Solids of Saturn

A quick and dirty run through the various proposed uses of Solid rockets to boost Saturn.

Ok, another quick document. This one covers the various Solid rockets intended to be used with or to replace Saturn's First stage straight up. I won't be covering Ullage or upper-stage solid rockets with this document

Segmented SRMs:

United Aircraft, Chemical System's Division (commonly abbreviated as either UA or CSD or CTD depending on the year) segmented 120" "TITAN" SRM family

There are 4 of the United Aircraft 120" SRMs considered for the Saturn Program. Two of the four types went on to fly on later Titan rockets.

UA-1205(Gen2) The UA-1205 Gen2 was the limited-run MAN RATED UA-1205 developed to "test" the MOL (KH-10 Dorian) upper stage. In the case of Man rating a large SRM, the process includes thrust cancelation devices (the giant circular ports on the nosecone in this case) as well as ways to "extinguish" the flame in the combustion chamber of the rocket itself. The latter is almost always a form of detonation cord that splits, breaks, or otherwise ruptures the outside of the rocket's pressure vessel. The UA-1205(Gen2) had detonation cord on the "outside" point furthest away from the Core stage rocket body. The Gen2 UA-1205s had a large fluid tank for the NTO that was used for thrust vectoring. The large tank is not modeled in BDB, only the smaller diameter 3rd generation tank is. After production began, the danger posed by these thrust cancelation ports was realized. This potential danger is why the ports disappear quickly after the Titan MOL test flight.

UA-1205(Gen3) The Gen 3 version of the UA-1205 was the final production version. This SRM is slightly lighter than the Gen2 and has the thinner TVC fluid tank we have come to know and appreciate in BDB. It was not man-rated and was only safe for unmanned launches, but that did not stop it from being drawn in as an S-IB first stage replacement. In a 5+2 or 6+1 arrangement, the UA-1205 could be used to launch supply craft to future space stations. The S-IVB stage forms the control point and 3rd stage of the rocket stack. The Gen3 UA-1205 was also chosen to power the Saturn II INT-18 on many of it's potential launch profiles. It is possible to convert a Gen3 UA-120x to man-rated. This involved adding the detonation cord opposite of the core stage side. As stated above, the blowout holes in the nosecone were more dangerous than the saftey feature they envisioned as. Flying debris and rocket efflux shooting up toward manned portions of the rocket were now considered extreme hazards in their own right.

UA-1206F. Twice the UA-1206 is mentioned in Saturn Documents, once in conjunction with early work on the Saturn INT-18. And secondely as a larger replacement for the S-IB stage than the UA-1205 as listed above. However this UA-1206 is NOT the rocket that flew on the Titan

34D. It was a six segment SRM. The Titan 34D's UA-1206 being a 5.5 segment SRM. Hence the letter F was added to the designation above. Given this engine does not appear in the final INT-18 documents and only the early ones, it is believed that 1206 was shelved before 1968 when the final report was drafted. Had the UA-1206F been built it would have been approximately 60 inches longer than the UA-1206 that flew on Titan 34D and only about 120" shorter than the UA-1207.

And of course, the UA-1207 can not be forgotten. UA-1207 with Man Ratting features was suggested in a 5x2 launch arrangement as a high capacity replacement for the Saturn S-1B first stage. Also, UA-1207s in 2, 4 or 5 rockets created the 0 stage for the Saturn II in heavy-load configurations. The five by SRM arrangement is not in the final report due to infrastructure costs at the launch pad. The UA-1207 was also considered the smallest SRM in the out of LEO launches for the Saturn MLV program. Remember, Earth orbit Saturn Rockets received an INT designation in the MLV program and beyond LEO orbit the rockets were designated as MLV. It the beyond earth orbit function, the UA-1207s would light on the pad with some of the F-1 engines on a Saturn S-IC derived first stage. Typically it was 4 of 5 or 4 of 6 F-1s and the four UA-1207s. However, the UA-1207 was barely an upgrade. To most launches, it added a few hundred kg of mass to a launch beyond Earth orbit.

The fourth UA-120x rocket (ha! You thought I had already given you 4,) was the UA-1208. The eight full segment UA-12x rocket was a dark horse. The rocket was too heavy to move easily and was too tall to assemble in place. While new infrastructure could solve this, it was far easier to use a shorter SRM that was wider and easier to build. The UA-1208 was proposed but never fully integrated into the Saturn II INT-18 studies. It would have been in a 4x arrangement only. The UA-1208 also was mentioned early in the rest of the Saturn MLV studies for Beyond LEO missions. No calculations are available to understand its performance in this role. Thus, in KSP, if you WANT to play with the UA-1208, by all means. Please remember, the UA-1208 never made it into any final reports, and data is incomplete at best.

Three companies, one segment size.

As mentioned above in the UA-120x section, The industry engineers working in various aspects of the MLV program looked at the 7 and 8 segment UA-120x rockets. They found that there were many situations where the cost to use them was far outweighed by the almost non-existent gains. Most of these engineers knew that United Aircraft, Lockheed and Thiokol were all working under contract to the USAF to develop an "improved" SRM of 156" in diameter. 156" was chosen as it was the maximum diameter that a train hauling segments from the production site could reasonably carry, by dimension… The dimensions fact will come into play later. Throughout this section, the USAF is branded as the contract issuing body. These contracts were let under the instigation of both the Silverstein commission and DARPA. The USAF was the organization chosen to issue these contracts because they had a stake in the program (for the Titan III rockets) and were not directly involved in any of the NASA contracts for Saturn. It was to keep these SRMs from mudding the waters as it were in the crash program that was Saturn.

CTD-156: United Aircraft CSD was working on the CTS or CTD-156 segment. It was a scaled-up UA-120x segment design with the same fluid injection thrust vectoring and similar structures. United Aircraft, however, was struggling as neither the thrust vectoring nor the binding agents for their solid fuel were working well in this larger scale. Much of this story sounds identical to the Westinghouse J40 jet engine of 15 years earlier. I mention the J40 only because it's story is widely published, where the CTD-156 is obscure by a factor of 500. While many provisional drawings of Titan and Saturn show the United Aircraft CTD-1563 or CTD-1564, it was never perfected. It would cause many issues with the future of United Aircraft in the SRM world.

Thiokol-Lockheed-Aerojet

These three companies were allocated funding for new SRM designs just as the ink was drying on the original Titan SR47 contract. SR47 being the USAF designation for the 1st generation UA-1205, not that it was ever on a contract after the initial prototypes were purchased.

At the time in question, NASA and the Saturn program were spooling up. Most solid rocket manufacturers lost many engineers to other companies working on the Saturn program directly. This led to a rare arrangement between Aerojet, Thiokol, and Lockheed Space and Missiles. Lockheed S&M had many engineers, but most were involved in "shh secret" projects… you know… Discov…err Corona etc. The few engineers still working the solid rocket side of Lockheed were tasked to develop a 156" segmented SRM, a Monolithic 156" SRM and appropriate controls for manufacturing and altering the rocket's flight profile. Thiokol likewise had a shortage of engineers and chemists available when they were tasked to develop a next-generation 156" segmented SRM in steel and composite structure segments. Aerojet, smarting over their recent loss of the contract to United Technology for the Titan III rocket SRMs, was given a contract, more conceptual than the Lockheed-Thiokol contracts. Aerojet was to develop a segmented 260" SRM for the USAF. As part of the contracts, the USAF realized a "Sharing the workload" would be the only path to success. This shared set of contracts led to some exciting things.

For example, one of Lockheed's steel 156" test segments fell off the train during shipment to the test site. After recovery and re-verification, the segment was re-shipped. No repairs were needed. After its use in a burn test of the Lockheed fuel mixture, the Lockheed segment went to Thiokol, where they used it to test one of the many forms of thrust vectoring that had to be verified under the contract. After the refurbishment of the case post-test, it went to Aerojet for use as a subscale demonstrator of their 260" segmented technology. Through the whole process, the segment only needed to be cleaned up and repainted for repairs. At some point this segment even made its rounds to United Aircraft for an unknown purpose.

Thiokol and Lockheed were tasked with dimensionally similar segments and testing their take on each of the three "exclusive" thrust vectoring concepts as the USAF understood at the time. Jet-tab, Fluid-injection, and I kid you not, Thrust Blocking flaps. The latter proved to be the most dangerous, with every TBF flying off as so much shrapnel during tests. The TBF flap debris then showering the test stand with debris. Jet tab also proved to be a no-go because the high heat of a full-up Rocket test was higher than the control surfaces could withstand. Lastly, Fluid injection was unworkable due to the significantly larger diameter of the thrust cone. The larger diameter and higher core pressures invalidating the entire fluid injection concept. During this time, a Lockheed Engineer discovered that bands of metal with a longitudinal curvature overlapped could effectively re-direct thrust without the ablation and heat issues that affected jet-tabs. This system was initially patented in 1967ish as “Lock-Roll TVC” Latter, in its production form, it would be called Flex-Seal. Hmm, not the spray rubber sealer we all see in those zany infomercials of today.

As part of these contracts, Lockheed was to build a monolithic 156” SRM. Thiokol was to construct a Composite wound segment. Both companies built their test motors to requirement. The Lockheed monolithic engine being the rough equivalent to a 3 segment 156” motor. The Final design pursued by Thiokol appears on several of the final MLV drawings.

Many histories talk about how Lockheed and Thiokol had a spirited competition in this SRM program. However the facts remain that much of the test hardware that was re-usable was moved from company A, to B, to C showcasing the unique nature of this set of contracts. I find this interesting given the spirit of co-operation during and indeed after the contract period that historians would characterize these interactions that way.

A production 156” SRM?

In the end, while the Lockheed-Thiokol 156” SRM was only showcased in its production form in 2 pieces of MLV derived art, the 156” SRM would live on, sub-scale, in the 148” Space Shuttle SRB. The smaller diameter is due to perceived shipping issues.

Significant differences between a MLV 156” SRB and a Space Shuttle SRB other than the diameter: The 156” SRB would have a cylindrical cuff immediately below the nosecone, the nose cone base being the larger diameter of this cuff. The cuff is the forward attachment point for the SRB. The base segment would have a complex shape, Bell-shaped except on the side attached to the rocket. That side would look and be as thick as the cylindrical cuff up top. Like the Space Shuttle SRB, the 156” segments would be 2 “factory joined” sub-segments, but unlike the Space shuttle, they would be uniform length with a maximum length of 200”. The Space Shuttle segments each have a unique dimension as the segments are divided by mass, not length. Most production 156” drawings show 3 or 4 segments. The author believes that the 3 segment version would have proliferated and the 4 segment version rarely if ever used.

MONOLITHIC Just good Solid fun

Large monolithic rockets have significant problems to overcome. Least of which is being rather un-wildly to move, or use. Yet Monolithic SRMs offer significant reliability increases and weight savings. There are 2 Large and one “Standard” size monolithic rockets to talk about on the Subject of Saturn. Working from smallest to largest:

Thiokol M55/TX-55/TU-122: This is the first stage of the LGM-30 Minuteman ICBM that was just entering service during this timeframe. The motor, about the size of a Strap on Agol, but had a significantly different thrust profile. This stage was considered for many parts of the Saturn Program, most infamously the Saturn II INT-19. In the INT-19, the M55 was carried in groups of 2, with upto 12 M55s on the Saturn S-II stage skirt. The payload of the INT-19 varied from 13,000kg with 2 M55s ignited at sea level to 34,000kg with 8 M55s ignited at sea level and 4 more ignited at initial M55 burnout and jettison. The limiting factor in this proposal was the Sea Level rated J-2 engine, as the J-2 would be ignited on the ground with the SRMs.

Lockheed 156” Monohull SRM. There is no known designation of this. But the Lockheed 156” Monohull was considered for Saturn… BRIEFLY. Manufacturing and shipping the SRM being the stumbling block. But a Monohull SRM would give almost 200lbs more payload to a deep space mission vs the same sized segmented 156” SRM. That is not a small feat. It likely would have looked almost identical to the Space Shuttle SRB with the changes described above for the Thiokol 156” SRM.

Aerojet AJ-260. Many superlatives could be given this monster. Likewise, there are many ways the AJ-260 was envisioned as being used by NASA. Unlike Lockheed, Aerojet planned for their future, and had purchased land just outside of the USAF base at Cape Canaveral to manufacture, load, test, and deliver these giant rockets to the flight line. Initially conceived as a high thrust high impulse rocket, the AJ-260 was too powerful to use. Thanks to Lockheed and Thiokol for a new chemical composition for their fuel, Aerojet brought about a reduction in thrust and an increase in burn time. Aerojet would produce 3 test engines, reusing one hull in the process. During its contract for a 260” segmented SRM, Aerojet started wondering why they should settle for the problems inherent in the segmented design, predicting failure points in the segmented design, long before Challenger in 1986. Mind you, one company deciding to avoid potential failures does not make a warning. Aerojet’s concern lay more with possible manufacturing defects as it was impossible to test the segment joints after assembly loaded with fuel. By the time the Space Shuttle flew, technology was such that manufacturing defects were much easier to diagnose in advance. That said, Aerojet re-negotiated their contract with the USAF to test the feasibility of a Monolithic large diameter engine. The 156” segment that rolled off the train mentioned above was transferred to Aerojet, which turned it into a subscale test hull. In the Tests, endcaps were installed, and then the engineers and production specialists at Aerojet attempted to fill the sealed segment with fuel and then test it. It was a single 156” segment tested on the same test stands as Lockheed and Thiokol’s 156” rockets. The results were promising enough that the USAF modified Aerojet’s contract for segmented or Monolithic construction.

Initially conceived as a Saturn S-I stage replacement, the AJ-260 was quickly determined to be too powerful. The engineers and chemists returned and reformulated the solid fuel. The AJ-260 would be capable of using either fuel formula depending on launch needs. Initially sketched in as a replacement for the Saturn I (covered previously in the Saturn MLV in LEO article,) the INT-05 was too powerful with the original fuel. Then the INT-05A and INT-05B were designed with a new fuel formula and both short and long hull AJ-260s. The AJ-260 was tested twice in the Short hull flyable configuration. Had further Saturn flights been funded, there was a good chance that AJ-260s would have flown given the local manufacture and already validated construction and fuel formulation.

During the early AJ-260 design process, no serious thought was given to how to attach it to a Saturn V. There was no perceived need at the time. So, the AJ-260, as designed, distributes its thrust only through structures at the top of the stage. Combine this with the fact that the Saturn Rocket is designed to absorb thrust from the BOTTOM of the stage you can see issues abound. Since you could not just slap the AJ-260 onto a Saturn V, a new structure was designed. The installation consisted of a lengthened S-I to S-II interstage barrel with a traverse beam. The beam would carry the thrust of the AJ-260s to the interstage, and have conic nosecones and a small fuel tank to which the AJ-260s would be attached. The height of the fuel tank is such that an AJ-260 would fit nicely underneath it, next to the MS-IC stage. The fuel in this fuel tank would feed into the MS-IC stage. The AJ-260 would then either be used as a Thrust augmentation device or as a Stage Zero device.

The AJ-260 would use the original fuel formula and generate a staggering impulse as a Stage Zero device. One that only the Mighty Saturn MLV could absorb. Once thrust dropped below 70% “optimum” thrust (about 85% fuel depletion), the F-1A engines would be ignited. In this mode of operation, only enough Kerolox to power the F-1 engines through that last 15% of solid fuel burn.

Using the newer fuel formula, the AJ-260 would be used as a Stage 1 thrust augmentation system. Some or all of the F-1 engines would ignite on the ground along with the two AJ-260s. The AJ-260s would burn to depletion and separate, taking the now empty fuel tanks and nose cones.

With the Saturn MLV, it does not matter what way you use the AJ260s, Any way you do so provides more payload to any orbit than any other scheme of Saturn rocket proposed and exceeds most of the Nova program rockets in payload performance.

With these various sold rockets, there were options to extend the Saturn Rocket in many ways.

Postscript, obligatory why the Saturn C-8 sucks… aka C-8 bashing

Please remember, Saturn C-8 is not a Nova Rocket. The Saturn MLVs with any large solid rockets in this document are buildable with only minor infrastructure changes at KSC. These rockets, having as much or more potential than a C-8. You can argue that the AJ-260 would add a high cost, but it is still less than just making a new VAB for the Saturn C-8, let alone an all-new factory at Michoud and all new ships to transport… The AJ-260 factory exists already, after all… Right next door to KSC.