Agena, the upper stage that killed its better competitor, so that its competitor's big brother could live.

AKA: Agena, The Program that Brought Emotions to a Head in Several Space Based Governmental Organizations

AKA: Agena, The stage that was managed by big bullies who didn't like new kids coming to play in the playground

AKA: Agena, a History of Playground Bullies in Space.

AKA: I am having fun with titles for this article! :D

Welcome to the next edition of Rocket History with Pappystein. I am a bit more opinionated about Agena and the various organizations trying to get to space than on most things I talk about, so I will do my best to mark out my opinions as such clearly. The Titles are the first opinion you get to contend with :D

Like my previous Titan Article, this subject is broken down into chapters. A lot of previously "unrelated" data is in this article. Specifically, on the origin of Agena, the three big Agenas and Agena E. Wait! Stop the presses. Did you say Agena E? YUP, thanks to team BDB's efforts on the KH-9 Hexagon, plus the official history of the Agena, we now know there was supposed to be a new Agena that was canceled in or about 1967, the same exact day the "Agena D upgrade" was canceled. Originally Agena E was supposed to be the power behind KH-9 when launching KH-9 off a Titan 33B. Obviously, like many of us did during this time of COVID-19… KH-9 got too big.

It is the discovery of the Agena E that spurred me to dig further into the background of Agena to give Agena a better spot in the histories I am writing… and to further roast the original bad boy upper stage because Agena killed the better upper stage, Vega! Whoops! I said it… Yeah, that is my opinion.

With rare exceptions, I will not cover the US Army's almost duplicate program at the Redstone Arsenal except where it intersects with Vega. There are two bullies in this article already. We do not need five of them in this article, making the article an even bigger mess!

Unlike my previous articles, I am going to do my best to list my sources… even if I do not cite them properly. This is because, unlike my last articles, I am defaming many organizations with my opinion. And while it is my opinion, and I have a right to it, I want you, the reader, to be able to draw your own opinion instead of just relying on my rather Janus-type opinion. EG Agena was an amazing upper stage / Agena can roast in hell it should be burnt with fire, depending on what sentence I am typing at the time!

I do want to be clear. Any time an organization feels a different organization is treading upon them, there will be fractious behavior. In the 1950s-1960s, Space was such a place where many organizations (US Governmental organizations) fought, sometimes excessively, for their perceived piece of the space pie. You have the USAF-CIA-NRO, USAF alone, US Army, NACA-NASA, and let's not forget the US Navy! Each thought THEY were destined to control space.

So primary sources:

https://www.nro.gov/Portals/65/documents/foia/declass/WS117L_Records/115.PDF

The above is just one of several Weapon System 117L documents used from the NRO FOIA archives but it includes much of the early history of Agena.

Document history of Agena circa 1971 by NRO is a fun way to burn your eyes out reading poorly copied/stored documents on Agena. But it has many good nuggets of fact for this series of documents.

Lockheed NASA documents on Lockheed Shuttle Agena proposal 1972 series: available via NASA NRTS server

Lockheed NASA documents on Lockheed Shuttle Agena proposal 1974 series: available via NASA NRTS server, the conclusion document is what drove the BDB SOT drop tanks for Agena currently in game.

https://ntrs.nasa.gov/search?q=Shuttle%20Agena

The above link gets you both sets of NASA documents listed above!

Several documents from TheSpaceReview.com including KH-9 histories as well as Corona/Samos etc histories are used in this document. These are not primary sources so I won't list them in detail.

Many documents from NASASpaceFlight.com's L2 servers were used. I do not list them because you need a membership to view them. If you want in on the "secret sauce," I highly recommend a lifetime membership!

And while it is used in an ancillary role covering the development of better fuels: IGNITION by John D Clark is an amazing book on Rocket fuel and everyone should have a copy!

Ok now that that pile of crap is out of the way :D lets dive into why you are reading this…. The History of Agena:

Next chapter release is scheduled for next week…

KIDDING!

To understand Agena, you need first to understand where it came from. You see, Agena was started by two unrelated companies doing two unrelated things, with two different contracting organizations also doing unrelated things. The fact that these two companies' ideas could be incorporated into a functional and workable system is an amazing story. I will not bore you with most of those details, however. Suffice it to say Agena started in the mid-1950s… as a nuclear-armed missile.

Yes, a nuclear-armed missile. You see, the USAF had just spent a bunch of money making their new B-58 Hustler Mach 2 "strategic" bomber. It was a Curtis LeMay special, I should add, and any of you who know the history of Strategic Air Command or the B-29 bombing campaign of Japan in WWII likely has come across that name. General LeMay was known for being hardheaded yet full of innovative ideas. He was better than average at math; he saw solutions to problems other people considered insurmountable, unavoidable, or impossible. Liked by some and feared by many, LeMay is, in fact, the bulk of the genesis of Agena without even trying. Seeing the writing on the wall as it were, LeMay wanted ways to make his new expensive B-58 Hustler able to safely nuke the enemy targets and then get the crew and craft home, or at least away from the blasts. The USAF's Wright Field Engineering and

Testing division was the main organization handling the Rocket Pod for the B-58 (as well as most of the B-58 program.) This fact will be important later.

The B-58 Hustler is an interesting aircraft. Designed for speed, it did not have a bomb bay. Rather, it carried a large external "Pod." The Pod contained a little extra fuel and the Warhead that would be dropped over the target. Later, as Nuclear warheads, shrank in size, it became possible to equip the plane with the "two-component pod" or TCP, which was a saddle-shaped drop tank suspended below a much smaller diameter nuclear bomb. The "Rocket Pod" was developed as an alternative to the TCP. It would have JP-4 jet fuel and what would later be called IRFNA-3 Nitric Acid as fuel and oxidizer and would have a range of about 50 to 150 nautical miles. The goal here was to keep the aircraft out of the direct nuclear blast so the crew had a good chance to survive. Bell Aircraft Corporation won the contest to build their liquid-fueled engine for this Nuclear missile… yeah you guessed it, the original XLR-81 that was famously used on the Agena. The Rocket Pod never really got anywhere other than the development of the XLR-81, major shortcomings in inertial guidance at the time, and the higher priority of the ICBM, which would lead to the Rocket Pod's cancelation. If the ICBM had not already been pushed through, for lack of a better term, the Rocket Pod would have been completed and fully tested. Because of these limitations, Wright Field has a well-designed Rocket engine with no use for it.

Some basic information on the B-58 Hustler bomb pods can be found at:
https://www.b-58.com/history_offensive.php

While I am certain the images on that website are from US Govt sources I can not find images as good that are not on a copyrighted web page.

Chapter 2 Pied Piper where poorly scanned blurry documents hold all the keys!

About this same time, aka 1955-1957, RAND Corporation and Ramo Woodbridge Corporation were working with the USAF "Western Division" on what would become to the Atlas and Titan I ICBMs. RAND and Ramo Woodbridge both saw the potential of these new ICBMs and their smaller IRBM/MRBMs siblings, to get things into Space. RAND Corporation based on their "ideal" diameter of 9ft sketched a 9ft diameter upper stage for satellite launch.

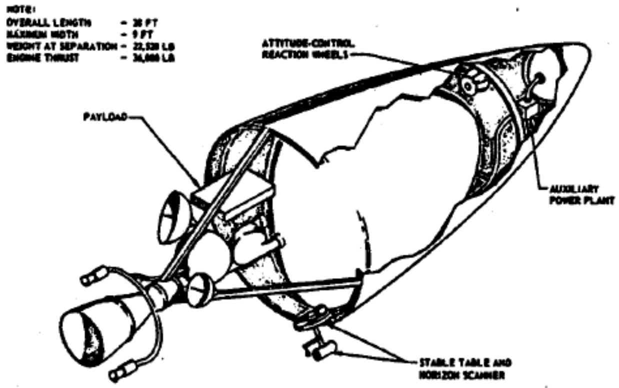

Fig. 1 Satellite Vehicle Proposed by RAND, 1954

This ingloriously named "9ft Upper Stage" would be powered by the new ABLE engine, the AJ10 of unknown version. The fuel load would be JP4 and IRFNA-3 and it would be equipped with two vernier engines as engine gimballing on the AJ10 had not been proven or designed yet. Shortly after this was sketched out by RAND and shared with Ramo Woodbridge, the idea was floated to the USAF. The USAF asked Ramo Woodbridge to refine the idea while the RAND corporation moved on to other projects. To be clear, until the letting of actual contracts, RAND was still involved with their 9ft Upper Stage but was taking a backseat role to Ramo Woodbridge. Ramo Woodbridge spent some time discussing size restrictions of the Upper to lower stage. At this point of development, not a lot was known about flying in vacuum conditions, so it was believed that every rocket had to have that ideal ".50 caliber bullet shape" that saw the X-1 break the sound barrier. Of course, they were all wrong; we can clearly see that today, but back then, when all you had was a slide rule to do your advanced calculus equations, it could take weeks to solve a math problem… Well, you get the idea. Ramo Woodbridge settled on a stage with a maximum diameter of five feet instead of the nine feet of the originally proposed RAND upper stage. This was chosen so the rocket's aerodynamics would not be disturbed and to reduce the re-engineering for the upcoming Thor and Atlas Rockets, both of which had about a five-foot interconnect area with their warhead bus.

Now, with the project in USAF hands, it was classified and named "Pied Piper." The upper stage was to be used for a series of 3 proposed space-based surveillance systems. The stage, while narrower than originally envisioned, was still powered by a now UDMH/IRFNA-3 fueled AJ10 engine and still had two vernier engines for general attitude control.

Here is where the available FOIA documents get blurry… literally. Pied Piper was never offered to Lockheed MSC, as far as I can see. One of the various engineers from RAND, Robert Salter, working now for Lockheed Missile and Space Company, on mostly his own initiative, started looking into Satellite launch on 3rd party ICBMs after Lockheed MSC was down-selected for the alternate (Titan) ICBM program. However, the competition of Pied Piper and Lockheed MSC's involvement still had no solid connection. While I have no facts in evidence to back this up, I believe that the CIA's use of the Lockheed Skunk Works for the U-2 Dragonlady and A-12 Blackbird is what led to Lockheed MSC being approved for Pied Piper. The company you know, etc. An alternative interpretation of the data was the 1956 Earth Satellite program, which started later than Pied Piper and was an "introduction" of companies to the USAF satellite program Pied Piper.

Now, in 1956, the USAF let a white (as in public) contract for an "Earth Satellite." This program started as a limited budget pie in the sky kind of contract. That is to say, no hardware was going to be built, the USAF was looking for ideas with simple engineering behind them so as to have a way to judge what kind of talent pool they might have to issue a future contract to. Almost every aviation contractor in the United States was invited to participate, except Martin Company and Consolidated Vultee (aka Convair AKA General Dynamics) because of Atlas and Titan. Lockheed MSC chose to participate in this contract and, because of the work done on their own initiative, had a decided edge over the competition. Once a "launcher" was chosen it was to be the Atlas C standard ICBM. Convair stated the Atlas C could only lift 3500 lbs as required by USAF standards. Lockheed MSC/Salter, doing their own calculations based on data Salter had from RAND, concluded that these throw weights quoted were hugely conservative and the basic Atlas C could carry 15,000lbs safely, with a nose area re-enforcement strap. Salter and Lockheed MSC began their Earth satellite by assuming a 10,000-lb payload on Atlas.

Now, here is where that FOIA blurriness really comes to the forefront. Lockheed MSC submitted a Pied Piper two-stage plan to the USAF. Pied Piper Pioneer was a 3,500lb mass satellite including 2nd stage, and Pied Piper Advance would be a 7800lb vehicle. Remember, Lockheed MSC was competing for the 3,500lb Earth Satellite program… yet they are submitting a proposal under Pied Piper, taking advantage of design changes to the Atlas that have not even been investigated at Convair! While many declassified documents cite communications between the various companies and USAF branches, no clear document invites Lockheed MSC to compete in Pied Piper or even a public program acknowledgment of said program. Pied Piper was a Grey program at this juncture (a few parts public and many parts considered secret or above.)

Oh, and the Pied Piper Pioneer is basically an Agena A with an AJ10 main engine and two supplemental verniers for attitude control. Pied Piper Advanced? Yep, an Agena B with the Pioneer's AJ10 engine arrangement!

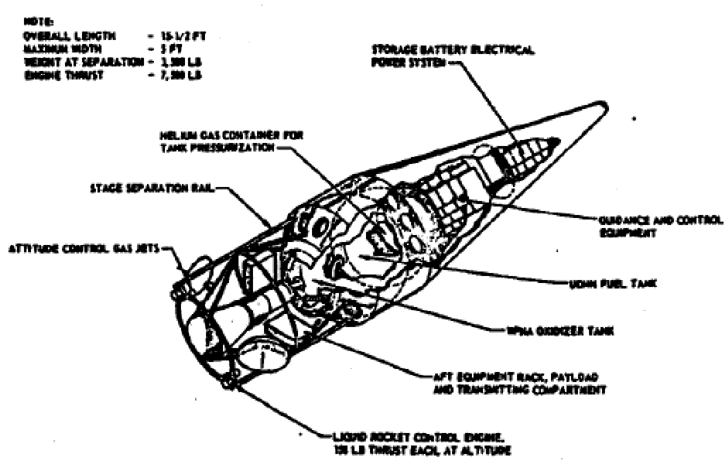

Fig 2 Pioneer Satellite Proposed by Lockheed, 1956

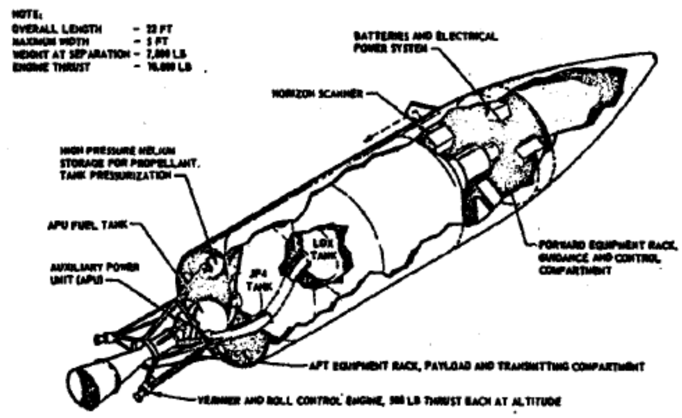

Fig 3 Advanced Satellite Proposed by Lockheed, 1956

Chapter 3, Enter USAF Wright Field, Bell, and the Rocket Pod:

During the Earth Satellite program, both USAF Western Division (ICBM) and USAF Wright Field were involved in the process. This is one of the few times that Wright Field was involved directly with a space based program. Up until about this point, Wright Field was THE experimental and design headquarters for the US Army Air Corp and later the USAF. Starting in the late 1940s however the move to what would become Edwards Air Force base was begun and Wright Field was feeling the “pull” of jobs and projects away from the original home of the US Army Air Corp experimental and design center. Wright Field was responsible for the B-58’s Rocket Pod program, meaning it is here in the Earth Satellite program that an alternative to the AJ10 exists. The alternative is the Bell Aircraft Corporation XLR81. Now Bell is hungry for a contract. They have an engine that has just lost it’s only function but it is a perfectly workable and usable engine. At this same time, Aerojet is working its collective tail off trying to meet all the contract requirements for Titan, Able, Project Phoenix, Large SRM… etc. This means that Aerojet did not have the engineering capacity to also work on a gimbaled version of their AJ10 at the time. Mind you, gimballing for the AJ10 would come soon, but not soon enough for the design process undertaken for Pied Piper. Bell was willing to put the effort in and modify their existing engine to meet new requirements on the quick and on the cheap. The engine bell was slightly extended from the original design, gimballing hardware was designed, and investigations into better fuel for space were begun. All in the span of a few weeks. You see, Bell knew their engine might be a winner in space, so they were working on all these problems even before the Earth Satellite program with their own funds, according to one telephone conversation log.

Pied Piper Pioneer becomes Agena A.

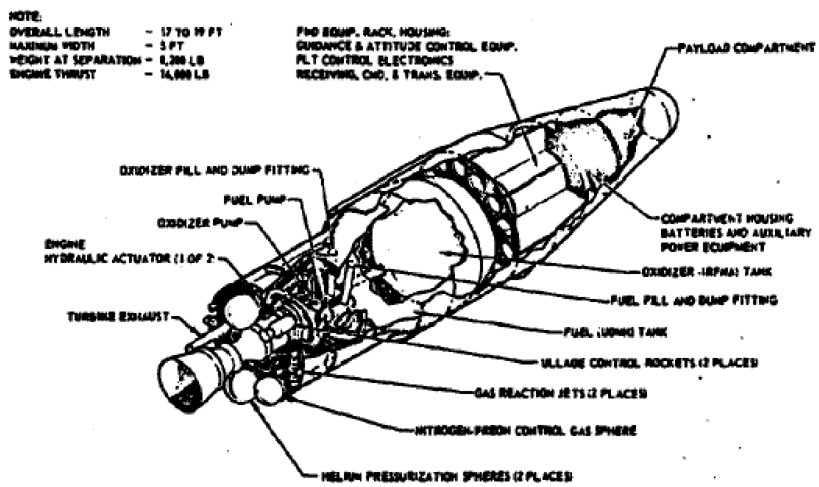

Fig 4 Agena A satellite, 1957 - 1961

While the original payload envisioned in Pied Piper was never built, Agena would become synonymous with the latter Keyhole / Corona / SAMOS programs. Agena A combines the Bell XLR81 engine in its Bell Engine Company's 8001 and, after two flights, 8048 versions. The 8001 is a space-rated prototype based on the original Hustler Rocket Pod engine, still using JP-4 as fuel and having a short bell with a

15:1 expansion ratio. 8048 switched to the Hypergolic combination of UDMH for fuel and the same IRFNA-3 nitric acid for oxidizer as 8001. The bell on 8048 grew to a 20:1 bell, and the weight savings by using Hypergolic fuel meant the engine barely gained any weight.

The Avionics was, at best, crude on the Agena A. Each mission had to have a custom-made Avionics structure and component list. The avionics combined into the Guidance Control Unit or GCU was at the top directly below the Payload fairing. Between it and the engine was the so-called Forward rack, which was, on some missions, an empty void in the spaceframe. For other missions, it was crammed with parts of the GCU, or it was used for small experiments. This forward rack would see the biggest changes from Agena to Agena as to what was in it or invading its space. The forward rack was open to the bottom side of the GCU, allowing the GCU direct access to this space. Some documents call the avionics on Agena the Telemetry Response Unit (TRU), and others the Guidance Control Unit (GCU.) For the sake of standardization, this series of articles uses the term GCU as this is an important distinction for later USAF Agena programs.

Each Agena A's GCU was hand-built depending on the mission flight profile, duration, altitude it was to fly, and attitude of the Agena stage itself. The attitude control seems to be where most of the changes from mission to mission happened on the GCU. This was because computers, in a small compact form, did not economically or numerically exist in 1957. Each flight had a unique profile that would require different modules to be added or removed from the GCU to provide a unique to the mission list of timed commands or a list of orders picked and sent by ground control. In the initial Pied Piper plans, the GCU would have extended from the fuel tank into the PLF. Early in the design process, it was realized that the GCU invading the payload envelop significantly reduced payload potential. To solve this engineering issue a structure, the previously mentioned Forward Rack was added between the fuel tank and the GCU.

Chapter 4, First Intermission: Agena and Vega

As seen in the previous chapter, Via three different projects, two groups created the original RAND Corporation dream of a space satellite launcher. Pied Piper, or latter as it would be named Agena, was not the only upper stage satellite launcher or satellite in development. Ramo Woodbridge or, more correctly, Thompson Ramo Woodbridge (AKA TRW) worked in conjunction with Convair to develop a quicker, "cheaper" alternative to the DARPA pie in the sky Centaur high energy upper stage. Vega, which I plan to cover in more detail in a future document, was designed as a quick and dirty re-use of Centaur design steps on a Kerolox stage. Vega would also combine with the proposed Juno IVB's upper stage to be the apparent stage for the early 1960s space exploration. As stated in the previous chapter Pied Piper come Agena A was a grey program. Meaning it was not well known outside of the USAF/CIA itself. Now, what you are about to read is mostly my opinion based on the following few facts.

- NASA was COMPETING with the USAF for space in 1959.
- The USAF was rapidly losing trust in Convair General Dynamics
- The USAF was still trying to bully other organizations out of their perceived territory.
- The USAF felt they were the only organization capable of handling anything with the word flight in it.

The USAF (and the so-called Military Industrial Complex) did not want civilian agencies involved in what they felt was "their turf." The USAF wanted full control over its contractors and did not like to share said control with a civilian agency that might harm the USAF's manifest destiny. In short, the USAF, just over 10 years old, defended its "territory" with zealous rancor. Anyone trying to enter the USAF's area of "expertise" was harangued, harassed, or made to look like they did not belong. Damn the torpedoes, full speed ahead, was the attitude that I perceive of that time. Many readers may feel this is an unfair portrayal of the early USAF. I give you a simple proof of this attitude with things like the Admiral's Revolt, Fixed-wing aircraft in the US Army, to name two easy to read up on examples of where my opinion comes from. The USAF is a fantastic organization. Once they found their place under a civilian government in the late 1950s and early 1960s, it became the spear that it is today in the United State's arsenal of democracy. But sadly, we are talking about those same 1950s and early 1960s when the US Government had to use more rod and less carrot with the USAF… the US Army… and to a lesser extent, the US Navy… and even with NASA!

Enter Agena and Vega. Vega, a Product of Convair who has not been pleasing the USAF recently with early Atlas failures, the F-102 Delta Dagger debacle, the equally bad F7Y Sea Dart, and R3Y Tradewind debacle for the US Navy…. Well, the USAF did not want Convair's engineers to spread thinner than needed. While the USAF is responsible for starting the Vega program as a quicker extension of the long-term Centaur program, the Vega program was seen as expendable, duplicative, and unnecessary in light of things like Juno IVB and Agena. This expendability was because the USAF already had Agena on the books, and while the Vega had better performance, the USAF did not think they needed it at this time, and they were wrong. The issue was that Vega was partially cryogenic with its liquid oxygen oxidizer. People may tell you LOX won't boil off rapidly. Sure, in comparison to Liquid Hydrogen LOX does not boil off all that fast. But it sure boils off enough to not last for more than a few orbits in space. It may be easier to prevent said boiloff than with Liquid Hydrogen, but you cannot stop it. This un-reliability in orbit is why the USAF thought the Agena had more potential. The Agena, in its final production form, could lift less than Vega to orbit. But it could continuously re-boost said payload if still attached. Something the Vega could not do. The LOX would boil off in a matter of days, turning gaseous and potentially rupturing the tanks. Of course, by adding the TRW Juno IVB upper stage to the Vega, you had a storable fuel final stage. In the USAF's mind, this made a bad job worse because the Juno IVB upper stage was tiny and had a small 6000lb thrust engine. USAF fighter and bomber pilot mentality at the time was "go fast or go home." See the XB-70 Valkyrie, B-58 Hustler, F-104 Starfighter, F-106 Delta Dart, and YF-12A Blackbird for good examples of this idea! So, we can thank the USAF for not wanting someone else to manage a space program. Remember, the USAF was the final decision maker on every NASA-purchased Thor, Atlas, or Titan Rocket and every Agena, Able, or Ablestar stage. You could even blame the USAF for Thor-Delta becoming just Delta and leading to that fun naming convention for NASA, as the USAF was not in charge of it! Of the main rockets listed above, only at the Titan 3E do we see the USAF step back away from much of the design decisions for a NASA production rocket. Finally, the USAF was ready to let someone else play in their patch of sky. Yes, you can see I have a LOT of opinions on the USAF seeking control of space. Now, what is the point of all this opinion? In 1958-1960, while still early in the development of both Vega and Centaur, the USAF offered NASA their new Agena Rocket. It would be cheaper and ready earlier than Vega (by a few months.) Of course, we all know the drawbacks of NASA choosing Agena over their preferred Vega.

- Small diameter means smaller physically sized payloads. While the TRW stage was tiny, the base Vega could lift Centaur-sized items into space.
- USAF still has control.
- No control of price spiral
- USAF preferential treatment when orders were placed
- Little say in the development of new versions (until Shuttle Agena in the 1970s)

But NASA was new, and to be perfectly frank, was having budget and leadership issues from the get-go. Honestly, any new organization has these issues, so that is not so surprising. Something else to consider, NASA did not want to rock the boat and wanted to have a civil discourse, at least in public. In private, with access to their own records, we know NASA also was a bit big-headed then, and we can see some of that today, Boeing Starliner… oops, sorry, not sorry! Sacrificing Vega for the sake of not rocking the boat was probably the right decision in the short term for NASA. But it left the long term open for lots of problems, not limited to Agena not meeting NASA's needs. No one seems to have seriously considered a combination of the Vega first stage with the Agena as an upper stage. But then again, the large size payload fairings (PLF)s technology was not really perfected until the early 1970s.

Chapter 5 Pied Piper Advance AKA Agena B:

Lockheed took their Pied Piper advance proposal and applied the new Bell Aircraft XLR81 rocket engine to it. The larger tank size and heavier mass meant the XLR81 needed both an increase in ISP thrust and improvement to take advantage of Pied Piper's changes fully. Enter the 8081 or USAF designated XLR81-BA-7 engine. Increasing the bell's size to a 45:1 expansion ratio, the 8081 gained a needed bump in thrust from 67kn for the earlier Agena A engine to 71kn on the Agena B. The key improvements were in ISP efficiency and restart in orbit capability, for a total of 3 ignitions, including at stage separation.

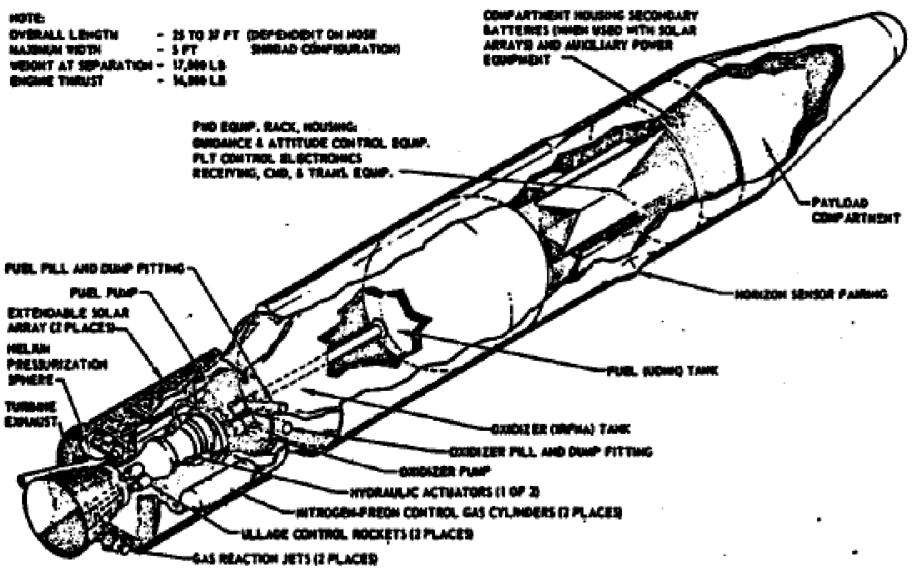

Fig 5. Agena B Satellite, 1959-1966

Like the Agena A, the Agena B would have a hand-built GCU that would oftentimes occupy the Forward rack. In the Agena B, the forward rack was longer than on the Agena A for additional GCU modules that were never installed as far as can be ascertained. The Agena B would use the same electrical supply batteries as the Agena A, and like the Agena A, most of them were mounted in or on the Aft rack that surrounded the engine combustion chamber. Beyond the forward rack changes, the fuel tank and the engine, Agena B and Agena A were broadly similar. Because of its extra fuel and the ability to restart the main engine, payloads attached to the Agena B could stay in orbit for much longer. As much as 90 days, verse less than 20 for the Agena A payloads. While intended to be the Standard Agena, the Agena

B was a limited run spacecraft due to the complex and constant need to alter the GCU. While an interim type, Agena B would set the standards that all later Agenas would be judged by.

Chapter 6 Enter the most hypothetical of hypotheticals: Agena C

While Agena A and Agena B fought to meet the USAF and NASA's needs, many failed due to low-quality control. Partly, this was to blame on Bell Engines, but the bulk of the blame rested right on Lockheed MSC's shoulders. At this time, Lockheed MSC dared to propose a new Vega-sized Agena, the Agena C. Features a 10ft maximum diameter and approximately a 7ft overall tank length. The Agena C, designed for the next generation of Spy and Communication satellites, was to keep Agena competitive with future growth needs. If built, the Agena C would have been more than capable of managing even the final production form of the KH-9 Hexagon… Well, with some small modifications. Of course, the USAF laughed this proposal right out of the office and into the circular file. While there are plenty of references to the Agena C proposal, no document has ever turned up covering its specifications. We only know it was a 10ft diameter Agena. Even the tank length suggested above is a suggestion. What we do know is a few small fragments taken from many second-tier sources, none of which originate at Lockheed, NASA or the USAF;

- Would use one or two un-named Bell XLR81 variant engines (source dependent)
- 10ft diameter (and compatible with Centaur interstage and hookups?!)
- It would have fit as a drop-in replacement for Vega.
- Higher orbital payload capability than all other upper stages built or planned at the time except Centaur.
- Proposed as either a USAF only (black) or USAF/NACA-NASA Joint program (Grey)
- Battery capacity to allow 30 days on orbit using existing loads. Extendable with Solar or SNAP
- Restartable in-flight via either many cartridges or bellows, like GATV

Each and every one of those “facts” can be called into question because none of them originate from a first-tier provider (eg Lockheed archives, USAF archives etc.) So at best, the information is questionable. Realistically it is downright ignorable. Sadly, Agena C appears to be a short trip to what happens when you, the manufacturer, think it is more important to deliver a new product when you do not currently have a fully functional product you have already sold. In short, the USAF told Lockheed to “get it together.” Agena C was destroyed before it was born. Instead, the USAF contracted for a completely new, partially digital GCU for the upcoming 2nd standard Agena. Agena D.

Chapter 7 Fixing Agena: Agena D and the final standard Agena… or is it?

With six of ten Thor Agena A failures, two of four Atlas Agena A failures, 7 of 45 Thor Agena B failures, and 5 of 29 Atlas Agena B failures, failure was on the mind of the USAF, not success. Twenty failures in the original Pied Piper orders…. Agena had problems. Some were due to re-designing the stage to take the Bell engine vs the Aerojet one. Some were due to GCU issues. But most were due to poor quality control. “Weld broke,” “Valve was stuck,” and “Wires were frayed” are all statements attached to many of the failures listed above. Each preventable. Lockheed had some issues in the plant, and at the launch site with maintaining the quality of their work. Or simply in preventing shipping damage.

Based on several documents, we know Bell was hard at work meeting new needs with their 8000 series of engines. For an engine originally designed to be used to fly a nuclear warhead just one hundred and fifty miles, this rocket was putting in yeoman work in space. However, it was not originally designed to run this long. So, multiple changes happened, even before the first Agena Launch. Most of Agena's failures at the engine involved welding of the fuel lines or stuck valves. These were areas that Bell could assist in, and assist they did.

The Guidance And Control section received the biggest changes. As part of a long-term improvement program to prepare for future CIA/NRO payloads, Lockheed and their computer contractors began improving the GCU. First, thanks to the transistor, it was possible to shrink many items used in the GCU section. Secondly, the use of the transistor to make an electronic clock greatly reduced the size of timing devices in the GCU and would allow multiple commands to be processed at once. While complete guesswork, I believe that the forward rack was often used to hold extra mechanical clocks which each governed different function. Digital clocks would eliminate the need for that because you could count pulses, and on pulse 32,874, you could run command X. Remember, there was little or no global communication. And a basic $25 digital calculator you can purchase anywhere today has more memory than the entire production run of Agena A, B and D stages combined!

Agena's computer systems in the mainstream D form… compared to today's computer systems is like using two tin cans and a string to talk to each other vs a 3G cellphone service (GSM or CDMA!) That being said, at the time of production, most Agena D's used their payload's own IMU/IU/GCS/GCU to control the entire Agena D + the payload. It was big, it was clunky, and it was obsolete even before it first flew. Agena D still used multiplexer arrays to do math and while JFET and FET transistors took over for many vacuum tubes, not all were eliminated. Further, by the time Agena D flew, the Integrated Circuit was in production form. The Agena D's GCU did have one major fact going for it. It worked when the Agena A and Agena B GCUs before it, didn't always. And as can be insinuated by the previous statement. All Agena D GCUs were identical to each other, meaning the Agena GCU was finaly a standardized item. The inclusion of a Guidance and Control override so that the payload could control the Agena stage, was probably the biggest improvement of all in the Agena D GCU.

Agena D are broadly similar to the Agena B before it with one exception. The Forward rack of Agena D would shrink a little. Yes, Agena B is SLIGHTLY longer than Agena D. Unless they were sided by side, it would be impossible to tell without a measuring device.

Agena D would become the most prolific US upper stage to launch to orbit. It will be a few more years before Centaur could replicate that number. But for all that, it was an upper stage that was actually too small to be effective in the long term. But it was in the right place at the right time to take over the bulk of military and civilian launches. Agena D would be the second US upper stage to get us to the Moon with the Lunar Orbiter payloads. Agena B was used to get the Ranger probes to the Moon.

Chapter 8 Second Interlude: KH-9 Gambit is an Agena?

About one year into the start of production of the Agena D, the USAF approached Lockheed about further updating the stage. This new "Improved Agena D" would, if built provide in orbit re-boost capabilities and have an all-digital Guidance unit taking advantage of the integrated Circuit now being touted in some circles of the avionics industries. At the same time, a different portion of Lockheed was entrusted with what would eventually be called the KH-9. The KH-9 was going to be a little bit bigger than the KH-8 before it and while the Agena D stage on top of the newest Stretched Titan III would be powerful enough to get it into orbit… the USAF and Lockheed started to hedge their bets as it were. First off the KH-9 would have it's own encapsulated guidance system separate from the Agena stage. While this was done previously on the KH-6 and KH-7 payloads, those older guidance units only kept the cameras pointing at the target zones and did little to fly the space craft once in orbit. The Agena D's passthrough ability was good enough for those payloads. The KH-9 however would not need the existing GCU as built into Agena D. Instead, the KH-9 would use a direct connection to the Agena's RCS, Engines and electrical supply to control the entire satellite and stage. Agena D would become a fuel tank, engine and control system of the satellite… whereas the early KH satellites were a Camera and recovery system attached to an Agena satellite. This difference might not seem like much, but it does three things. First off, it "finally" separates NASA from launching Agena-based rockets. Secondly, the Agena is turned from an autonomous stage into a dumb booster stage. The most important change is now a smaller group of people need to be compartmentalized as the manufacture of the Spy satellite alone now held the important information. No longer would NASA people need to pass a security screening… Heck, NASA was not in the market for small, dumb booster stages.

This document isn't intended to be a history of the Keyhole program at large but please bear with me. When KH-9 was first proposed, it was basically an improved KH-8. It would add a 3rd return capsule, and the film would be the same size with a slightly longer spool (film) length. The Agena stage for this new KH-9 would feature a new fuel combination to allow for longer storage on the pad and in space and would utilize features of the just entering into production Gemini Agena Target Vehicle. Specifically, the restart capability of the Bell model 8247. These changes, including a removed GCU would shorten the length of the Agena Stage by over eight inches. The weight savings would be offset by the heavier fuel and engine. The new Agena stage would be called Agena E. It would be equipped with the Bell 8533 version of the LR81. The 8533 would have likely received the USAF designation LR81-BA-15 or -17. The Fuel for the 8533 would be UDMH/NTO instead of UDMH/IRFNA-3. The combination of UDMH/NTO would be used for the last production Agena series.

Sadly the KH-9 program began to experience mission creep. Even the improved performance of the new Agena stage, still called "Improved Agena D" at this point, the KH-9 would need something different. Initially that difference came in the form of an enlarged "secondary propulsion system" The SPS, as used on Agena D and GATV, would be changed and re-engined with a single larger engine having ½ the thrust of the LR81 main engine. This would make the now renamed Agena E, have 2x the thrust of an Agena D, using USAF math. The USAF did not launch most of their Agena stages with SPS systems installed. The Agena E would quickly shut down the SPS system once on orbit and rely on the 8533 engine for reboost and orbital plane changes. Calculations at Lockheed quickly pointed out that even with these SPS engines, the Agena E as designed would not have enough remaining Fuel to be more effective at reboosting the still growing KH-9 Satellite. Lockheed saw the writing on the wall and began to sketch an alternative to Agena reusing as much tech and knowledge as could be gleaned from the Agena program to make the KH-9SPS module of the SBA (Satellite Basic Assembly.) The new SPS motors from the now failing Agena E would as a single engine with a bigger bell, provide the final orbit position thrust for the ever growing KH-9. Agena, as a stage and Bell as a rocket manufacture wouldn't quit here however.

Chapter 9, the ACTUAL end of Agena:

At the time of the cancelation of both the "Advanced Guidance computer" and the Agena E, the USAF was still placing orders for KH-8 satellites and they were getting heavier with each launch. Lockheed quickly threw together a new Agena design based on combining the Agena D's Aft rack with the Agena E's Guidance computer (there wasn't one) and the Forward Rack to create a lightened, more efficient Agena. Combined with this would be a new engine and fuel supply in the form of the 8096A engine utilizing a 75:1 expansion ratio bell and UDMH/NTO. All of these changes resulted in a more efficient Agena than Agena D. This more efficient Agena is known as Ascent Agena. The last 16 Agenas ordered for the KH-8 program were all Ascent Agenas. Because of the switch from having a functional guidance computer to just a secondary attitude sensor set, the Ascent Agena relied on the KH-8's own guidance and control equipment, which likewise improved. As you can tell by how scant this chapter is, not a lot is actually published on Ascent Agena except those bare facts… most of the documents that would give further light to the latter KH-8 Keyhole missions and the Ascent Agena are still behind the "Shh it is a Sekret" government security wall. And that is fine as countries DO need to protect their self-interests and technical means… to a point. But what it means to you, the "recreational" Kerbal Space Program Player, is that you have probably never heard of Ascent Agena or thought it was an Agena D with a fancy schmancy name. In KSP, we don't include a GCU onto our Agena stage to represent Ascent Agena (and choose the appropriate 8096A engine.) That means your payload has to be able to control the Agena… which for the most part it should be able to.

BUT WAIT!!!! There's MORE!

What you didn't think we were done yet did you? Agena, for all the problems it and its parent organization's caused, still has 2 or 3 "last gasps" to cover. There is enough meat on the bones as it were to create a whole new article set on the following "not USAF Agena" projects. Lockheed MSC's Shuttle Agena from the mid 1970s, as well as what little we can cover on the canceled Agena 2000 and Agena F. That article will come very soon.