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On February 21, 1969, the Soviet Union set a record for the world’s most powerful rocket to fly. A title they would hold onto for over 50 years. But on April 20th, 2023, that record would finally be broken by SpaceX’s Starship and its Super Heavy booster.

People have been quick to point out the similarities between these two rockets. Most notably the ridiculous number of engines on the first stage of each rocket. The N1 featured 30 NK-15 engines on its first stage while Starhip’s Super Heavy booster sports 33 Raptor 2 engines.

But the similarities don’t end there, in fact, the first integrated launch of Starship proved the rocket to be even more similar to the N1 than most would be comfortable, considering the N1 flew 4 times but never made it all the way through the first stage burn.

And this has brought up the all important question. Has SpaceX fallen into a similarly flawed design that plagued the N1? Why did they choose so many engines? Will it continue to suffer a similar fate over and over like the N1 or is there something inherently different?

So today we’ll answer those questions and compare the two most powerful rockets ever made, from different sides of the world and from completely different eras to figure out how they’re similar and perhaps more importantly, how they’re different.

And like always, here’s the time stamps for this video. The youtube timeline is broken up into these sections and we have an article version of this video up at everydayastronaut.com for links and sources.

Let’s get started

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Let’s start off by comparing these two vehicles side by side. I’ve talked about each of these vehicles pretty extensively in previous videos, such as “Starship VS Falcon 9” and my “Entire History of Soviet Rocket Engines” video, but I’ve never actually directly compared them before.

The N1 was the Soviet Union’s attempt at a moon rocket, a rocket that would nearly match the capabilities of the United State’s incredible Saturn V rocket.

It was massive, at the base it was a ridiculous 17 m wide and it tapered up to a point with the supper stages about 6 m in width. It stood an impressive 105 m tall and fully fueled weighed a total of 2,735 metric tonnes.

SpaceX's Starship on the other hand is even more of a skyscraper, it's 9 m wide on both stages and comes in at 120 m tall. But where Starship's numbers get shocking is its weight when fully fueled at about 5,000 metric tonnes. Almost twice as heavy as the N1.

The N1 was capable of putting 95 tonnes into low Earth orbit while Starship is designed to be able to take up to 150 tonnes into low Earth orbit. This puts both rockets squarely in the super heavy lift category, with Starship being the most capable rocket ever built.

Each rocket utilized different propellants. The N1 was powered by kerolox, specifically RG-1 and liquid oxygen. Starship on the other hand uses Methalox, so liquid methane and liquid oxygen.

The N1 had a lot of stages. The rocket had a minimum of 3 stages, but when sending a payload to the moon, it would've utilized up to 5 stages, in a similar fashion to the Saturn V with the Apollo Service Module and Lander stages. And of course, the entire rocket was expended.

Starship on the other hand is only a two stage rocket. And perhaps most importantly both the massive Super Heavy booster stage and the Starship upper stage are designed to be fully and rapidly reusable, eventually.

But perhaps the biggest thing these rockets each share is the ludicrous amount of engines. The N1 had 30 NK-15's on its Block A first stage, 8 NK-15V's on its Block B second stage, 4 NK 19's on the Block V third stage, one NK-21 on the Blok G fourth stage and an RD-58 on the Block D descent stage.

Starship is a little easier to remember since it only uses Raptor engines, and specifically Raptors 2's as of the making of this video.

There's 33 Raptor 2 engines on the Super Heavy booster and 3 more sea level Raptors and 3 vacuum optimized Raptors on the Starship upper stage. But these numbers are all subject to change as Starship is still in development.

The NK-15 on the Block A Booster of N1 utilized the oxygen rich closed cycle, which as those of you who have watched my deep dive on Soviet Rockets engines may know, is something the soviets mastered in the early 60's.

The engines were impressive, capable of 1,526 kN of thrust and 297 s of specific impulse at sea level and had a mass of about 1,250 kg.

Raptor 2 on the other hand produces 2,255 kN of thrust and 327 s of specific impulse at sea level while having a mass of only 1,600 kg.

This means the Raptor has approximately a 144 : 1 thrust to weight ratio while the NK-15 had a thrust to weight ratio of about 122 : 1. So not only is the Raptor 2 much more efficient, it also produces more thrust kg for kg, which is important!

So as you can see, the rockets are quite different from each other, but they do share a couple similarities like being super heavy lift rockets and utilizing several smaller engines rather than a few bigger ones.

But they actually share more in common than just their hardware, so let's dive into some core philosophies they share, including the pros and cons of utilizing so many engines, why they both believe in testing by flying and heavily leaning on the iterative process.

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Philosophies
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Let's start off with the biggest question people have. Why do these rockets have so many engines? Doesn't more engines mean more potential points of failure and ultimately a more complicated system?

Well many less powerful engines have a few advantages over fewer, more powerful engines. Most obviously is that the loss of an engine has less of an impact on total thrust levels with many smaller engines vs fewer larger engines.

Let's look at the N1 vs the Saturn V. The N1 had 30 engines producing 45 mN of thrust where as the Saturn V had 35 mN of thrust from just 5 engines. So if you were to lose 1 engine on the Saturn V, you'd lose 20% of your thrust, which if early on in flight, would have likely led to a loss in mission.

Where as if you lost one of your 30 engines, you only lose about 3% of your thrust, which is well within margins to continue on in pretty much any situation.

But as far as reliability goes, more engines also has the potential for more failure points. More moving parts, more chances for failure, more complications and more chances that one engine's failure could affect its neighbor and cause a cascading failure scenario.

So there's a bit of a bell curve between fewer engines is simpler, but more susceptible when there is a failure, but more engines is more likey to have a failure but it can be more robust when an engine does fail.

SpaceX's Falcon 9 already takes this approach by having 9 smaller engines instead of 1 larger engine. This is different than one of its bigger competitors historically, ULA's Atlas V which only has a single RD-180 engine.

So how's that been going for SpaceX? Well, for the Falcon 9, in total 2 Merlin engines have shut down on ascent. And to date, none of their failures have caused a loss in mission.

Two other losses of engines caused the failure of a Falcon 9 landing, but that's not mission critical, so overall, a larger number of engines has helped Falcon 9 become one of the most reliable rockets ever created.

And even the landing has become more reliable than almost any other rocket in general, with over 115 consecutive landings in a row. So their LANDING of a rocket success streak is better than pretty much any other rocket's overall launch success streak!

And SpaceX has already taken this approach up three fold with their Falcon Heavy rocket. Falcon Heavy uses 27 Merlin 1D engines at lift off and to date, that rocket has had a flawless track record for mission success.

But there's a few things you can do to help many smaller engines be even more reliable, including having each engine inside its own blast containment shield. This way if the engine does experience a catastrophic failure, it won't affect its neighboring engines.

This is something SpaceX has already improved between the first Super Heavy booster that flew, Booster 7, and boosters after which have a much more robust blast containment shield on each engine.

But beyond the actual operation of the rocket, many small engines have a few huge advantages over fewer large engines. First off, cost. The R&D and tooling costs can be depreciated through each engine much quicker if you're making let's say 5 times more of something.

There's economies of scale that work well on smaller engines when you're cranking them out almost once a day. In fact, SpaceX is already making the Raptor 2 engines for under $1,000,000 now and continually pushing to make them even less expensive.

Compare that to the F-1 engine that was on the Saturn V which cost about $115,000,000 per engine in today's dollar… So even though that engine produced 3.5 times more thrust, it was about 35 times more expensive on a $ per kN of thrust measurement.

Smaller engines also don't suffer the same problems of combustion instability like large ones do. This is where the combustion chamber is so big, different areas of the chamber can experience slightly different pressures and temperatures and it can lead to oscillations.

These small instabilities can lead to big problems and it's combustion instability that almost grounded the Saturn V because its gargantuan F-1 engines were plagued with combustion instability issues. The US figured it out, but the Soviet Union never really did.

Instead it was most common for the Soviet Union to take one engine and split its combustion chamber up into 2 or 4 smaller combustion chambers as a way to avoid combustion instability.

When designing the N1, lead engineer Sergei Korolev reached out to a new engine designer, the Kuznetsov Design Bureau or OKB-276 and wanted smaller engines to avoid combustion instability.

Another advantage of smaller engines is they're easier to handle, test, install and just move around in general. We see SpaceX moving Raptors around all the time like it's nothing down at Starbase and at McGregor.

Being smaller and easier to handle ends up being an efficiency in time and labor hours. It's easy to imagine that it's much easier to install an engine like Raptor that can be installed in hours vs an entire F-1 engine on the Saturn V which would take days and huge machinery to install.

But high production rates also help find flaws in design and production much quicker. If you have let's say 5 times more engines than another design that has fewer engines, that's 5 times more opportunities to find flaws or make improvements in manufacturing.

This also applies to testing. If each engine goes through a similar testing phase, you'll rack up 5 times more test stand time in total with several smaller engines which will lead to a better understanding of the system, and a more reliable engine in the long run.

This means 5 times more start ups and shut down sequences, it means there's more time to really hone in what works and what doesn't work.

Now it might be easy to point to the first test flight of Starship in 2023 and say "well it doesn't look like those Raptors were all that reliable after all". But let's not forget, those were literally some of the first Raptor 2 engines ever made.

As of the making of this video, SpaceX has now produced over 300 Raptor engines and have developed a much more robust testing regime for each engine which will hopefully lead to outstanding reliability. I don't think it'll be nearly as much of an issue on later Super Heavy's.

But at the end of the day, SpaceX still decided to fly Booster 7, despite knowing it had a relatively low chance of success. Why? Why did they do that and why did the Soviet's do something similar with the N1?

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Trial by Flying
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The Soviet Union didn't actually have much of a choice in the matter other than to just fly the N1. The N-1 not only couldn't static fire test the whole Block A first stage on a stand or at the launch pad, but they couldn't even test fire each individual engine!

The N1's that flew all utilized the NK-15 engine. One flaw it had was it relied on pyrotechnics to open valves. This means they were single use and required a massive overhaul to fire again.

So instead, the Soviets decided to just test one in every 6 engines that came off the manufacturing line to try and test for general errors in production. As you can imagine, this means the engines flown on these flights weren't actually test fired before being lit for take off.

This all means the only way to actually test the N1 at all was to just launch it. This is exactly what the soviet union did, all four times, and again, never getting all the way through the first stage burn. Just send it is the common philosophy that both the Soviets and SpaceX have adopted.

So why did SpaceX choose a similar philosophy and just fly Starship? Isn't it different with SpaceX who does test each engine, and performed a handful of static fire tests with the booster and Starship upper stage?

Well SpaceX still believes the best way to gather data and get to the next step is to test, even if the test fails, there's still a lot to learn. Instead of trying to completely solve the complex problem of flying, landing and reusing the world's largest rocket, just start by trying it and see what goes right and wrong.

The goal of the first Starship integrated test flight was to clear the launch pad and not blow it up. Although the rocket cleared the launch pad, a large amount of concrete was violently ejected from below the pad and tore up a good amount of the complex.

But I'll bet that will just be a small blip in history and in 2 years after that first launch, no one will be thinking much about the concrete ejection problem from the first launch.

But the first flight did validate many things, the rocket made it through the point of maximum aerodynamic pressure, or Max Q, it put the heat shield tiles through strong wind shears, it validated aerodynamic models and guidance and control.

It proved the launch pad and systems including the tank farm, the pumps, the coolers, the quick disconnects and launch clamps all worked as designed. They got real world experience from flying.

So overall, SpaceX validated many things and even learned the rocket was perhaps a bit too robust with maybe a bit too small of a flight termination system since the flight termination system failed to immediately destroy the rocket when activated.

But this still all raises the question of why did SpaceX and the Soviet Union do this iterative design process instead of just doing it quote un quote "right" and engineer and test every part until it's all perfect and you have a high degree of success on the first flight?

Well, let's look at NASA's SLS rocket. It took 12 years to go from signed legislation to flight. But SLS had to work perfectly or else it was at risk of cancellation. So things were tested, engineered and worked out to a high degree of likelihood of success. Which it nailed.

Granted its cost is in the billions per launch vehicle and has cost over 30 billion to get to the first launch of SLS and Orion, but it goes to say how important it was that it all worked virtually flawlessly on the first launch.

Starship on the other hand began engine development in 2016 and around that same time became a legitimate project at SpaceX. So it took 7 years before the first integrated flight test, and it didn't complete all milestones and the rocket is still far from being operational.

But we can imagine where the program will be in 5 years. Likely by then it will be operational, at least to the point of flying tankers, payloads like Starlink and even NASA's HLS moon lander variant.

And then from there, the rapid production rate and evolution of the rocket means it will only continue to improve and become more capable and more reliable, something that is harder for SLS to do because it doesn't have the freedom of failing or rapidly making changes in designs.

So SpaceX is following in the footsteps of the Soviet Union by build fast, test, break stuff, iterate, fly, blow stuff up, learn from it, repeat. But will Starship ultimately suffer a similar fate as the N1? Well now it's time for my final thoughts on whether or not Starship might repeat history.

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Will Starship suffer a similar fate as the N1?
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So why did the N1 fail and is Starship doomed to do the same? Is there just simply such a thing as too big, too powerful, too many engines, and engineering too fast?

The biggest misconception is that the N1 failed simply because it had so many engines. While in some ways it was a contributing factor, it was not the root cause of failure.

The main reason the engines on the N1 failed wasn't because of quantity, but quality. The NK-15's flown on the N1 were extremely primitive and as we know, they were relatively untested and still quite failure prone.

Couple these relatively new engines that couldn't be tested, a full first stage that couldn't be tested without flying it and then a primitive computer called KORD that was in charge of managing that many engines, it was a recipe for disaster.

The N1 also steered via a pretty advanced mode of steering known as thrust differential.

Thrust differential is where you throttle engines to provide pitch or yaw. So increase thrust on one side and decrease the thrust on the engines opposite and it will pitch or yaw the vehicle over.

This means the engines need to handle precise throttle commands and they spend more time in transients as they throttle up and down. This is a fairly advanced task, even for today's rockets with modern computers.

A major downside to relying on thrust differential is that if an engine shuts down, the KORD computer had to shut down the engine opposite it so as to maintain equal thrust.

The N1 could fly nominally with 4 engines shut down, but that actually means they could only lose 2 engines since each engine shut down would require the shutdown of its opposite pair. So there wasn't actually much room for error.

Starship's Super Heavy booster on the other hand primarily steers via the center 13 engines that all gimbal. Gimballing is where the engine itself can swivel to provide pitch and yaw, but assuming there's at least two engines, they can even provide roll control that way too.

The Raptor has an astonishing gimbal range of 15 degrees. This is the most gimbal of any main engine that I know of, and they can do so at ridiculous rates with the new electromechanical servo thrust vector controls that will be on all Raptor 2's after the inaugural launch.

This means that Starship doesn't need to shut down opposite pairs to maintain control, the rocket can simply use the gimbals to correct for any offset in thrust if an engine fails.

We saw this in action on the first flight test of Starship where the rocket lost many engines but maintained control via gimballing and it didn't need to shut down opposing pairs.

I honestly have no doubt that had the N1 been able to continue flying, they would have figured it out. And likely within the next flight or two, and especially because the next N1, called the N1-F, would have had much upgraded and much more reliable NK-33 engines.

Starship on the other hand has over 50 years of computer and aerospace advancements to lean into, which I don't think I need to even begin to explain how much computers and aerospace has advanced in 50 years.

In fact, thanks to modern computers, the engines can be less prone to catastrophic failure because the engine can sense when things are off nominal and quickly shut things down before they get worse.

But in the end the biggest reason the N1 failed and never got those additional flights is the untimely and unfortunate death of lead engineer Sergei Korolev who died right in the middle of the development in 1966.

Unfortunately for the program, Korolev was the main advocate of the program while his contemporaries Valentin Glushko and Michael Yangel had other plans and weren't very supportive of the N1.

The program was underfunded to begin with and after Korolev's death and then being defeated by the United State's Apollo Program, the N1 was canceled before it ever got a chance to really mature and live out its ultimate goal of sending humans to the moon.

But isn't SpaceX still susceptible to running out of money, or an untimely death of Elon Musk, or just canceling Starship altogether. At this point, I genuinely don't think so.

SpaceX has a solid revenue stream by not only being the most prolific launch provider by a huge margin, they also are likely operating at the highest profit margins by reusing their Falcon 9 boosters and fairings, but they also are quickly becoming one of the largest internet providers.

They're investing billions into making Starship happen, and not just make it happen, but mass produce Starships.

Although the N1 was set up in a similar fashion though with a production rate of up to 1 a month and engines coming out about once every 1.5 days, there has never ever been an engine built as often and as inexpensively as Raptor already and they're still pushing that envelope.

They're developing multiple massive facilities to build Starhips at scale. They're baking in efficiencies to maximize economies of scale, iterative design processes, and of course a reusable vehicle that once proven will be beyond disruptive, it'll be transformative.

Much of what I just said can be backed up by the fact that there's already several vehicles mostly finished just waiting to fly. Granted they currently don't have a working launch pad to launch on, but I think SpaceX can get that part figured out no problem.

I know SpaceX and especially Elon want things to be as simple as possible with the mantra the best part is no part, but it does seem they found a limit with the launch pad and a complete lack of a water deluge system.

But, even if it takes them two years to complete the rework of the site before flying again, I still believe they have all the right parts and processes in place to actually make this absurd rocket work out, eventually.

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So what do you think? Do you think Starship will suffer a similar fate? Do you think we'll ever see a completed first stage burn and a full clean stage separation? Do you think we'll see it operational in a year, 2 years? 10 years? Never?

Let me know your thoughts in the comments below and don’t hesitate to ask any additional questions! I’ll get to as many of them as I can!