One Hundred and Twenty Inches of Agena

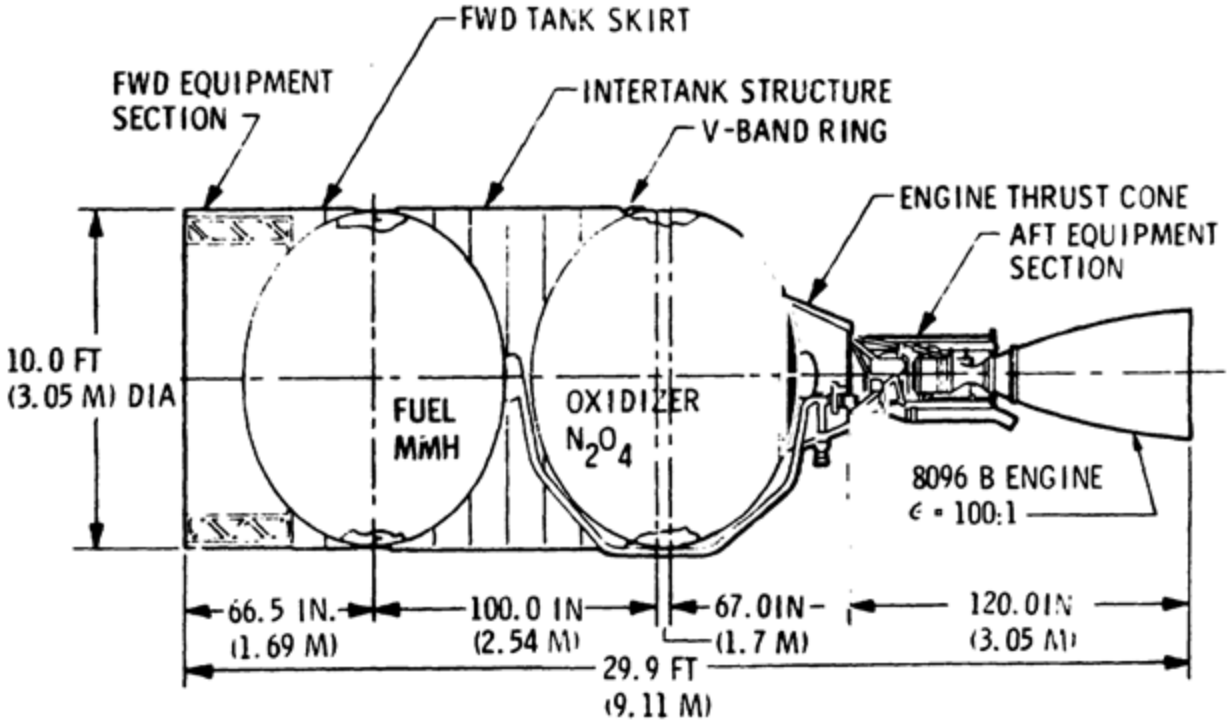
So, as a researcher and author of this piece, I need to lay some groundwork. We are dealing in a world of spy satellites from the 1960s and early 1970s, with much of the conversation in this article. I have made every effort to get accurate information. That does not mean what I present here is accurate or true. Because for every document we have on Agena C, E, and F, as well as Shuttle Agena, there are likely hundreds of documents we do not have because of national security or privileged information to the companies in question. And unlike much of what was "classified" on the NASA NTRS server, this ACTUALLY IS National Security, and I will respect that and not talk about payloads other than to mention public information in general terms as a point in purpose of the design of these upper rocket stages. I will not spend significant effort or time on payloads for these stages as it gets too close to the National Security side of things, and I just do not want to risk someone's life by covering that. And yes, covering such things CAN risk an innocent person's life. To quote George Bush 41, "not gonna do it."

This article would not be possible without the work that CobaltWolf did when designing the KH-9 Hexagon parts for the Bluedog Design Bureau mod for KSP1. CobaltWolf stumbled into some public domain documents that shed new light on the history of Agena. This started me digging further.

That said, it is time for me to share some details on Agena's growth program.

AGENA C:

As covered in my previous Agena article, Agena C was a proposal by Lockheed Missile and Space Company (LMS) to replace the then "standard" Agena B. The new Upper stage would have the same diameter as the Atlas booster that was launching Agena A and Agena B into space. Inferring here because there is not a lot of documentation on the reasons Agena C was thought up directly, but it appears that Lockheed realized that the Agena Forward Rack and GCU were too small for all the analog clocks to perform complicated missions. The larger Guidance section and Forward Rack would allow for several things: Extra Film return buckets, duplication of guidance channels for redundancy, and larger cameras on the satellite payload itself.



Please note this is an early drawing of the latter Shuttle Agena; it is, however, the approximate size of what we are describing here. Both the Large and narrow diameters of production Agenas utilized a common bulkhead tank system, not these two spheroid tanks as depicted here.

However, as I stated in the previous article on the Production Agenas, the USAF basically laughed LMS back to the drawing board to fix the current Agena issues that were affecting the near-term Corona satellite program. So, Agena C was conceptualized with Lockheed Missile and Space's own funds. It was proposed without request from the Government and promptly shot down.

I believe the proposal drawings for the Agena C reappeared on the Shuttle Agena program of the early 1970s, 6 to 10 years later. The Guidance and Control drawings from Shuttle Agena show a mostly analog computer system, not the advanced Digital GCU that was promised for Shuttle Agena. Also, the Aft rack is a simple tubular affair that cannot support the required Solar panels that were to be included.

Agena C dies… so that Agena can live:

Yes, the first attempt at a 10ft/120inch diameter Agena failed. Lockheed would go on to improve the reliability of the Agena Guidance and Control Unit (GCU) throughout the entire production run of Agena B and D, but in the end, the analog computer just wasn't reliable enough to work as intended. This resulted in the Advanced Agena Guidance Computer program and, shortly after that, the Agena E program.

SIDEGRADE: Ascent Agena:

I'm jumping ahead of time here to explain something that wasn't clear from my previous article. And that is Ascent Agena. Ascent Agena is the result of a USAF contract cancellation of Agena E, which I will be discussing shortly. As such, Ascent Agena is the last Agena ever built. And one of the last ever designed. We will cover the timing of such things later in this article. I just want to make certain the reader understands the order of things. Advanced Agena Guidance Computer, Agena E, THEN Ascent Agena. I am explaining this here because Ascent Agena really muddies the water in the development of the other late Agena stages. Something to remember: while some drawings of Ascent Agena show no Guidance Control Unit and forward rack, it is entirely possible that the body of the GCU and Forward racks were still on this stage but empty of all guidance devices.

New Agena, the Agena E:

Now, there is some confusion as to what Agena E, Agena F, and potentially Agena G really were. One was going to be the initial propulsive bus for KH-9 Gambit 4. Yes, that is correct. It seems that KH-9 was just going to be an enlarged KH-8 Gambit 3 as initially ordered. Mission creep would see it change enough to gain a new codename, but we will get to that later. The other would be the next step in developing what would become Shuttle Agena. It would combine the features from Agena GATV (Gemini Agena Target Vehicle) and Ascent Agena with the new Advanced GCU.

Advanced Agena Guidance Computer (AAGC):

The Agena D was underperforming on its Gambit missions, which is in no small part to why the latter KH-7 and KH-8 Gambit 2 and 3 satellites would have their own guidance computer. Lockheed Missile and Space Company, along with Bell Labs, believed they could solve the issue by switching to an all-digital computer. The Advanced Agena Guidance Computer (AAGC.) It would turn out, just as NASA and IBM discovered with the Saturn Rockets, older engine technology did not mix well with Digital electronics. Nonetheless, removing all the mechanical clocks from the GCU would dramatically improve the mass, size,

and power requirements, improving station time and control. The AAGC contract was begun around 1965 based on inference. The only publicly released document I have seen on this was started in 1967 and is more focused on engine upgrades. The Agena D for KH-7 Gambit 2 was initially supposed to have this AAGC. KH-7s roll out would happen long before LMS/Bell Labs would have a working AAGC. So the new Agena E is bumped to KH-8 and then quickly bumped again to KH-9 Gambit 4, which is in the long lead planning phase only. When compared to the original Agena GCUs, the AAGC was lighter by about 10 kg empty, shorter by about 2 inches, and required significantly less power to operate. The AAGC would do away with the mechanical clocks and instead have a computer program in memory to execute, with commands based on an internal clock and an inertial guidance unit like those on submarines. The cancelation of the AAGC, in the short term in late 1967, is what allowed funds to be re-directed into the Ascent Agena. This cancelation and redirection of funds is also why Ascent Agena does not actually have an official USAF Designation. The USAF cancelation of the AAGC happened right as LMS and Bell Labs had perfected the Digital computer and digital-to-analog interface computer. Basically, LMS now had a fully functional but untested AAGC with no use for it.

Agena E:

Now, to be clear, Agena E, F, and G are all designations that COULD be correct, but sources conflict or talk about the "next Agena version." I am arbitrarily applying Agena E to the KH-9 Gambit 4 program to make some logical sense in this article. But this decision could be proven wrong with new data releases from the US Government, Lockheed Martin/ULA, and the National Reconnaissance Office. As such, the Agena E design was started as part of the Improved Agena Initiative. It would utilize a new Bell engine optimized for a new fuel mixture, it would have the Advance Agena Guidance Computer, it would utilize engines with restart capabilities like those from the Gemini Agena Target Vehicle (GATV) program, and it would also utilize the SPS system from the GATV. All these features would combine to make the Agena E a more reliable Satellite with a lower power consumption, allowing for a longer time in orbit alive and functional.

The new engine, a member of the Bell LR-81-8096 family, would support various fuel mixtures and have restart capability between 10 and 100 restarts. Agena E would have been the first USAF Agena to take advantage of the restart features from the NASA Agena D GATV vehicles. The new engine would be running High-Density Acid or Inhibited Red Fuming Nitric Acid IV (they are the same thing) and including, for the first time on a USAF Agena, the SPS modules as built by TRW for the NASA GATV. But wait, didn't Gambit 3 (KH-8) fly with SPS you ask? Why, of course, it did. The Agena E program had technology spin-offs into other programs. Utilization of the SPS system was adopted on the Agena D for use with the KH-8 system in specific.

Now, the SPS or Secondary Propulsive system, was developed for the Agena GATV as part of the NASA Gemini program. It was designed and produced by TRW under the designation 8250. This engine, while small, tapped directly into the fuel tanks of the Agena rocket and was pumped electrically. The electrical pumping of a rocket engine is not efficient in large motors,

but in small ones, it makes perfect sense. The 8250 engine, in a paired arrangement, would provide better control for orbital circulation and position-keeping over the larger Bell LR81 engine. To cater to the ever-larger Gambit Satellites, TRW, Lockheed and Bell would re-design the aft of the Agena to accept two larger versions of the 8250 than what was carried on the Agena GATV. With these larger engines and the HDA/IRFNA-IV oxidizer, it was hoped that the Agena E, with its KH-9 Gambit, would have a similar performance to the early KH-8 Gambits on Agena D.

Agena E Described:

First, there are no published drawings that I could find, preliminary or otherwise, of the Agena E and KH-9 Gambit. So, all of this info is a compilation of verbal descriptions from multiple sources. Agena E would have a new GCU and Forward Rack akin to what was on Agena D. The Agena Tanks would be enlarged by a few inches each to cater to the changes in fuel density. The Forward Rack would carry fuel bottles for the Reaction control system. These bottles would also displace most of the helium tankage in the Rocket. The Aft rack would be removed and replaced by a combined TRW/Bell propulsive section, which would include 2 of the new TRW SPS engines, which were enlarged 8250s of higher thrust and ISP, and a Bell LR81-8096 version with either a 75:1, 100:1 or a 150:1 expansion ratio bell and the HDA Oxidizer. The Propulsive section would also have Solar panel attachment points in symmetry around the whole package. The Interface with the Titan Rocket would see significant changes because of this new setup. One document talks about a Titan Rocket with solid Rocket motors for lifting the KH-9 Gambit Agena E combination. But no details were given.

Agena E Canceled?:

Ok, just like the KH-8 Gambit 3 before it, the KH-9 Gambit 4 program experienced mission creep during its design phase. Creep that would continue right up until its last flight. New sensors were added, new capabilities were required, and KH-9 Gambit 4 grew and grew and grew. What was intended to be a slightly longer KH-8 Gambit 3 with 3 return buckets, extra film, and batteries was now a School Bus in space. The KH-9 Program was renamed from Gambit 4 to Hexagon. USAF approached Lockheed Missile and Space Company about re-designing Agena to work in this situation. LMS was on board with the program, but it was realized that with the use of the now-required and new Titan 23D, much of Agena's capabilities would be wasted. It was there for a "clean sheet" design for the Hexagon Propulsive section was called for. So, TRW, already under contract designing the enlarged SPS engine, was tapped to enlarge the engine even further than was intended. I am uncertain if Bell was offered a chance to engineer a new LR81 for this stage. Regardless, this new TRW engine would be the sole propulsive engine for the Gambit. In the new 10ft by 8ft SCS or Satellite Control Section. While some of the basic tankage construction from the Agena D/Ascent Agena programs remains, the Hexagon propulsive section is not considered a true Agena. May Agena E rust in peace.

Agena F, Civilian Agena E:

At the same time, Agena E was going through its design process, Lockheed Missile and Space Company began developing a NASA-specific Agena F. Mostly with their own funds. The Nixon Administration was in the White House, and President Nixon was famous for not liking space exploration and sciences. As part of the process of politics he would have to continue programs to some extent that were already moving down the road. But Nixion figured if a "new horse" was in town, he could quietly cancel it, and things would go back to the way they were… At least that is one take that can be made by his administration's work in the sphere of Space. The result? The stand-up guy known as the "Shuttle Transportation System," aka the Space Shuttle.

LMS, seeing Space Shuttle as achievable with their parent company's Aircraft programs and their own space programs, quickly looked for a way to incorporate their existing parts catalog into the Shuttle program. Shuttle Agena, or, as we are in this document, Agena F, is that place. Now since we are talking about NASA and Agenas, there seems to be a small school of thought that the Gemini Agena Target Vehicle is Agena E or F. I do not hold to that since all the publication documents cite them as Agena Ds that were then altered to meet NASA manned flight specifications. There is no indication that they are a new form of Agena, just a conversion of the existing form. Shuttle Agena would leverage the now-in-production Agena D, GATV, and Ascent Agena knowledge into a new stage. Proposed in two versions, the Agena F or Shuttle Agena would begin life as a 60" Agena, utilizing the same basic tooling as Agena D. The tanks would be altered in length due to the switch to a more stable storable propellant, Monomethyl-hydrazine (MMH) and HDA IRFNA-IV. The change in propellant was to match the fuel mixture of the Second Phase proposal from Lockheed for the Space Shuttle and improve efficiency. We will get to the reason many Shuttle Agena documents quote the old UDMH/HDA mixture in the Agena G section. The developed Advanced Agena Guidance Computer would be included and see an upgrade to support pre-programmed as well as radio-controlled flight. This would, in later years, allow for the Shuttle Agena F to return to the Space Shuttle and be recovered after flight, allowing for Agena re-use. Early on it was planned to utilize the work on Agena in the Shuttle Agena program, but shrinking budgets and demands for higher efficiency would change that, at least initially. In the end, Agena F would stay 60" in diameter. To gain back the fuel lost in staying with a 60" diameter, Lockheed developed, rather quickly, the concept of SOT tanks. SOT is literally "Strap on tanks" for the Agena.

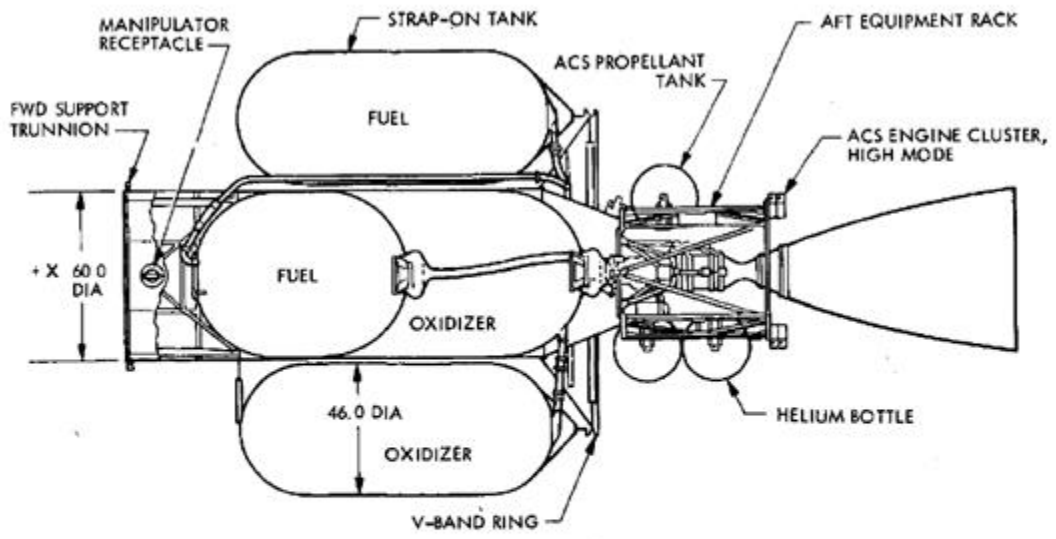


Fig. 2-2 Inboard Profile of Shuttle/Agena Upper Stage Concept With Strap-on Tank Option

The SOT tanks were to include fuel and oxidizer, as well as an option for a small tank on the nose of the SOT tank to carry more propellant for the reaction control system. These SOT tanks were meant to be dropped when empty to shed mass and allow the Agena and its payload to fly faster and higher.

The Agena F/Shuttle Agena could be used with or without the expensive Advanced Agena Guidance Computer. With the Guidance computer and upgrades, including a Doppler radar system, the Shuttle Agena could potentially be re-used on the Space Shuttle. Multiple manipulator effectors were planned to be positioned on the core Agena stage for manipulation by the Space Shuttle. A docking cradle for the Agena F and the payload was designed to include payloads as large as the maximum design of the shuttle bay. It was the length of the Space Shuttles cargo bay being the primary driver for the second Generation of bigger diameter Agenas. But Agena F is strictly the same 60inch base diameter of the basic Agena A/B/D/Ascent family in conjunction with SOT. It would have been included in the first Agena article but it fits better here given its lineage.

Agena G, Evolved Shuttle Agena, aka Agena Evo:

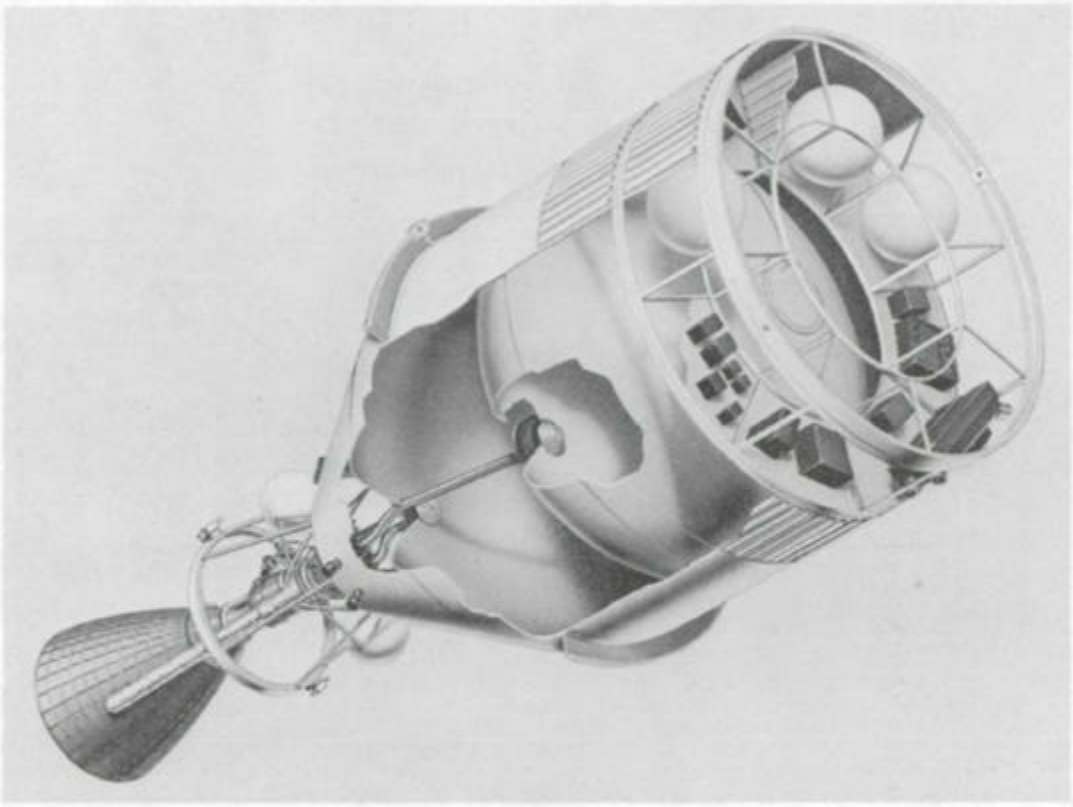
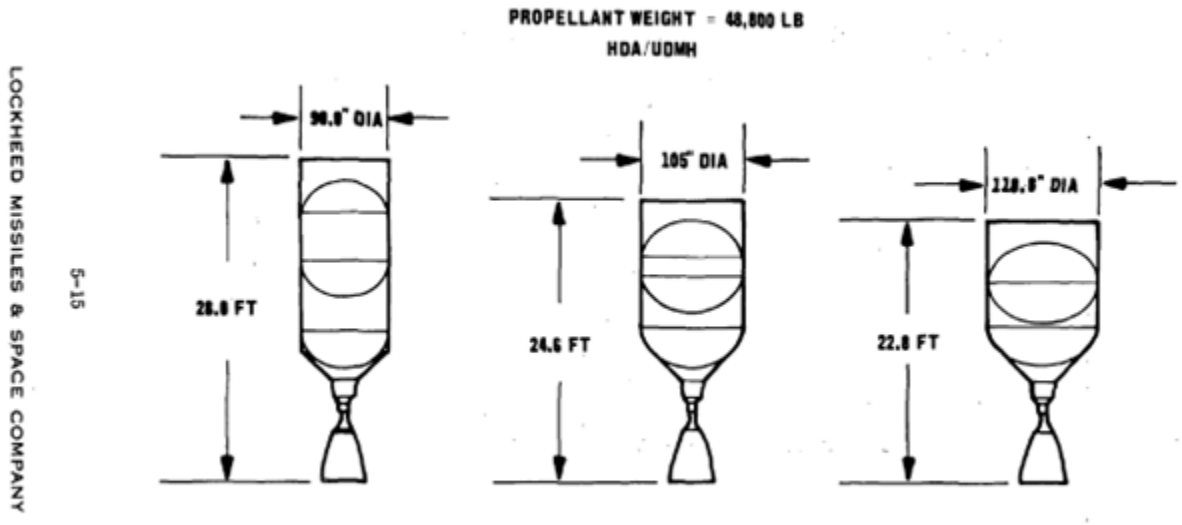


Fig. 2-17 Evolutionary Stage (Cutaway View)

Now, we covered some of this in Agena F. But the reason Agena F isn't a big Agena, is because, to put it simply, the Nixion Administration between 1972 and 1974 cut funding further. Therefore, every erg of use needed to be gotten out of existing parts when possible. It was in this 1972-1974 time-frame when the SOT tanks were developed. Also in this time-frame was the switch from UDMH/HDA to MON. With a slight increase in Agena tankage length, the fuel switch alone accounted for a 3% gain in performance.

But all of this left a problem. Even with the SOT tanks the Agena F still is a legacy system that is… well rather long. An Agena with or without SOT tanks would take up a significant portion

of the Shuttle's Payload bay. So a 2nd Generation Shuttle Agena was proposed for those bigger payloads. Often called "Evolved Shuttle Agena," the new Agena G would be a clean sheet design, maybe. NASA tasked Lockheed with studying new Agena stages at 105" in diameter. As part of the study, Lockheed included data for a 90" diameter stage as well as regurgitating their previous large diameter Agena concept at just shy of 120" diameter.



The Various diameters and lengths studied for the Evolved Shuttle Agena

In the end, the length of the larger diameter Agena E would win out and NASA would "suggest" its preference for that diameter. Agena E becomes Agena G. Like Shuttle Agena F, Shuttle Agena G would utilize the newer LR81-8096L engine which combines the best features of the NASA GATV specific -8247 version with the USAF LR81-BA-11 or 8096. The engine has the restart capability of the -8247, the 100:1 or 150:1 Bell from the other 8096 family, and runs on MMH/HDA.

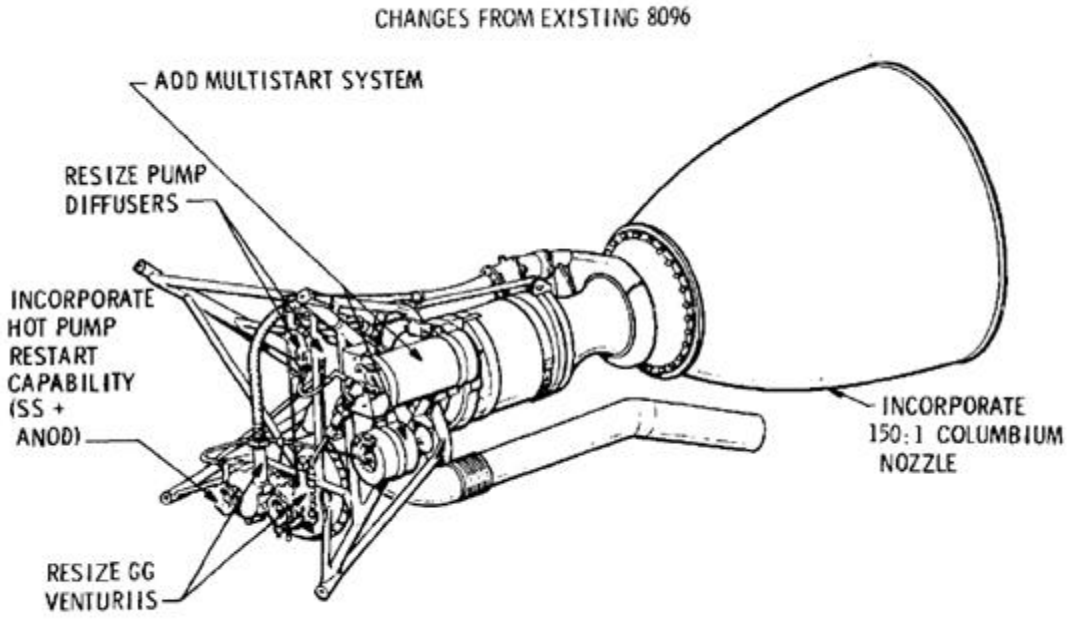


Fig. 2-3 Minimum Agena Engine Changes

Here is a drawing of the 8096L

Of course, as we are all now painfully aware. Presidents Nixion, Ford, Carter, Reagan, and Bush(41) would all mostly ignore the Shuttle program while feeding it a minimalist amount of money for the baseline features alone. Some of this had to do with the changing role of the Shuttle, and some of this had to do with the economics of the time. But in the end, no contract was made for the actual construction of real Shuttle Agenas. We have the basic Agena F with the SOT tanks in the Bluedog Design Bureau mod for KSP1. At the time of this writing, there are no 120" diameter Agena parts. However, by combining Atlas Vega and Atlas Centaur parts with the Hypergolic fuel patch in the BDB Extras folder, you can jury-rig a passable Agena at 120 inches.

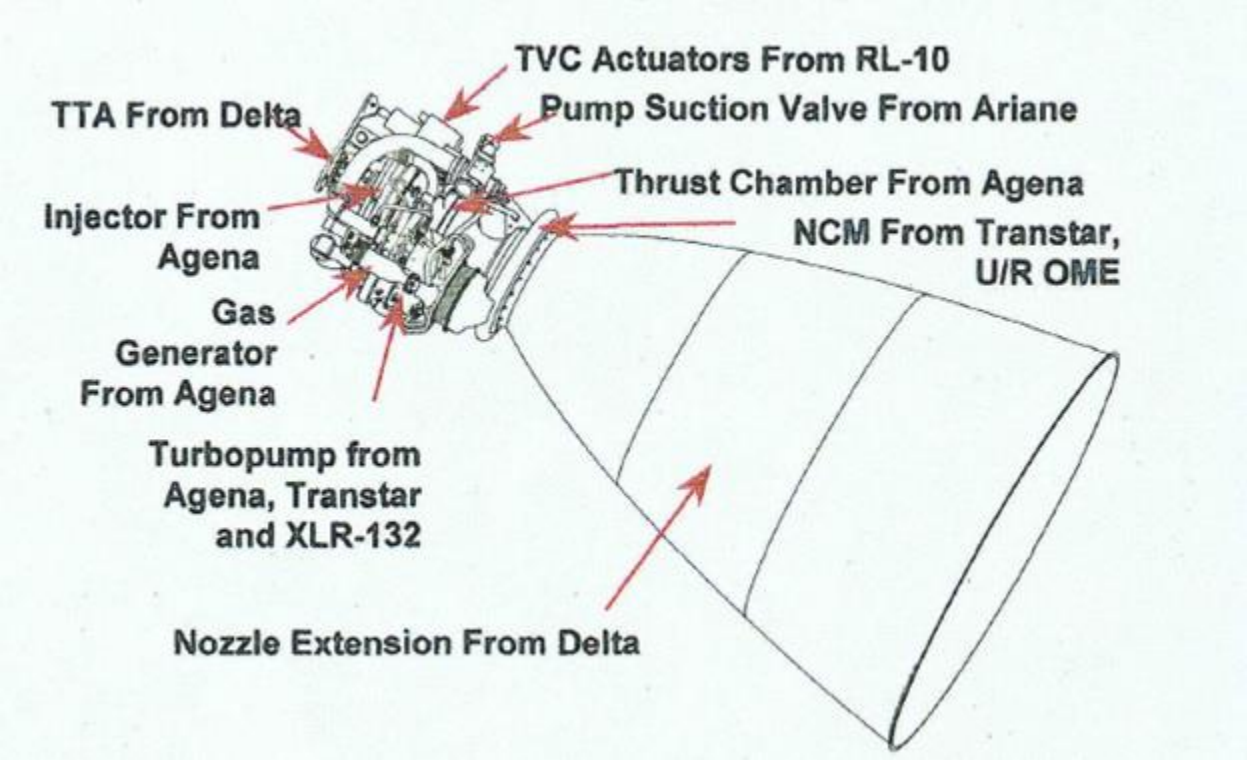
Wait! There's More! (said in the voice of Ronco Ron Popeil)

Yeah, This article is done, there are no more Agenas to talk about. Nothing new was designed for Agena after its last flight on February 12 1987. Case closed! Article done! Fin! THE END!

Wait, what do you mean I forgot an Agena? Nope, no, I didn't. All Agenas ever designed by Lockheed Missile and Space Company have been covered. All Bell Agena engine uses have been covered. There are no other Agenas.

Agena 2000:

Ok so this starts with a bit of a rant. No company involved with the Agena program was involved with "Agena 2000." The name is the byproduct of the politics of the time, with government contracting companies trying to reuse existing names because modifications get built when new things don't. Yeah, I am looking at you, F-24A/B… err, F/A-18E/F! Sigh, I guess this is now the story of the Agena 2000: There is not a lot of information to share here. A Storable Upper Stage was meant to be part of both the General Dynamics and the McDonnell Douglas entrants into the Evolved Expendable Launch Vehicle program (EELV.) The Storable Upper Stage is the only official name for this stage. The Delta IV version would be an improved Delta K upper stage, thus maintaining some sort of lineage to the original Delta series of Rockets. However, General Dynamics did not do the same thing. They contracted Atlantic Research Corporation, then a division of the Marathon Oil Company, to develop a new upper-stage engine as cheaply as possible. Atlantic Research decided it would be best not to have to certify literally hundreds of new parts. So, when possible, they re-used parts from existing engines. The result is an engine they dubbed the "Agena 2000" engine. It was named as such because their test engine design utilized more parts from the Bell Agena engine than any other, including, in theory, the combustion chamber. There was no contract between Atlantic Research and Bell Textron at the time allowing for the use, and the parts, now long out of production, would have to have been re-engineered and certified anyway. In short, it was a hair-brained scheme by Atlantic Research to make a bunch of cash without being able to follow through with the product.



Here is a drawing of Atlantic Research's engine concept… Please compare it with the LR81-8960L in the previous chapter.

Please note the thrust chamber for Agena they are talking about is just the Nozzle throat attachment part. The combustion chamber itself is all new on this rocket.

Agena Version order:

- Agena A
- Agena B
- Agena C
- Agena D
- Agena E
- Agena G
- Ascent Agena
- Agena F

Technically speaking, what we have assigned the Agena G designation to was actually designed in detail prior to Agena F or Civilian Agena E. Since Agena E and Agena F are the same forward, the engine section I decided to proceed this way.

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Nro.gov released a huge collection of thousands of publicly released documents on the KH-7,8,9, etc., in just a few files, which provided a wealth of knowledge. Most of the documents in question are hard to read, blurry, or downright assaulting on the average person's eyesight. Between the poor quality of the copies and redactions, it is nearly impossible to cite individual documents.

I have many documents on Agena, and Shuttle Agena from the NASA NTRS servers. However I only cited the Shuttle Agena Summary and Final report because most of the images and final data was located in just those two documents.