I Built the Ultimate 2.5 Liter SFF Workstation PC

18 MIN · YOUTUBE · HTTPS://WWW.YOUTUBE.COM/WATCH?V=CTEBR0HBSN8
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SUMMARY

Jeff Friesen shares his journey of building a compact 2.5 L Mini ITX PC, a project that evolved from a month-long endeavor into a nine-month challenge. The final product not only meets his needs as a portable workstation but also outperforms his previous setups in both efficiency and performance.

- *The build started as a solution to the inefficiencies of using separate desktops and underwhelming laptops for work.*
- *He chose the Velka 5 case for its ability to accommodate a full-size GPU while remaining portable.*
- *The PC features an efficient Ryzen 7900X CPU paired with the Nvidia RTX 4000 SFF GPU, optimizing performance per watt.*
- *The custom aluminum housing serves as a heat sink, enhancing thermal management.*
- *Extensive testing and modifications were required to ensure compatibility and stability, including troubleshooting BIOS and GPU recognition issues.*
- *Performance benchmarks show significant improvements over previous systems, with faster rebuild times in SolidWorks and lower power consumption.*
- *The total cost of the build was approximately $2,911, and he is considering a small manufacturing run for enthusiasts interested in similar builds.*
- *Jeff invites feedback and interest from viewers regarding potential kits for building similar PCs.*

[Music] hello guys today I wanted to share with you how I built this Compact and powerful 2.5 L Mini itx PC. It was way more work than I ever expected but what started as a one-month side project has taken me the better part of 9 months to finish. I got to say the result has really been worth all the effort. This is one of my favorite tools I've built for myself. I mean just look at how cool this tiny little guy is and you won't believe how well something this small benchmarks but we'll take a look at that in a bit. I'm considering doing a small manufacturing run for enthusiasts who want to use this custom case so stick around until the end if you want to hear more about how much a build like this costs and let me know in the comments if that's something that sounds interesting to you. First I should probably give you some context my name is Jeff Friesen and I am an electrical and mechanical design engineer. I live in Sacramento California but frequently travel to Stockholm Sweden for work where I'm the lead mechanical designer of an electric surf board for a startup called Lind Art and Technology. We'll be launching in just a few short months but there's still a ton of work ahead. Over the past 3 years I haven't been able to find my perfect solution for a portable workstation until now. I started out with separate desktops in California and Sweden but this just led to the

annoyance of moving around solidworks licenses and making sure all my files were versioned correctly. Then I opted instead to use a small work laptop paired with an external GPU but the performance was pretty underwhelming. As someone who can be pretty chaotic during my creative process with rapidly evolving designs of complex Parts the rebuild times in solidworks get quite long. sometimes leading me to waste minutes every time a part needs to be rebuilt which can happen hundreds of times a day. Losing precious hours of my life waiting for a slower computer does not spark Joy. Additionally, I ran into a lot of driver glitches with the external GPU setup as it just wasn't very polished. After watching way too many YouTube videos on Mini ITX builds I stumbled across the velka 5 case and decided instead to make a build in this 5 L case capable of holding a fullsize GPU. With how many times I've lost my checked bag during travel I knew I wanted to keep the desktop in my backpack. This was one of the smallest cases that still fit a full-size GPU, and while physically possible to put in my backpack I got to say TSA was not terribly impressed with me lugging this 5 kg metal brick. I always managed to get through but on the 17-hour multi-leg flight getting hassled by security and having to forgo bringing a lot of other gadgets that no longer fit just wasn't ideal. That's when I saw the all new Nvidia RTX 4000 SFF Ada generation. An amazing graphics card with a terrible name. Its performance matches or exceeds my older full-size Quadro RTX 5000 card while drawing like a quarter of the power. I was already aware of the A2000 which is mechanically identical to this new GPU but the improved performance and more importantly the 8 extra gigs of vram meant there was finally a small form factor GPU that met my requirements. It was then I knew I had to make my ultimate mini work station and I knew I wanted to go all in shaving as much volume and weight as possible.

So at the core of this build is the the efficient
mini GPU and since we want to stay small keeping the thermal design power or TDP down is paramount. So the plan was to pair that with the ryzen 7900x which at the time was one of the highest ratings in performance per watt of desktop class processors, more on that later. This CPU runs efficiently around 100 to 130 Watts putting our total TDP for CPU and GPU at 200 watts. To avoid the need for an external power brick I was able to find this really awesome 250 W fanless design from hdplex that has been working great. Now, a well balanced individual that enjoys keeping their manufacturers warranties on their expensive PC components would have taken them and found one of the existing 3 and a half to four lit cases and that would be that lucky for us I'm a little more unhinged than that so I spent every spare moment of the next month ordering disassembling and measuring these components and CADing and playing twister with them to pack them as tight and small as I could. Also lucky for us I didn't record any of this so I'll save us the boredom of watching CAD and just show you the finished model here. So I decided I wanted to for an Ultra Premium Vibe and Mill the entire housing from a single block of aluminum since aluminum is such a great thermal conductor we can use the housing itself as a heat path out of the case I also opted to remove the power supply circuitry from its fanless metal housing and instead used its thermal pads to make direct contact with the PC case I used this small right angle pciu Riser from Amazon to tilt the GPU and removed its fan trout in case instead building the air flow path into the case itself I found that the gpu's small blower fan moved a surprising amount of air for its size with good static pressure and a nice sound profile under load also I think it just looks clean I figured

that if one fan was enough for a 75 WT GPU then two more should do the trick for 130 watt CPU I found a really nice and cheap copper CPU Cooler with a vapor chamber to spread Heat across its fins that was designed for servers and I custom designed a 3D printed shroud to move air through it using these mini fans since I wasn't interested in having those insanely loud 40 mm server fans running in my office so first things first uh quoting this part on JL PCB showed it was going to be around $300 in Machining so I wanted to be confident things were going to fit luckily I have a few really nice resin and fdm machines here at my home office and I was able to use those to confirm here you can see me cleaning and prepping a final resin print for my piol Phenom Prime the lid got a bit warped but the body print itself showed the fitment were looking really promising this was the third version I printed and I decided it was finally good enough to order the machine parts in between this cut is about a six-month Gap where I had to shove this side project to focus on my actual job and maybe a personal life and I'm still wondering how many hours of my life I lost leaving these awesome components collecting dust while I used my old computer to get through the mountain of cat I had on my plate well you might notice that I ended up swapping out the CPU for the newer and more efficient ryzen 9900x and I vowed I needed to get this build together before any newer and fancier things made my build obsolete so it was time to press forward and while we waited for the machine components to arrive we started testing assembling and modding all of the internal components here we can see I printed off the fan trout in Black pet G using silver pla as the support material on my new pra XL this print came out nicely and I got a snug fit with the heat SN fan and lid The Next Step was to break out the mini four pin jst pH connectors on the two fans in the fan trout and reverse engineer the breakout so we could solder up an adapter using my current limiting power supply and a bit of deductive reasoning first we sorted out which wires were powering ground and then by tapping the yellow wire to the ground when it was powered on we observed this stopped the fan spinning so this was likely the pwm wire, leaving the final white wire as the rpm sense wire. Next up was trimming down this metal piece on the MSI B650i motherboard. The included rear face plate and aluminum shroud for the rear IO would have made the build significantly thicker so I machined individual IO holes into the case itself and used this angle grinder to do some light trimming of this piece.

My garage might be a total disaster but the cut
came out what we like to call "good enough". I do want to note here even a hacksaw would get the job done, but this was faster. We then reinstalled it onto the motherboard making sure the thermal pads were back in place. Next up we installed the hard drive and CPU into the motherboard. We also installed the RAM which I forgot to film, and then it was time to install the fan shroud and heat sink onto the CPU. I used these carbon cooling pads from Thermal Grizzly and because they can be easily reused and don't require cleaning and re-application like thermal paste I saved myself a ton of time since I had to uninstall this heat sink several times as I figured out the wiring and debugged the build.

Around this time the Machined housing arrived
in the mail and as you can probably tell from this sped up clip I couldn't have been more excited. Everything was fitting great and the anodized and bead blasted surface finish

was looking so clean so it was finally time to start installing everything into the case. First up was the 250 W power supply. We needed to be extra careful on this piece getting all the thermal pads installed and making sure none of the mains voltage was able to make contact with the housing. We used the pads and shielding from the original PSU case alongside some kapton tape to be extra safe. We screwed the five small screws it came with to hold it securely. Next we install a small 40x40x10 mm fan to get some small amount of passive air moving inside the case and screw in four screws at the corner. Then it was time to install the assembled motherboard and screw it into the tapped M3 holes. I also secured a small thermal pad to pull some heat out of the motherboard though this addition is likely unneeded. We got everything secured nicely and then installed the included short cable for the larger PSU connector that fits snugly with a bit of massaging. Next we installed the C6 Mains connector that was included with the PSU.

Off camera we removed the bulky intermediate connector and soldered the cable to appropriate length so it could be tucked nicely next to the sawed heat sink. two M2.5 screws hold the C6 connector snugly. The 8 Pin CPU power cable proved a little trickier to route and we had to remove the fan shroud and Tuck its wires down below the external air path here to get the routing right. We held it in place with some kapton tape and reinstalled the fan shroud and heatsink. Next up it was time to install the power switch. This was a small Easter egg I added to the build as the power switch is an RGB momentary switch that was made for stormcore motor controllers back when I worked with the sadly now at a business E-skate company lacroix. We use jumper wires and kapton tape alongside referencing the motherboard documentation to get this wired up which required to yet again uninstall and reinstall the fan shroud and heatsink to access the connector.

In hindsight I am not sure why I didn't just leave this fan shroud and heatsink uninstalled until the end. Unfortunately I ended up with some camera troubles here and so we are missing the footage of the housing removal of the GPU including installing a custom 3D printed component I made to hold the fan and direct airflow. This isn't really meant to be an instructional video anyway, but rather an overview of the steps so I'll quickly explain what this entails.

First the stock housing and fan shroud was unscrewed from the GPU the fan was unplugged and then instead mounted to a 3D printed PETG bracket with a similar shape but which conformed to the machined housing. This was then secured to the GPU with two 20mm M2 screws and the fan was plugged back into the GPU. Then the GPU was plugged into a small right angle PCIE riser. This assembly is what you see me holding at the start of this next section and from here this is inserted into the motherboard ensuring the riser makes it into the PCIE connector on the motherboard. With a bit more massaging wires and some more kapton tape for good measure it was finally time to close this thing up and power it on for the first time. To say I was nervous would be a huge understatement, when the fans fired up for the first time I was so pumped and I couldn't wait

to test it out, but alas, my hopes were quickly dashed when I realized it was not posting and I couldn't even get the BIOS to boot. I was so worried I had somehow damaged my CPU or GPU. After a late night debugging and a very brief and restless night's sleep I found there were three separate things holding me back from success.

Firstly I needed to update the BIOS as the
ram was being very finicky and not working at all. This finally let me boot and install Windows but the GPU was not recognized at all. The second and more time consuming fix was realizing that one of the pins in my GPU riser had gotten bent, so the GPU was not being seen by the computer. Even after I repaired this bent pin the GPU was seen but randomly crashing when I would increase the PCIE bus speeds over 2.0.

After a lot more assembly and disassembly
I realized that the soldering of the pcie connector on the Riser was extremely shoddy and so after reflowing all 80 something of its pins by hand and adding some better quality solder I finally got it working reliably without crashing and it's been extremely stable even at pcie 4.0 speeds. Problem solved. Once things started working I could already tell that this machine was pretty excellent but it was then time to get all my software set up and installed and do some benchmarking to compare the build and make sure everything was working nicely for this comparison I wanted to stack it up against both my small 14-in AMD laptop as well as my previous small form factor 5.3 L build I also found some specs for a top- ofthe line 17-inch modern gaming laptop to compare though it should be noted that gaming class video cards aren't great when it comes to solarworks workloads especially with regard to stability so I don't really see this as a super viable option additionally the laptops with Quadro cards just don't really impress me with their performance or price and it was difficult to track down benchmarks online for those so I'm leaving them out of the the comparison obviously these aren't apples to apples comparisons as my older laptop and desktop are using OU ofd components and laptops also include a built-in display and keyboard and trackpad but for my use case at an office where I always offer dedicated monitor anyways this isn't really relevant and the comparisons are just for fun first up to compare is the portability at less than half the volume of my previous desktop I found this build to be extremely easy to slip into my backpack and it left tons of room for spare devices for my camera and other stuff it blew my mind that it was so tiny I was able to fit it in my backpack in what I will call Landscape aspect ratio I weighed each of these PCS and was pleased to see this desktop class build with full metal housing weighing it at only 6 lb or 2.75 kilos it was 60% of the weight of my previous build a full 42 LB lighter or 2 kg it only weighed about 1 kilo or 2 lb more than my 14-in laptop if we compare it to the strict 17.3in scar with built-in 490 GPU it is almost a full kilogram or 2 lb lighter than this 17 monster and full and a full liter volume smaller next we'll take a look at The Thermals I took some thermal footage of the housing and we can see the heat from the PSU is transferring nicely into the housing and it's getting up just under the 50 Celsius range in some hot spots which should be just fine the CPU temps hover around 60 to 65c during light use with near silent fans my cheap deel meter reads around 42 to 45 DB like this and I find the fan noise to be very

unobtrusive under more heavy loads the fans ramp up and it Peaks around 85 to 90 Celsius again depending on fan curves and the fan definitely make themselves Heard Around 50 to 52 DB but again very subjectively I find the noise to be very tolerable and not have any high pitched or sharp components I think the Nvidia or PNY Engineers did a great job designing this fan to have a mild sound profile unfortunately I don't have adequate equipment to really capture the sound properly to show you guys next up I wanted to analyze performance and efficiency I thought it'd be fun to do some head-to-head benchmarking and I plugged my desktops into a wall outlet power meter to get true ratings it should be noted I'm limiting the CPU power of the two desktops pretty heavily as I wanted to keep them as I use them in the real world with low TDP to maximize efficiency and reduce fan noise I don't find the extra 5 to 10% performance to be worth the trade-offs of extra heat in my office here are the cine bench results I got and we can see in this synthetic Benchmark the single and multi core scores are between 1.5 to two times as fast as my previous desktop all while using considerably less power the multi four CPU benchmarks for the 17-in monster laptop are only slightly faster and this is attributable to its four extra cores even though its single core speeds are 10% slower than our desktop variant CPU on the GPU side it was incredible to see this newer 75 watt mini GPU absolutely crush the larger but older 230 watt Quadro RTX 5000 with almost double its score really amazing to see the gains that are being made here in the past few years we can see the scores of the 17in laptop 4090 are pretty impressive as well but these likely wouldn't translate into solid works well and really the GPU numbers are generally less important for solid works workloads since frame rate isn't a major concern and what really matters is simply having enough vram available and having stable drivers that never crash it was also so impressive during these benchmarks to see how much less wattage was being pulled from the wall compared to my last desktop generally somewhere between 50 to 75% of the wattage during the benchmarks and I have noticed my office staying significantly cooler since I switched over which is a nice added bonus for solid works the benchmarks available are fairly sketchy and inconsistent so I opted to time a full part rebuild I wasn't able to grab scores for the laptop since they did have solid works installed they didn't have solid works installed currently but my old desktop was building this complicated part in roughly 62 seconds while the newer lower power machine completed it in just 42 seconds while this roughly 1.5 times speed up may not seem like much when you are constantly waiting on these things all day the feel is just such a major Improvement and I was so happy to see this working on the machine for the past couple weeks has felt so Snappy and smooth um I'm over the moon lastly uh I made this plot to compare the cinebench metrics and I kind of weighted the GPU and CPU metrics and scaled them so they had about even weight and then I again scaled those by dividing by the volume weight cost and peak power draw respectively. You can pause the video if you want to think harder about these numbers but I just wanted to highlight a couple of interesting points. Firstly, I was very surprised to see the performance per dollar between these examples come out with less than 10% variance across the builds I expected the hire in stuff to see a higher price per performance penalty second we can see this build is absolutely crushing in the performance per walk category though this is a very limited sample size and I'm sure something in the Ultrabook category might Crush here instead I was also very surprised to see the build right in line with the 17 inch monster laptop and performance even with its much lower GPU score.

in cinebench. Next up before we wrap this video
up, is a cost breakdown of all the components. You can pause the video here if you want to see what each component cost me. The total came out to around $2,911 and I would easily pay that again for this awesome little machine. If you made it this far in the video thanks so much for watching and I would super appreciate any likes, subscribes, comments, you know the drill. It's always nice to get that positive feedback and engagement from you guys. My final thing I would ask is if this is something you'd be interested in building yourself?

I have been thinking about maybe ordering a run
of 20 cases and maybe selling them in some form of kit with the included custom printed bits and screws for I don't know $500-$1000 depending on what was included (the PSU and motherboard for instance). I should note that the quadro A2000 mini GPU is also compatible with this housing so it's possible to put together a more budget friendly build by saving around $750 there, and also saving maybe another 200 bucks on a lower-tier CPU like a ryzen 7700 or something like that and that puts the build closer to the $2,000 range if that's you know where your budget is sitting as as you can probably tell from this video, it's a higher skill level build, but I have a hunch there might be a few people out there who' want to give it a go. Let me know what you guys think down in the comments. If I get enough people expressing interest I might put together a more thorough build instruction video and front the money for a small run. Thank you so much for watching.
It has been an absolute delight to share this thing I made with you and I'm looking forward to building a lot more cool stuff to show on this channel.

yeah so *falls* oh God glad I got that on video