The Still Mighty Titan II, Titan GLV and Titan 23G and other Titan II variants.

I am writing this on the assumption you have already read the Titan I article. This article could be slightly confusing if you have not read that article first.

Early in the development of both the Atlas and Titan Missiles, the Remo-Wooldridge corporation, the soon to be TRW, pointed out to the USAF that a better fuel source than cryogenic Liquid Oxygen should be found. Liquid Oxygen boils off at a prodigious rate when exposed to normal terrestrial temperatures. The USAF approached both General Dynamics (Convair Division) and the Martin Company about converting to some form of storable liquid fuel. Convair pointed out that a storable fuel would destroy the balloon tanks in short order… and the extra weight would inviolate their entire launch principal. This quickly excluded Atlas from being “up fueled” to a new storable propellant. You see, even today with all our advances in chemistry and metallurgy, storable fuels tend to be very caustic, very cancerous, and generally unbelievably BAD to be around. Back in the 1950s we are talking about nitric acid and any of various fuel types that nitric acid self-combusts or goes hypergolic with. Why is self-combustion an important factor for room temperature stored fuels? The short answer is I do not know. The longer answer involves a lot of chemical and engineering equations that deal with ISP. I will stick with I DON’T KNOW because it is easier to say and takes up less space in this article… by tens of paragraphs!

Some of the fuels investigated, were declared too violent even in storage. Things like High Test Peroxide. Hydrogen Peroxide, readily available over the counter in 2% to 6% concentrations in normal water is a great astringent and wound sterilizer. But at 80% to 90% concentration…. Can dissolve organic matter in moments… this includes an all-up Human, much to the chagrin of many German pilots in World War II who flew the ME-163 Komet in various forms as the HTP as the high percentage Hydrogen Peroxide is often called, would leak. There being cases where Me-163s just exploded on the tarmac. So in short, Hypergolic fuels require a lot of care when dealing with them. More so that the Cryogenic LOX.

The good news for Titan, was that this was 20 years latter and while Hypergolic rockets were tested and knowledge was gained, few were flown. When it was decided to convert the Titan to Hypergolic fuel, it was a simple choice as Aerojet General was about the only rocket company in the US with then current Hypergolic fuel use between their AJ-10 engine as well as some of their semi disposable JATO/RATO aircraft takeoff assistance motors. Aerojet had started to perfect their Hypergolic line even before being asked to convert the AJ-23 family of engines to Hypergolic fuels. Even before being approached about converting the AJ-23 family to hypergolic fuels, Aerojet had begun developing their own custom fuel that would be easier to store and use than the previous they used. Previously Aerojet was using Unsymmetrical dimethylhydrazine (UDMH) and inhibited red fuming nitric acid (IRFNA.) The new fuel combination would also be unique in utilizing almost the same burn ratio as the KeroLOX fuel currently used in the Titan I rocket, by mass flow. This new fuel was known as Aerozine50 and was a 50:50 mixture of UDMH and Hydrazine which are closely related to each other, and the improved Di-Nitrogen Tetroxide (NTO) was a replacement for IRFNA. Aerojet catching on that the more corrosion inhibiter they added to their IRFNA mixture the better their engines burned. Nitrogen Tetroxide or NTO was being used in the IRFNA formulation as a corrosion inhibiter in the fuel tank. The More NTO added to the fuel mixture, the higher the ISP of the rocket stage…. So Aerojet just pulled the IRFNA and left NTO in the tanks and achieved the best performance yet. To the improved NTO oxidizer, Aerojet would use a 50:50 mixture of UDMH and Hydrazine for fuel. With the trade name Aerozine-50 (Az-50) this new mixture would burn more efficiently with NTO than any other fuel then tested. While still caustic, corrosive, and cancerous, the combination of Az50 and NTO would greatly improve the safety of every rocket stage it was used on when compared to the previous UDMH/IRFNA fuel combination.

This major leap did not come without problems, however. Developing the new LR87 and LR91 AJ-5 variants took much more money and much longer than anticipated. Enough so that the USAF instituted a CRASH program, one of the first times said type of program was initiated after WWII. Aerojet, for about 6 months was confined to working on the problems with the LR87 and LR91 conversion to Hypergolic fuel. While 6 months might seem like a short time, you must understand, everything else that Aerojet was doing was curtailed or in danger of being stopped by the USAF. So, when in the same timeframe Aerojet submitted a version of the LR87 to power the upper stages of the ABMA Saturn I and V Rockets…. Well, that did not happen. Even though Aerojet's engine was best in 10 out of 11 criteria, Rocketdyne got the contract, and the J-2 exists. You can read more about that in my pieces on the J-2 and E-1 engines.

How did the Titan II change from the Titan I? Well knowing all the problems that Titan I had with stage separation, including several photographs from space showing the interstage collapsed in or exploded out preventing separation… Martin changed how the two stages would separate. Like on the previous Titan I, the Titan II would utilize a zero-ullage motor 2nd stage start aka the "fire in the hole" method. This meaning the 2nd stage was started while the first stage was still or just powering down. The big difference is the first stage would add thrust cancelation motors which were not powerful enough to completely stop the 1st stage at full thrust, were more than powerful enough to overcome the turbopumps exhaust thrust. It was believed that the Titan I turbopumps ran for several moments after the stop thrust commands were sent. This proved to be mostly true. It turns out that there is still quit a bit of fuel flowing to the engine after the stop thrust command is issued. This is caused by the flow rate and the distance traveled after the fuel shutoff valves. It is these same reasons why the LR87 takes so long to get to full thrust in the game. If you are not using any of the upper stage patches or Spool patches in BDB you can clearly see this after you shut off the First stage Titan engine… it still provides meaningful thrust for several seconds. But back to the changes. Instead of a solid Interstage with blow-out panels. The new Titan II with it's larger diameter upper stage (the same ~~3.05m~~ 10 ft as the lower stage now,) was believed to "block" most of the drag from leaving the interstage open. Of course, this was not true but the loss in drag was more than made up for the much more powerful first stage as well as the much more reliable 2nd stage. A major change to the design choice of the 2nd stage involved not using a two stage starting method for the LR91 as the Titan I had. The Titan I as previously discussed activated the 4x vernier motors for almost 12 seconds of flight time before the main combustion chamber came on. With the LR91-AJ-5 for Titan II, the entire role of the verniers was deleted. This meant that the turbopump exhaust did not need to be augmented nor was it used in the same way. Instead on the Titan II the turbopump exhaust would only provide roll control by a gimbal and twisting joint prior to the last 90-degree elbow pipe. This greatly simplified both the startup of the 2nd stage as well as reduced the chances of damage to the 1st stage and the interstage structure like happened to the Titan I with some regularity early in it's flight testing. This also allowed the engineers at Martin to move the turbopump exhaust under the 2nd stage reducing parasitic drag and eliminating four high pressure points on the outside of the rocket as it accelerated to space. Some documents claim that removing the 4 vernier exhaust from the airflow around the rocket more than offset the drag caused by open blow out panels on the interstage.

A new warhead was eventually developed for the Titan II, it would be one of the largest service warheads ever produced and would stay on alert with the Titan II until their withdrawal starting in 1982. A withdrawal due mostly to needing major manufacture level overhaul that would be needed to serve further, not due to any sort of treaty as many "historical documents" will contend. Titan II was not deactivated due to any arms reduction talks. However it's removal from service would affect current and future talks in the mid 1980s and early 1990s arms control talks.

After it was retired from service many in the USAF had the bright idea to combine useable stages from the remaining missiles to create a cheap space launcher since every other launcher was soon to leave service…. As the result of the Space Shuttle. Of course, history would stop the process of canceling the disposable rockets with the Challenger disaster in January 1986. Challenger happened right in the middle of the USAF looking into such a conversion of the remaining Titan II stages. Of 56 surviving Titan II missiles, only the 14 best were initially chosen for conversion. Be it due to miss-handling or just over all dilapidated status, as a sign of the quality of the 2nd stage, a 15th second stage was sent to Martin Marietta as part of the conversion process. After the initial orders were placed, it was quickly discovered that to fully update the Titan II ICBM into a space launcher would become prohibitive quickly due to the dilapidated state of the rockets and the cost of further conversions was, to put it mildly, more expensive than the just entering service new production satellite launchers of similar performance. When all was said and done, only a few Titan II stages were still sound enough to be converted to Satellite launch vehicles. These refurbished Titan II missiles received a new deployment bus atop the 2nd stage and a standardized fairing based on those used on other rockets. There is a very nice picture of this on the 14th and final Titan II(23)G at the Evergreen air museum. https://upload.wikimedia.org/wikipedia/commons/7/7c/LGM-25C_Titan_II_%286586628193%29_%282%29.jpg

Some of the Titan II 2nd stages received an "ACS" system which is a self-contained Reaction control system, to orient the 2nd stage after burnout to properly deploy the 3rd stage or payload. While ACS is not completely installed in the photo above, you can see the off-colored patches as well as the tubes the control wires run down from the avionics structure below the fairing. In the end, the Titan IIG(23G) was available to launch a few payloads when launchers were hard to come by. But it was not cheap and when launchers became available again in the form of the Delta II, the Titan IIG faded into history. It should be noted that the Titan 23G is not correct following USAF naming standards. The 23 series of Titan Rockets were equipped with LR87 and LR91 engines of the AJ-11 subset. The Titan IIG flew with it's original, but recertified, LR87-AJ-5 and LR91-AJ-5 engines. Given at the time, the USAF designation standards were being converted from a "HARD" standard to a "HANDBOOK" this is not totally surprising.   This is why most documents in open publication have 4 different names assigned to the Titan II derived SLV. They are: Titan IISLV, Titan II(23G), Titan IIG(23G), and Titan 23G.   More permutations if you sub the

The Semi-related Titan II.5 and Titan IIGLV were proposals and actual flight articles for the Gemini program.   Initially Martin corporation proposed the Titan II.5 to NASA, it would have a slight stretch to take advantage of the lighter Gemini capsule payload and provide better orbital dynamics for the Gemini program.   I have found no actual documents detailing the proposal in detail, but Ed Kyle of Space Launch report suggested a 40" stretch to the first stage.   Every document I have found on the Titan II.5 suggests that NASA was seriously considering it.   Given the issues with Pogo we will discuss in the next few paragraphs it was a good decision by NASA to NOT accept a new version of Titan and rather just alter the Titan II into the Titan II GLV.   Titan II.5 is not buildable as described but a reasonable facsimile can be made by using the Titan IIIM first stage tank setup and reducing the fuel slightly.

The Titan II GLV was a program that was relatively on time. RARE for a government acquisition.   Starting with the base Titan II that was just entering testing for the USAF, NASA developed the appropriate changes to the basic Rocket that would be required for NASA to feel safe putting astronauts on board. Chiefly the changes centered around lowering the pressure in the turbines of the engines, and many thousands of built-in test sensors throughout the spaceframe.   Here is where things get hinky... this is also why Aerojet General was forced into the CRASH program for their new LR87 and LR91 AJ-5s….   POGO. Pogo is a vertical (through the body of the rocket) oscillation resulting in up-to several gees of positive and negative acceleration along the flight direction with a rapid repetition. This can lead to structural failure, and in the case of pilots, injury, or death.   In USAF tests Pogo was only experienced once… as seen by their test instruments. Since the USAF does not use as many test instruments for launches as NASA did, it is not surprising that many launches that entered Pogo went un-detected. So, NASA sort of pressured the USAF to add extra test equipment to the next few test Launches of the Titan II.   What was found resulted in a lot of re-engineering of the new hypergolic LR87 and LR91 engines as well as the fuel pipes and tanks on the rocket stages themselves. These changes reduced the vertical oscillations to significantly less than 1g of acceleration and much less often than the 11hz or 11x per second the pogo was detected initially.   Most of the "anti-Pogo" changes involved flex lines in the fuel system (instead of rigid fuel lines) as well as flow rate dampers in the fuel system itself to prevent over acceleration of the fuel or oxidizer in the engines (leading to altered burn profiles.)   These changes are the prime result in the Titan II having few "failed launches" when compared to the Titan I.   The base Titan II would have 77 successful flights on 81 launches.   A much higher ratio of success when compared to the previous Titan I variant. When you add the Titan GLV and the converted Titan 23Gs mentioned above the launch ratio is 101 to 107 with only one Titan 23G failure out of the additional 24 launches.   It should be noted that several early launches in the USAF test program, where POGO was present, were still considered a success and are not counted as failures as the warhead simulator landed near enough the target zone to be considered successful.

In BDB we can build the All-up Titan II missile… the warhead is replaced by an aerodynamic cover. We can also make the All-Up Titan IIGLV. However, we are unable to make the Titan II.5 mostly because there is no real-world data. You can make a loose analog by using the Titan IIIM first stage tanks with a small reduction in max fuel. In the case of this conversion to a Titan II.5 every other part beyond the upper first stage tank is the same as the Titan IIGLV.

Lastly, we can build ANY version of the Titan 23G satellite launcher including the Titan 2S, Titan 2L and 3L. The Titan 2S would be a core Titan 23G with the addition of either Castor IV SRMs or GEM-40 SRMs. The SRMs would be mounted in quantities starting at 4 and ending at 10. If 10 rockets were carried, they would be burned in a 4, 4, 2 or 4,3,3 profile. Such a combination would double the payload of the Titan 23G but would cause problems because a new aft skirt (the engine mount in BDB parlance) to protect the AJ-5 engine (just switch to the "Titan III" engine mount type when you have your AJ5 engine installed) and would require structural changes to the core. Given that only ~23 all up Titan 23Gs were possible to make this would have been an expensive undertaking. The Titan 23G(S) or Titan 2S is fully buildable in BDB. The Titan 2L would be a Titan 23G with 2 Titan 23G first stages strapped on as boosters. All 3 engines would ignite and burn at the same fuel rate (booster and 1st stage.) and all three would burn out and separate at the same time. The Titan 3L would use the Commercial Titan 3 core but with Titan II AJ-5 engines on the first stage. As it is using the Commercial Titan 3 as the core stage it would use Titan IIIM tanks. Just like the 2L the 3L would ignite all 3 LR87-AJ-5s at once. It is unclear if the Commercial Titan 3 2nd stage would use the LR91-AJ-11A of the nominal production or use the LR91-AJ-5 for the 2nd stage. Given how few of the LR91s survived to be considered re-usable it is likely the Titan 3L would use Titan IV 2nd stage tanks made new, and the LR91-AJ-11A of the CT3 and Titan IV.

While there were enough first stages and spare engines that were of enough quality to consider the concept, it is unlikely that the 3L would have flown as designed and instead I feel the best "Liquid boosted Titan" to build is the Titan 2L. The Titan 2L is fully buildable in BDB and 3L is nearly completely buildable. Only the CT3's AJ-11A engine upgrade is missing to fully give this rocket it's due. The Titan 3L would fly with the CT3's fairing as well I should mention.

There are a lot of variants of the Titan II that can be fully built in BDB. In-fact there is one I have not mentioned. The Titan IIIA.

Err WHAT! The Titan IIIA is a Titan III you say? WRONG. The Titan IIIA was a proof-of-concept rocket and is closer to the Titan II than any other Titan III. First off, the Titan IIIA flew with LR87-AJ-5 and LR91-AJ-5 engines. With one exception, it is the only Titan III to do so. Secondly, while the Titan IIIA did have the slight second stage Stretch associated with all Titan IIIs that was the only change vs the Titan II that was integrated into the Titan IIIA.

So Titan IIIA has the longer 2nd stage tank… But is otherwise a Titan II that carries Transtage. We will see this generational kind of mix of technology in the real Titan III family which is the subject of one of our next articles.