Saturn C-2 and C-3, the Unflown and Unloved Rockets in the Saturn Family

The Saturn family all started because DARPA, the Defense Advanced Research Projects Agency, was looking to the future of the fledgling space program. DARPA, often shortened to ARPA to seem less militant, had money and a goal of getting an American Astronaut into space. DARPA utilized this project to push technology to ensure space dominance by the United States. DARPA approached the nearly out-of-work ABMA or Army Ballistic Missile Agency and Von Braun to utilize their rocketry know-how to build a cheap large, diameter rocket to get payloads to space. The Projected growth in the size of satellites is somewhat staggering and astounding. Mind you all; this was still in the days when a Digital computer was the size of a large school.

Von Braun and team immediately made a significant compromise to keep things cheap and quick. They would reuse the tooling for both their Redstone and Jupiter missiles. With this tooling, they could make cylinders any length they wanted at the diameter of these two rockets. This decision added mass and complexity to the design but likely cut several years off its design process. Of course, this Cluster stage was called Juno V as we all know. The Juno V stage would be the basis for several rockets and rocket stages before finally flying as the Saturn S-I stage a few years later. ABMA and Von Braun proposed to DARPA that the rocket should be as modular as possible so that different parts could be swapped from one rocket to the next to make a new different rocket. In early 1960 these building block stages were as follows:

- Juno V (C-1) What would later become the S-I and, after modification, the S-IB
- Juno V (C-2) Similar to the above but 65" shorter to reduce maximum fuel and oxidizer to 650,000lbs
- S-I Monohull Replacement monohull for the C-1's Juno V
- S-I Monohull Replacement for the C-2's Cluster tank with a monohull, shorter than the C-1's Monohull option.
- S-I New twin F-1 Engine first stage for C-3 of 320" diameter, monohull construction
- S-II-260 (C-2) 4 engine 260" Diameter stage for C-2
- S-II-320 (C-3) 4 engine 320" Diameter 2nd Stage for the C-3
- S-III (C-2/C-3) 2 J-2 engine 220-260" Diameter stage, usable as the 2nd stage on C-2 or the 3rd stage on C-3
- S-IV 220" (C-1) Original four RL10B-3 powered stage for the C-1 rocket
- S-IV 240" (C-1) Finalized six RL10A-3S powered stage for Saturn I Rocket
- S-IV (C-2) 240" Four RL10B-3 powered upper stage for the C-2 rocket
- S-IV (C-3) 240" six RL10B-3 powered upper stage for the C-3 rocket, a RL10A-3S powered version would be the final C-2 variant
- S-IVB (C-1 & C-2) Standard S-IVB-100 from the Saturn IB rocket***
- S-IVC (C-3) 260" S-IVB design with inline (nose to tail) docking for similar S-IVC stages to allow building in space and refueling of the S-IVC stages.
- S-V (C-1/C-2/C-3) Centaur C. Was an improved Centaur that would carry its insulation to stage ignition and then burn for departure. Power was by 2x RL10B-3 engines, and the skin was

thicker, making it no longer a proper Balloon tank structure. Extra HTP Peroxide tanks for extended use of the Reaction Control System.

Some notes here:

1. The S-IV (C-2/C-3) jettisoned much of it's insulation at stage ignition. Insulation was not discarded before stage ignition to reduce boiloff during any early cruise portions of the flight. The same is true for the S-V stage.
2. The RL-10B-3 is the uprated "XLR-119" that we have heard about for years but never knew much about. It is unclear how Pratt and Whitney applied any Nomenclature to their engines, so when more information is available, we may be able to share it. The designed thrust (never reached in testing) was 20,000lbs force.
3. The RL10-A3S is not an uprated RL10A-3 but rather just an RL10A-3 with Saturn-specific modifications. Thrust is still 15,000lbs force.
4. Initially, the H-1 engine topped out at about 188,000lbf thrust. Latter, Saturn I's would fly at 200,000lbf thrust, and there was room to grow to about 250,000lbf thrust via the H-2 Engine upgrade. While not much is known about the latter H-2 we do know it was a basic H-1 with a new type of Turbopump that was faster and more efficient, which allowed the pressure in the combustion chamber to be raised, creating more thrust.
5. Much of this article is based on the Preliminary design for the C-2 from Marshal Space Flight Center (eg ex ABMA.) These building blocks were not "Solid" and could still change… Just look as the S-IV stage for Saturn I… it grew 20" in diameter and gained 2 engines after said PDR was released!
6. North American Aviation, the designer and fabricator of the S-II stage, chose to delineate the various S-II stages by their diameter as the stages were unique in each diameter. So the, Saturn V's S-II stage was called S-II-396 for example, the last number being the average diameter of the stage in inches. Since only one S-II stage was proposed for each of these rockets at the specified diameter, we will use the same terminology in the document.
7. KSP scale and BDB are referenced in this document. KSP being Kerbal Space Program and BDB being the Bluedog Design Bureau mod for Kerbal Space Program. The intended original audience of this document.
8. While this document lists the S-IVB-100 as appropriate for the Saturn C-2 the Saturn C-2 was actually canceled about the same time as the development of the lower massed Orbital vs Lunar Saturn S-IVB.

Saturn Stage Nomenclature:

NASA and ABMA/MSFC did an abysmal job with stage designations, lots of assumptions were made that you knew what rocket you were talking about when talking about, say the S-I stage.

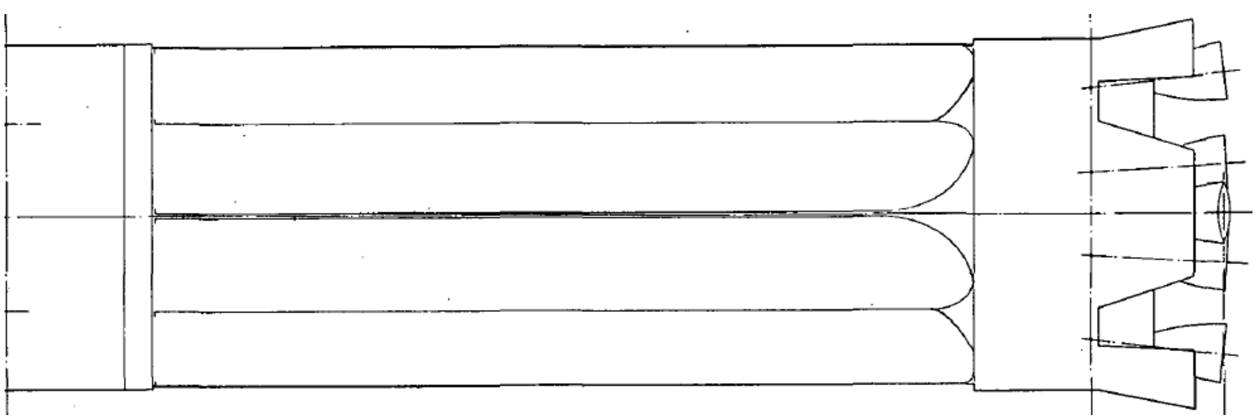
SATURN C-1	S-I, S-IV, S-V
SATURN C-2	S-I, S-II, S-IV, S-V
SATURN C-3	Uprated (new)S-I, S-II, S-III and S-IV or S-V

The above text is directly from *The Saturn C-2 Preliminary Design Phase I* document. Utilizing the S-I stage, the differences between the C-1 and C-2 stages are relatively minor… the C-2's S-I is shorter and carries 200,000lbs less fuel. Conversely the C-3's stage is all new 320" diameter mono hull with 2 of the new F-1 engines. But they are all called S-I. Same with S-II, and S-IV each rocket that has one of these stages has a uniquely, or nearly uniquely to it stage. For the purposes of clarity, in this document any stage named will have it's base rocket in parentheses eg S-I(C-3.) Please note that there are no references to a S-IB-2 as listed on Astronautix or Wikipedia (quoting Astronautix.) That appears to be a fictitious name to separate it from the Saturn IB's S-IB stage on Astronautix. As stated above, we will use North American Aviation's designation for their various S-II stages because they A) make sense and B) give you the size of the thing, in one simple package.

Building Block S-I:

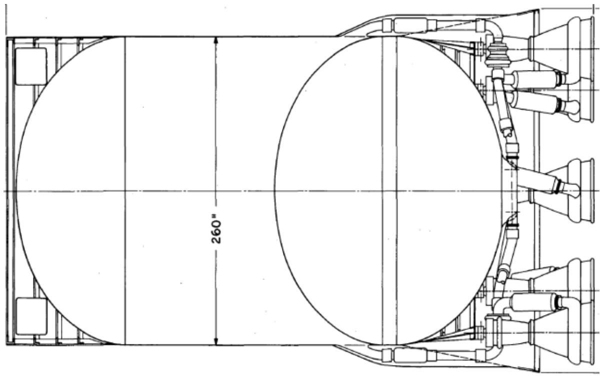
The S-I stage on the C-2 rocket differed only slightly for the Block 1 Saturn I Rocket that first flew on 10/27/1961. The major structural changes were in shortening the stage by 65" to reduce fuel capacity to a maximum of 650,000lbs between the fuel and oxidizer. There were no drawings with the S-I stage carrying fins on the C-2 rocket that the author could find.

Like the Saturn I rocket, the S-I stage for this rocket was large, kludgey, and the only thing it had going for it was low cost to begin manufacture due to the reuse of many of the Redstone/Jupiter tools.



Building Block S-I Monohull:

No NASA designation was listed for this unique Saturn C-2 development. Designed as a production standard for the C-2's S-I stage, the Mono-hull used 8 H-1 engines in a single ring around the outer edge of the stage. None of the engines were particularly submerged like the original Cluster S-I as described above. Because of the nature of the simplified construction, there was no provision in the stage at the time of the source material, for Fins to be attached. The total tank and engine length is 496" long. Compared to the S-I Cluster stage at 1915" long a significant size shrinkage can be seen. This led to improvements in payload to orbit and total rocket size, which can lead to reduced launch costs. Suggested designation is **S-IM(C-2)** M for monohull in this case.

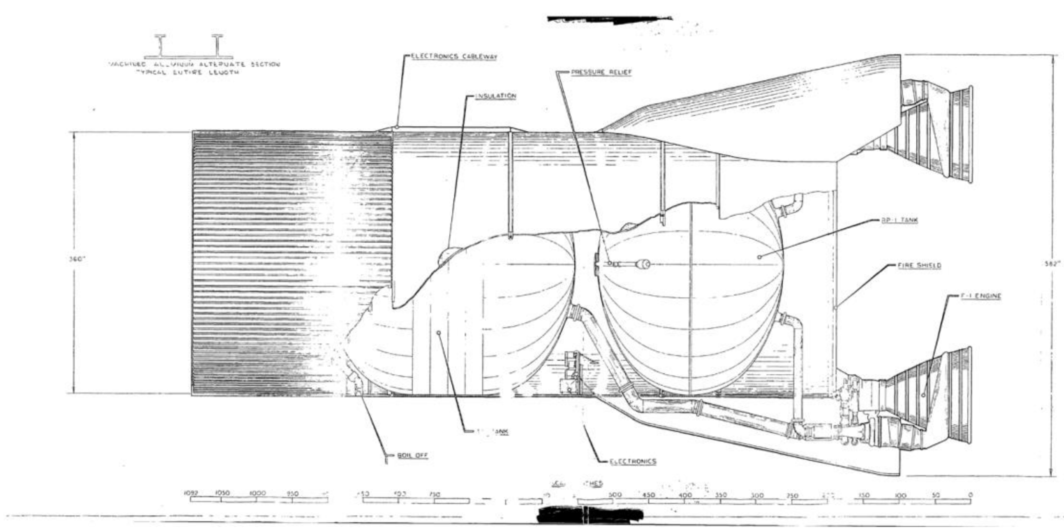


With a modest estimated 30" stretch, the S-IM(C-2) could become the S-IM(C-1) for Saturn I rockets. No document found to date covers the Saturn I usage, however. Stretched size is estimated based on adding 200,000 of fuel and oxidizer back onto the first stage.

While no Solid first stage was ever designed for the C-2 rocket, it is likely that any of the Saturn I Solid first stages would have worked in situ.

Building Block: S-I (C-3)

Here, we see the first vestiges of what would become the Saturn V moon Rocket emerge. The F-1 engine is, for the first time, planned on a rocket stage; a large monohull stage of 320" diameter is planned. Two versions of this stage are designed based mainly on the positioning of the engines. The wider stance of engines allows enough room for a 3rd engine in the center of the rocket should it be needed (and this is the drawing we have.) The more economical version, smaller in it's maximum diameter, has the two engines 45" closer together. The gross dimensions are 320" main diameter by 1092" long from the bottom of the F-1s to the top of the upper tank lip.



C-3 FIRST STAGE
INBOARD PROFILE
FIG. 2.2-7

For the thrust structure, three different options were studied.   From the standpoint of reliability and cost, the main drawing has the most efficient, but it is the second tallest option, and height adds weight in this case.   Included is an illustration of the three thrust structure choices.

Thrust Structure options and descriptions:

- Option A) Gains 10" in excess height off the baseline drawing.   Engines are moved 45" closer to the center, this reduces instant yaw/pitch if an engine out situation arises but does not effectively provide any sort of efficiency or drag reduction.
- Option BASELINE) standardized stage structure.   Base structure design can be reused in future rocket stages.   Not the most efficient for weight or height
- Option C) Reduces total height of stage by a staggering 100." While this shortening of the stage potentially reduces overall mass, it significantly increases complexity. Likely a 2nd set of turbopumps would be required.

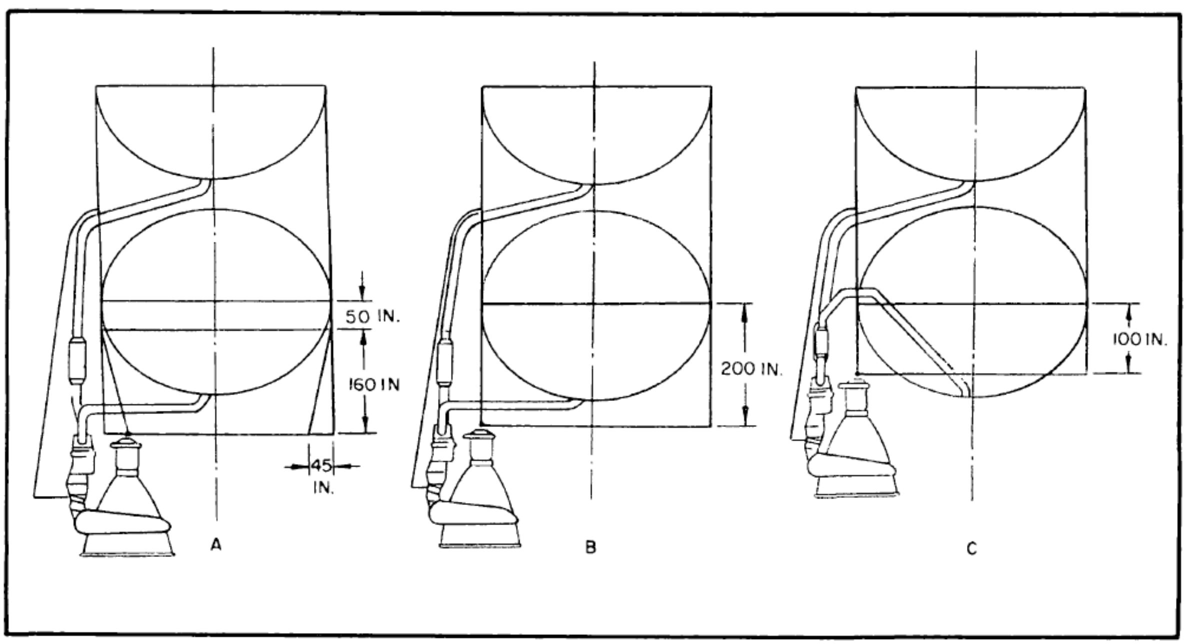
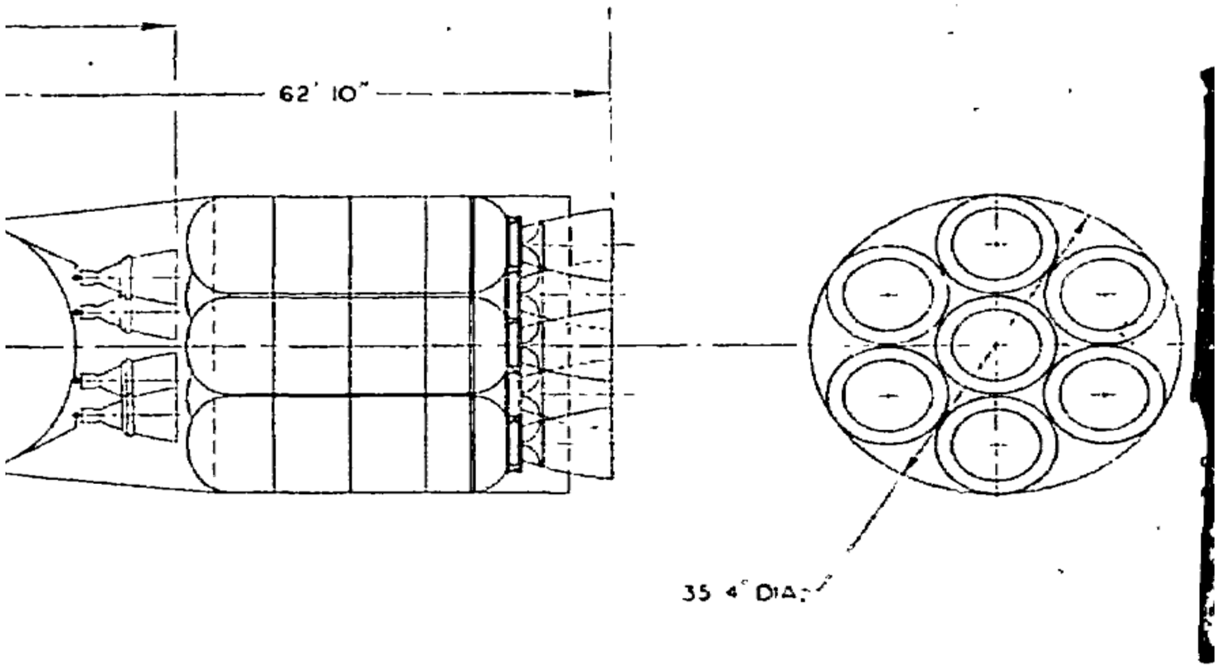


Fig. 2.2-11 Thrust Structure Configurations

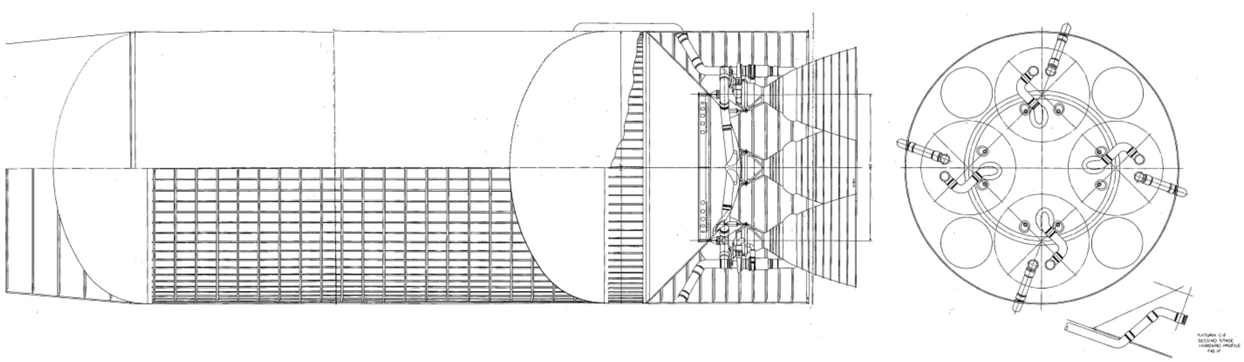
Building Block S-IS (C-3)

In a departure from the norm at the time, the C-3 was planned with an alternative "low cost," Solid rocket stage to repace S-I (C-3.)   In drawings, the rockets used appear to be 4 segment UA-1204s but they lack the Liquid TVC injection tanks.   Likely instead of 7x 4segment Rockets, it would be 6x 5 or 6 segment rockets to deliver a similar thrust. This leaves enough room for TVC liquid injection tanks.   The drawing is missing all scale references, and it appears to have a diameter of greater than 354" 354/3 is approximately 118" lending credence to the thought of a 120" SRM utilized in this stage.



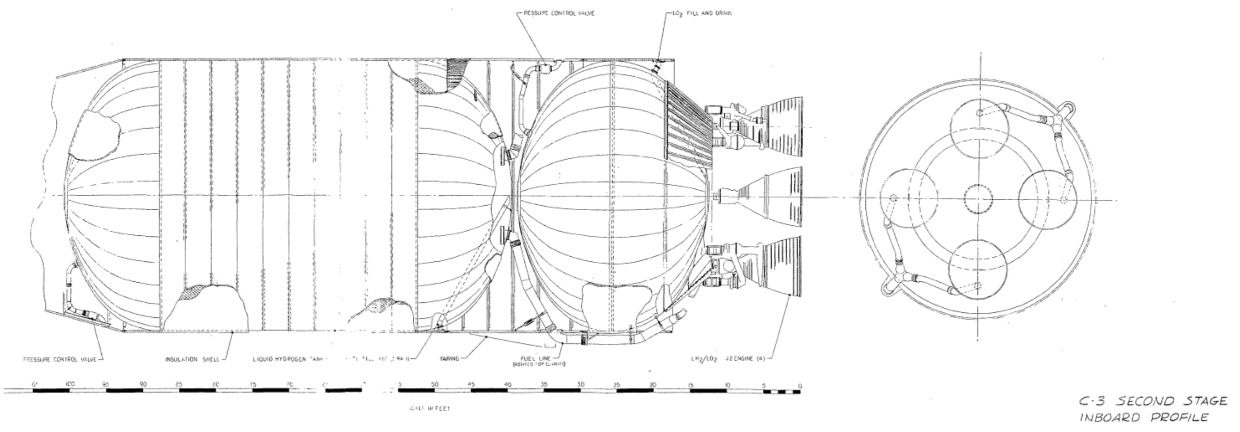
Building Block S-II-260 (C-2):

Between 1959 and June 1960, it was determined that the proposed S-III stage for the C-2 rocket would be too small. Further, the 220" diameter of the tank caused issues with bending moments when combined with the 260" first stage diameter. The decision was made to move the S-III to the C-3 rocket at this juncture and then build a smaller 220" Diameter S-II stage for the C-2 rocket with four engines. Quickly, this again fell by the wayside as the 220" diameter did not work without severe compromise on the C-2 rocket. The final stage, a 260" by approximately 700" tank and engine stage, would provide enough thrust for the largest then planned payloads to orbit.



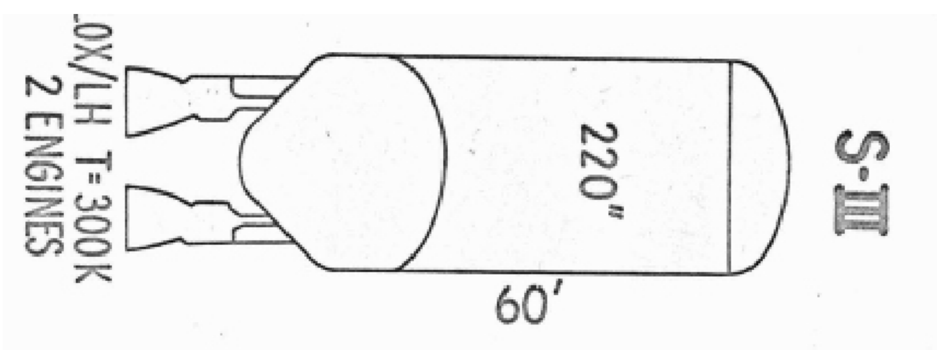
Building Block S-II-320 (C-3):

When conceptualizing the need for a bigger rocket than the C-2, the engineers at MSFS quickly conceptualized the new monohull S-II stage for the C-3. Designed here first at 320" diameter, before being shrunk down to fit on the C-2 rocket as an S-III replacement, the C-3's S-II-320 design was the most complete before canceling. While drawings for the C-2 S-II-260 sometimes show an individual hydrogen feed to each engine, the author believes that the combined twin feed as depicted here would continue production as it did on the S-II-396 stage Saturn V.



Building Block S-III (C-2 and C-3):

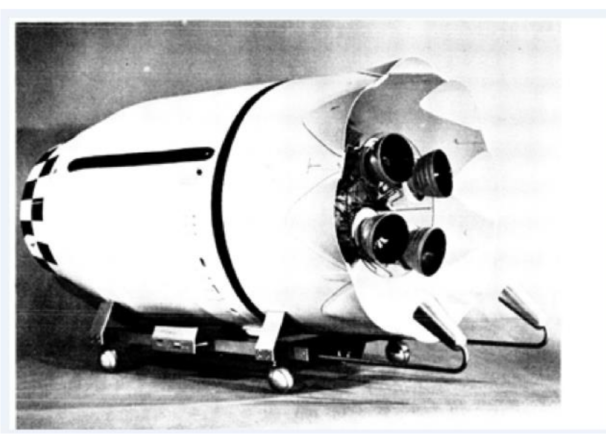
In the face of the growing payload requirements, the 220" S-III stage was deleted from the C-2 Program. The S-II-260" stage replaced the S-III stage. The S-III stage would evolve into a 260" stage very briefly but was never assigned to a Rocket in that size. Instead, the S-III was removed from consideration for the C-3 rocket at the time S-II-320 was expanded from 260 to 320" diameter. There was no attempt at designing a 320" diameter version of the S-III.



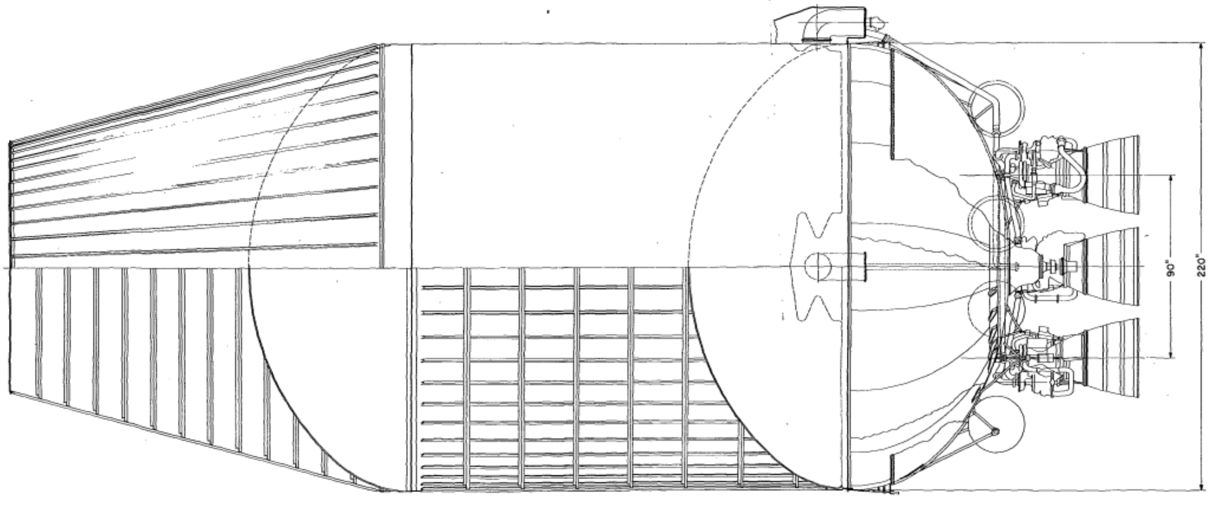
This image is from a different source and predates the 260" size increase.

Building Block: S-IV(C-1, C-2, and C-3)

As initially conceived, the S-IV stage would be the same between the C-1, C-2 and C-3 rockets. It would be a 220" diameter Hydrolox stage powered by 4x of the still-to-be-built LR119 aka RL10B-3 engines. Quickly it was realized that the C-3 could take advantage of a larger S-IV stage and it was expanded to 240" with 6x of the RL10B-3 engines. As progress was made on the other stages, the decision to eliminate the 220" diameter for the S-II(any) and S-III(any) stages had an impact on the S-IV. Why make it with two diameters if 220" is bad? The S-IV became 240" across all three rockets. Differences being limited to tank profile and overall tank length between each of the Rockets, engines excluded. The S-IV(C-1) and S-IV(C-2) are similar except for insulation. The S-IV(C-3) is slightly longer than the S-IV(C-2) as well. The engine mounts and interfaces to lower stages remaining consistent for each of the 3 iterations of the S-IV stage. Due to a looming cancelation of the RL10B-3, it was decided to convert the S-IV stage for the C-1 and C-2 Rocket to a 6 engine design. The six-engine mount already planned for the S-IV (C-3) would be utilized with the lower power RL10A-3. In the case of the S-IV(C-3) the design was altered to a single J-2 engine. This set of engine switches would eventually lead to the optimized S-IVB that flew to space on the Saturn I and V rockets. Only a few minor changes were required with the decision to utilize the RL10A-3 from the Centaur. These new engines, designated RL10A-3S, only have modifications to allow the centaur engine to interface with the Saturn S-IV rocket stage. One other significant change existed between the C-1 S-IV and the C-2's S-IV. The S-IV(C-2) utilized an add-on, jettisonable insulation blanket outside the standard S-IV tankage to reduce boiloff before engine ignition during the coast phase. These panels surround the conic and cylindrical portions of the tankage up to the LOX portion of the tank. There are also extra thermal blankets between the top of the S-IV(C-2) stage and the Instrument Unit (IU). Internally, additional insulation is added between the Hydrogen and Oxygen tanks. The Larger S-IV(C-3) with its longer tank utilized the same discardable insulation for use up to engine ignition. The S-IV stage had the most in common structurally from one Saturn rocket variant to the next. During the creation of this document, I could find zero drawings of a C-2 S-IV at 240". The C-3's S-IV disappeared simultaneously as the decision to fly Saturn with the S-IVB stage.



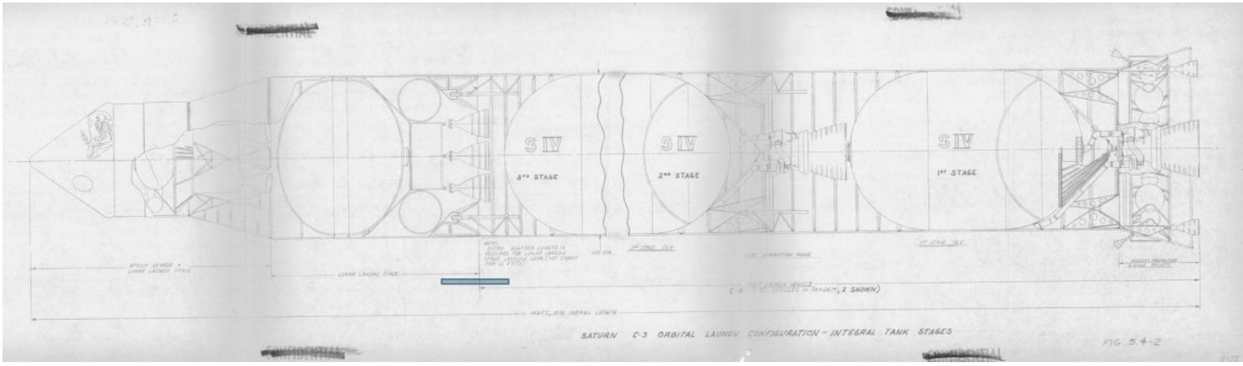
C-I S-IV-220" Mockup note 4x RL10-B-3 engines. Note the "blown out" scallops to inter-mesh with the 240" interface on the S-I to S-IV interstage. These would become almost smoothly cylindrical on the 240" version of this stage.

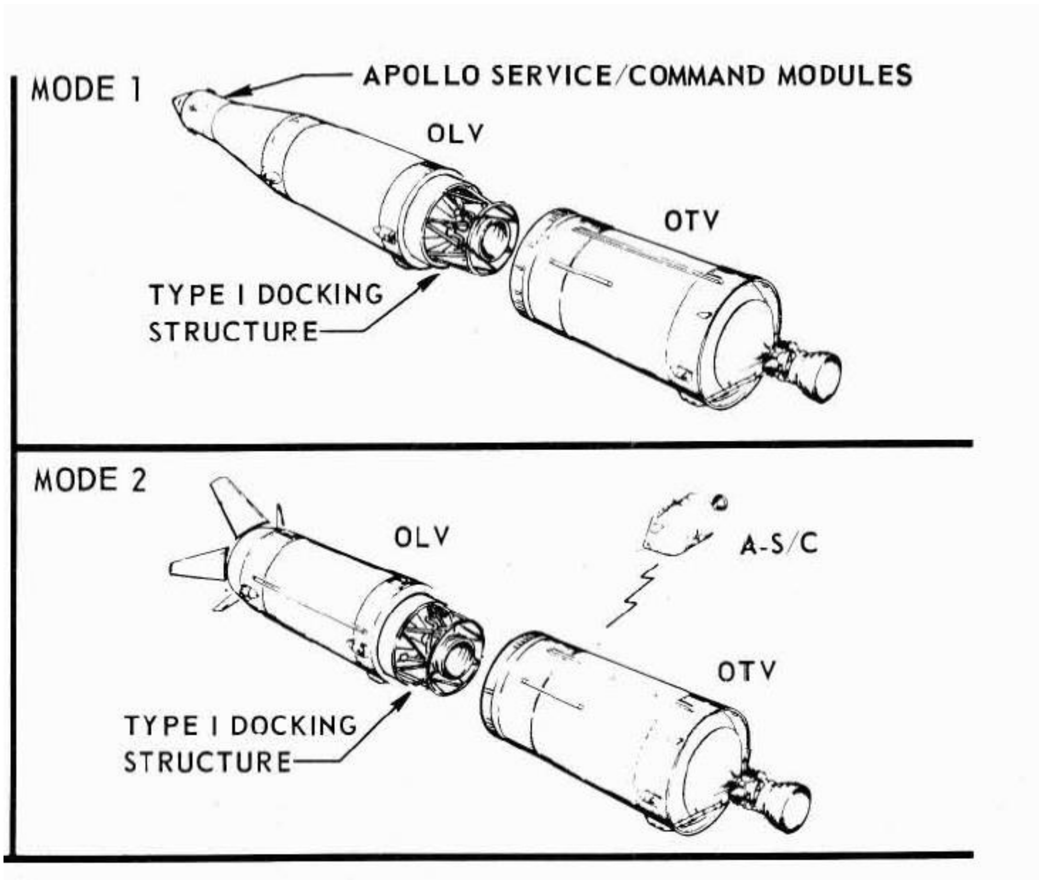


Saturn C-2 S-IV-220" drawing (note the similar length vs the Saturn C-1/S-1's S-IV?)

Building Block Interlude, the Saturn S-IVB and S-IVC (no, not the ETS one!):

While not designed or even really thought out at the point of the C-2 rocket preliminary design, we can not afford to ignore the S-IVB and it's S-IVC sibling. The S-IVB stage took a fair but overly complex S-IV stage and replaced it with a higher thrust but similar total Delta-V and a much simpler stage. With the S-IVB we can have a larger payload fairing. This means the S-V stage can carry less external insulation. The S-IVC introduced slush fuel LH2 and end-to-end docking ports. All of the changes were planned to bring about the orbital construction of a Lunar rocket. The S-IVC stage was proposed to fly the Command/lander module of a Saturn C-3 to a Lunar landing. An Un-crewed Lunar lander C-3 would launch with 1x S-IVC, A second C-3 drone ship equipped with a PLF to protect the S-IVC would then launch rendezvous with the on-orbit C-3 stack and dock nose to the tail of the on-orbit C-3 stack. Then a 3rd S-IVC would launch with a small tug attached. From here, several refueling flights and a crew delivery flight would be flown before sending the stack off to the Moon.





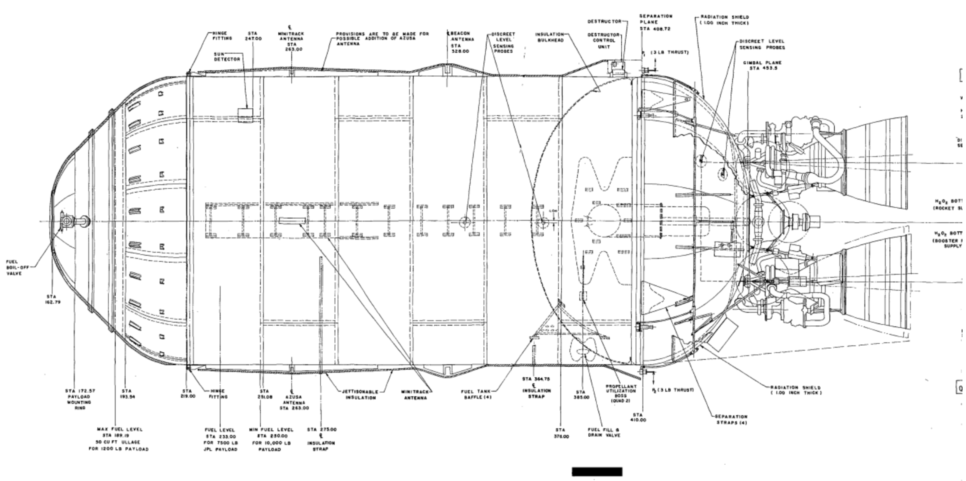
Building Block S-V, not your daddy's Centaur:

The S-V stage is loosely based upon the Centaur that flew on Atlas and Titan rockets. However, it is not the same stage beyond initial concepts and broad shapes. Initially called Centaur C by Convair and the newly named Marshal Space Flight Center, the S-V stage would support greater payloads and longer coast times than pre-SOFI Centaurs. The tanks' skin thickness was almost tripled to support these longer flight times and greater payloads, making them self-supporting or monocoque. These improvements had the benefit of reducing boiloff as the tank's maximum pressure level was significantly higher. Additional propellant bottles for the cold gas RCS system were added. Finally, the detachable insulation was thickened. All these changes translate into a rocket stage that has the overall performance of a Centaur but can last longer in space and or carry a heavier payload. Of course, the additional mass of all these changes needed new engines; as mentioned in the S-IV section above, Pratt and Whitney were working on the LR119/RL10B-3 for the USAF, and they would power the S-V stage.

Two factors prevented Centaur C from ever flying on Saturn.

1. Cancelation of the RL10B-3 Hydrolox engine and its increased performance
2. The failure of the early Centaur test flights on Atlas-Centaur

When NASA took over the development of the failing Centaur, they changed the designation scheme that Convair had in place.   The Atlas Centaur's stage, which was initially Centaur B, was moved to Centaur D, with each successive version of the Centaur D being designated as D.1, D.5 etc.   The then non-existent but on paper S-V Centaur C became the S-V Centaur E simultaneously.   The initial flight version would be Centaur E.1. This causes some fractures in the documentation of the Centaur program.   Something that is a severe mess even today as the modern incarnation of Convair, Lockheed Martin has their own new 3rd designation systems for the Centaur stage.



The S-V Centaur C (latter Centaur E) stage

NASA's whole 1970s space program would have been vastly different had Centaur S-V proceeded. Titan IIIE and IIIF would not exist, and a different launcher would be used to place a myriad of satellites in orbit.

Utilizing Building block designs to make a Rocket:

Von Braun et al at what is now known as Marshal Space Flight Center, and then known as the Army Ballistic Missile Administration out of the Redstone Arsenal, were quite adept and slapping two rocket parts together and getting a third functional rocket out of the mess. Of all rocket design centers at the time, they were the leaders of this "cost-effective" process.

With these blocks as designated above, a myriad of rockets can be constructed. My favorite combination of the S-I(C-1) with the S-III(C-3 260") to launch A Full up Apollo CSM and LEM is a prime example of this.

If you have played around with these building blocks yourself, I am curious about what you have built.

Sources: (Primary)

NTRS 19740076058

NTRS 19630045066

Sources: (Secondary)

Stages to Saturn

En.wikipedia.org articles on Saturn Rocket family