC without the Transtage, this new launch vehicle was used for a dozen years in parallel with the Titan IIIC.

In 1974 the Titan IIIE made its debut. It was a Titan IIID modified to carry the high performance Centaur stage which previously had only been used with the Atlas. This rocket launched large interplanetary probes for NASA which, with the retirement of the Saturn, lacked a heavy lift capability. Eventually the Titan IIIE-Centaur launched a pair each of Viking, Voyager, and German-built Helios spacecraft.

It was originally planned that the Space Shuttle, with its advertised 29.5 metric ton payload capacity, would orbit military satellites starting in the early 1980s. But a series of delays made an interim launch vehicle necessary. In 1982 the USAF introduced the improved Titan 34D. It had a pair of 5 1/2-segement solid rocket motors and the propellant tanks of the core were stretched. The Titan 34D could carry a variety of upper stages to boost payloads into high Earth orbits or be flown without any to send heavy payloads into low orbit.

After the Challenger accident in 1986, it was realized that the Space Shuttle could not reliably meet defense launch needs. Instead the Titan 34D continued to be used until 1992 and a new heavy lift vehicle, called the Titan 4, was developed. The core stages were further stretched to increase its propellant load and a pair of larger, seven-segment solid rocket motors generating 15,900 kilonewtons of thrust at liftoff were employed. In addition, all the avionics and other systems in the rocket were upgraded. But all these improvements over the decades had made the Titan very expensive to fly. High costs doomed the Commercial Titan 3, which was based on the Titan 34D, after just a handful of launches. Today a further improved but still expensive Titan 4B is used almost exclusively by the military to meet their heavy lift requirements.

Today the Titan 4B provides a heavy lift capability primarily for national defense payloads and on occasion for NASA. Here we see the launch of the Cassini Saturn probe on a Titan 4B-Centaur on October 15, 1997. (NASA)

Adapting the Shuttle and Beyond

Even before the maiden flight of the Space Shuttle, NASA planners recognized that the Shuttle might be replaced with an unmanned pod capable of carrying larger payloads without endangering a crew. Starting in 1977 NASA began studies of cargo variants of the Space Shuttle capable of orbiting in excess of 90 metric tons. After the loss of Challenger, NASA and the USAF began investigating a cargo version of the Shuttle in 1987 called "Shuttle-C". Very quickly the USAF dropped out of the program opting instead to pursue the development of the improved Titan 4. After so many problems, they decided to phase out military use of the Shuttle and any vehicle derived from it.

Proceeding alone, NASA continued study of the Shuttle-C. To minimize costs, the Shuttle-C would have used as much Space Shuttle hardware as possible and be configured to remain fully compatible existing support equipment. Depending on the exact configuration, it could orbit as much as 77 metric tons of cargo - more than enough to launch large modules in support of the International Space Station. Other more advanced concepts which relied less on existing technologies or facilities were also studied as part of the Shuttle-Z. Up to 136 tons could be orbited but the Shuttle-Z would take even longer to develop and be much more expensive.

A launch that never was: Here we see the launch of the Shuttle-C. Relying on Shuttle hardware, this heavy lift vehicle was cancelled in 1991 to make way for more advanced and cost effective designs. (NASA)

Finally the Shuttle-C and studies of other Shuttle-derived vehicles were stopped in 1991 in a cost cutting move. It was felt that a totally new launch vehicle developed by industry with various degrees of government involvement would offer much more cost effective access to space. In the near term, NASA, like the USAF, relied on the Titan for their heavy lift needs. Now significantly modernized and upgraded rockets from the venerable Delta- and Atlas- families of launch vehicles are becoming available that are less expensive than the Titan. In the future, the totally reusable VentureStar with a payload capacity in excess of 25 tons promises to cut launch costs by a factor of ten. No matter how the technology evolves, the need for a heavy lift launch capability will exist for some time to come and new giants will be built.

About the Author

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