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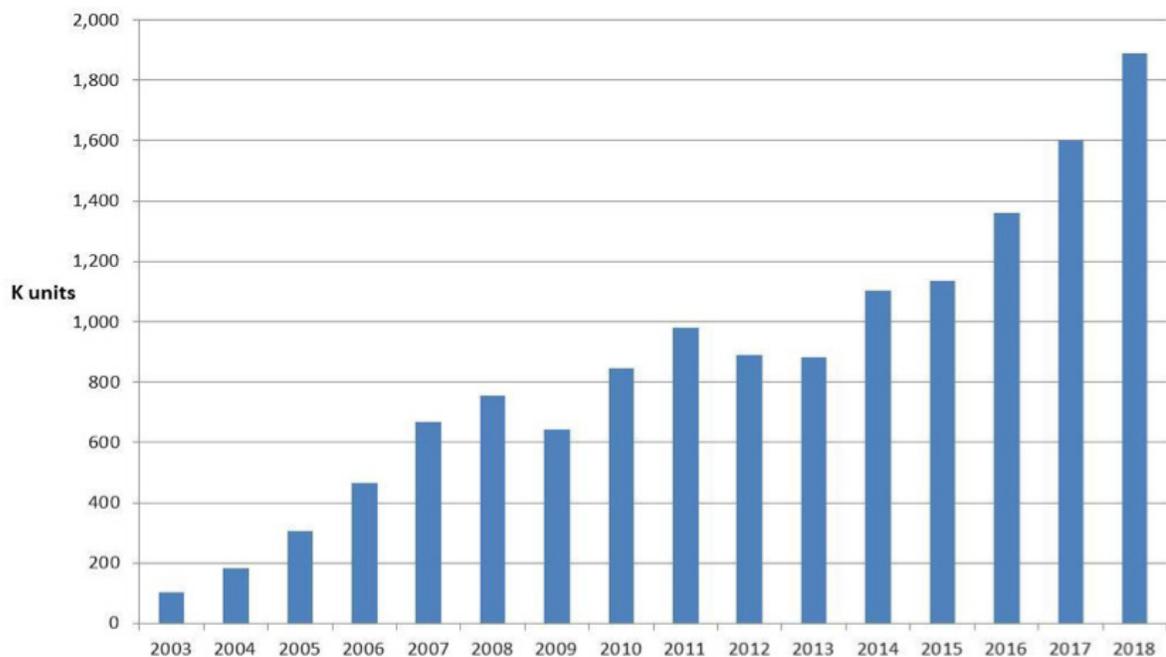
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» **Figure 1.** The mobile workstation is an unmitigated success in the market, and for good reason. Source: Jon Peddie Research.

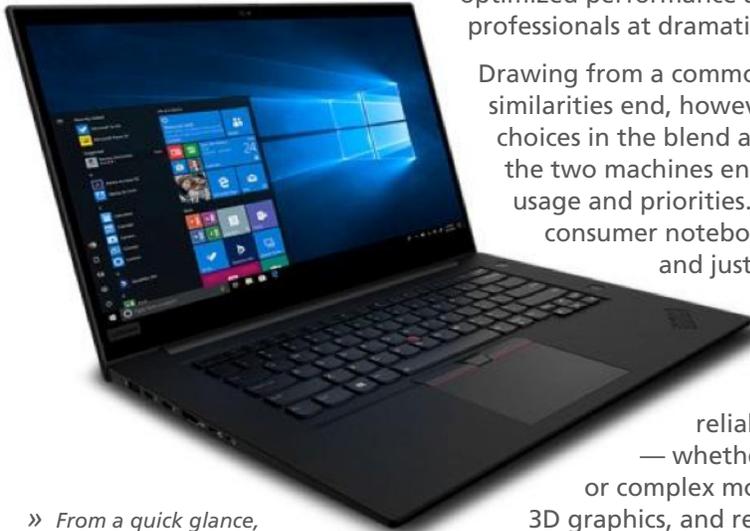
Compared to its deskbound sibling, with its long and storied history, the mobile workstation is a relative newcomer on the professional computing scene. Whereas the paradigm-defining tower and desktop machines from Sun, SGI, HP, and IBM dominated the computing landscape for CAD and digital content creation from the 1980s on, the mobile workstation did not emerge till the early 2000s. Its appeal to engineers, designers, and creators was immediate, spurring explosive growth to the point that today the platform accounts for more than a third of all workstations sold (**figure 1**). The reason for its success is obvious, as it offers the same compelling argument to professionals as its desk-based predecessor: Compared to the alternatives available, the mobile workstation represents the most appropriate, productive, and cost-effective tool available for visual professionals on the road.



» **Cover image:**  
[iStockphoto.com/laurielaki](https://www.istockphoto.com/laurielaki)

## Two Breeds That Share DNA — Yet Fundamentally Different Species

PCs and workstations historically haven't been confused for one another, as decades ago the two were essentially different species, right down to the DNA level. But over time, the two have evolved into two breeds that share many of the same genes, a trend that's proven the linchpin in creating a workstation that can combine optimized performance and reliability for visual computing professionals at dramatically lower price points.



» From a quick glance, anyone would be hard-pressed to tell this Lenovo ThinkPad P1 is a mobile workstation.

Drawing from a common pool of technologies is where the similarities end, however. Because given their respective choices in the blend and balance of hardware and software, the two machines end up deliberately shaped for different usage and priorities. Where the typical corporate or consumer notebook will deliver excellent battery life and just enough performance for mainstream computing tasks, the recipe for the mobile workstation takes a very different tack, prioritizing mission-critical performance and reliability that CAD professionals demand — whether that involves simpler 2D schematics or complex modeling, simulation, analysis, interactive 3D graphics, and rendering. Each machine is built to suit its respective base of customers and applications, and when it comes to high-demand, visually intensive CAD computation, the mobile workstation has established itself as the superior, best-fit computing tool for professional users on the move.

» Notebook PCs are fine for the mainstream, but mobile workstations are specifically tailored for maximum productivity for these high-demand visual computing applications. Image source: NVIDIA.

For CAD information technology (IT), the primary avenues to drive design and development productivity are twofold: one, to shorten the time required to complete individual tasks and improve the workflow overall; and two, to avoid idle time by ensuring all critical IT resources (hardware and software) are always up and running, available to users. The former requires the best possible throughput for a range of CAD workloads, and the latter requires the most reliable computing tools. Workstations are specifically engineered to achieve both, with features PCs can't match, such as independent software vendor (ISV) certification, professional-

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	Workstation	Typical Commercial Notebook PC
Design rationale	CAD-optimized performance without sacrificing reliability	Mainstream performance for commercial applications
ISV certification	Yes	No
Central processing unit (CPU)	Intel® Core™ and professional-grade Intel® Xeon® processor SKUs geared to best performance at reasonable power	Intel® Core™ processor SKUs, geared to adequate performance at minimal power
Graphics processing unit (GPU)	Professional-grade discrete GPU and driver: NVIDIA Quadro	CPU-integrated graphics for optimal power
Memory	Error-correcting code (ECC)-capable	No ECC
Storage	RAID-capable	No RAID

» **Table 1.** Typical characteristics of a mobile workstation versus a commercial/consumer-oriented notebook PC.

caliber CPUs and GPUs, enhanced memory and storage capacity and protection, more capable power supplies (PSUs), more robust chassis design and materials, and more comprehensive warranties and support (**table 1**).

Crafted specifically for high-availability workstations and servers, Intel® Xeon® processors deliver exclusive features such as memory error protection (in the form of error-correcting code, or ECC) and optimal clock frequencies that maximize performance without sacrificing reliability. Similarly, NVIDIA offers a professionally tailored line of its industry-leading GPUs, Quadro, with hardware and driver optimized for the type of visual processing most common in CAD. Supported memory footprints — like the P1's 64-GB capacity — exceed what mainstream corporate or consumer notebook PCs support or need. Storage subsystems allow not only high-speed, low-latency access to capacity beyond the mainstream norms, but the redundancy (RAID) to ensure a single failure doesn't crash the whole system. Wrapping all that up into a workstation package, suppliers team up on comprehensive regression testing with ISVs like Autodesk and Dassault Systèmes to verify the complete workstation system, ensuring every certified workstation reliably runs the most popular CAD applications. And workstation vendors often go one step further on the software front, providing tools that allow users to control how different applications run on their machines. One example, the Lenovo Performance Tuner, specifies default values to deliver sound performance in the majority of use cases, while giving users and IT administrators the option to fine-tune the allocation of hardware resources, down to a specific selection of which applications run on which CPU cores. All the above comes supported not only in desktop workstations, but carried over to mobile workstations like ThinkPad ... but not to corporate- or gaming-focused laptops.

### Performance on CAD Computing Workloads

The appeal and tradeoffs of any computer extend beyond raw performance, and that's especially true for workstations. But let's be honest, when it comes to demanding, compute-intensive applications like CAD, most will want to start with performance.

	Lenovo ThinkPad P1 mobile workstation	Typical Commercial Notebook PC
<b>MSRP<sup>1</sup></b>	\$2,000	~\$1,200
<b>CPU (base/cores/TDP)</b>	Intel® Core™ i7-9850H (2.7 GHz / 6 / 45 W)	Intel® Core™ i5-8250U (1.9 GHz / 4 / 15 W)
<b>GPU</b>	NVIDIA Quadro T2000 with 4 GB of graphics memory	Integrated Intel® UHD Graphics 620
<b>Memory</b>	32 GB	8 GB
<b>Storage</b>	512-GB SSD (M.2 PCIe / NVMe)	256-GB SSD (M.2 PCIe / NVMe)

» **Table 2.** Specifications for SPECwpc benchmarking: mobile workstation versus typical commercial notebook.

To contrast what a mobile workstation can deliver on CAD workloads, we ran the best open, aggregate benchmark suite available: SPECwpc 3.02 from SPEC. We specifically chose a Lenovo ThinkPad P1 mobile workstation configured to price at around \$2,000 — the average selling price of a mobile workstation in 2019<sup>2</sup> — and a generic notebook PC marketed for commercial applications. The key hardware specifications for both models are shown above (**table 2**), and illustrated below (see **figure 2**, p.6).

We employed the Product Development suite of SPECwpc tests, which are designed to give those relying on CAD for design, engineering, manufacturing, architecture, and construction a comprehensive sampling of the range of workloads they'll see in a day of modeling, visualization, and simulation. The Product Development suite is essentially composed of two parts: one primarily (but not only) stressing the CPU's aptitude for multi-threaded computation (Rodinia, WPCcfd, and Calculix), and the other primarily stressing the GPU's speed in drawing 3D graphics viewsets (showcase-02, sw-04, snx-03, creo-02, and catia-05).

All told, the ThinkPad P1 mobile workstation outperformed the commercial laptop by a wide margin on the Product Development test suite, and particularly on graphics-focused workloads, which ran about 7 to 11 times faster.<sup>3</sup>

**CPU-focused workloads.** On multi-threaded, compute-focused workloads primarily stressing the CPU, the ThinkPad P1 ran more than twice as fast as the notebook PC, with the P1's H-class 2.6-GHz (base) 6-core Core i7-9850 handily outperforming the PC's U-class 1.7-GHz (base) quad-core Core i5-8350U (see **figure 3**, p.6). It's not hard to see that, barring any significant bottlenecks in memory or storage, that edge comes courtesy of populating 50% more cores (as all three tests support multi-threading to take advantage of all cores and Hyper-Threading<sup>4</sup> supported) running at a roughly 50% faster base clock rate.

Not a fair fight for the Core i5, perhaps, going up against an obviously better-equipped Core i7? Well, yes and no. Yes, with proper forethought in configuring your system — both the CPU and supporting hardware — a PC buyer may be able to find and select a 6-core CPU as well in a corporate notebook. But no, it is fair from a very important perspective. A fundamental value in purchasing a workstation is that it's a tool intentionally shaped for professional workloads, where other machines are tailored to

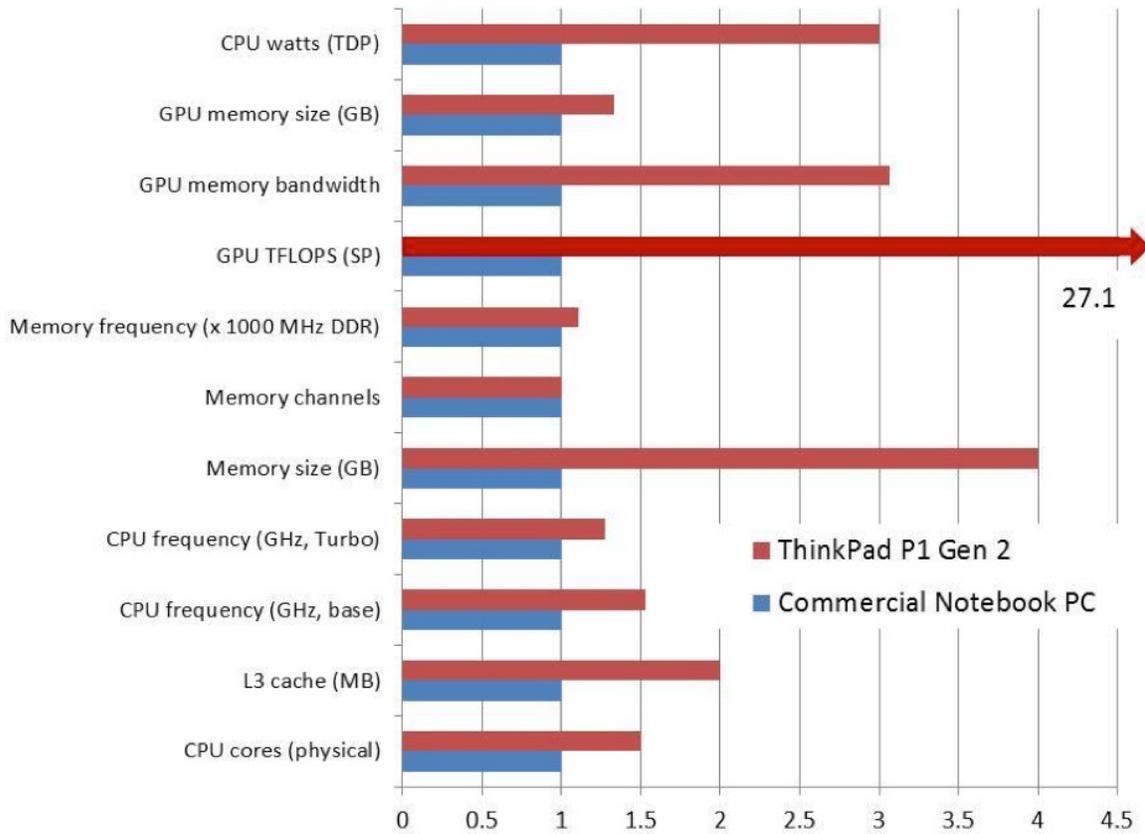
<sup>1</sup> MSRPs sampled online on the same day in October 2019

<sup>2</sup> Source: Jon Peddie Research

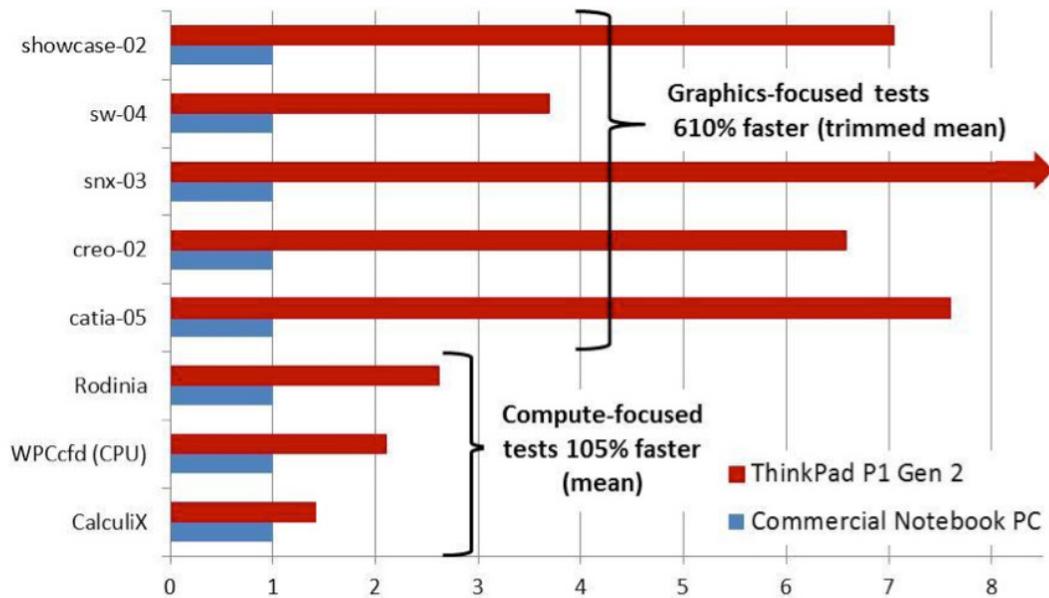
<sup>3</sup> Arithmetic mean of 11.29 times faster, or a trimmed (outliers removed) mean of 7.1 times faster

<sup>4</sup> Intel's brand of technology that allows each core to run two time-sliced threads concurrently (sharing CPU resources)

» **Figure 2:** Raw component metrics for our test-case ThinkPad P1 mobile workstation, normalized to a typical commercial notebook PC.



» **Figure 3:** SPECwpc 3.02 scores for Product Development test suite run on the Lenovo ThinkPad P1 mobile workstation (normalized to a general-purpose commercial notebook PC).



A fundamental value in purchasing a workstation is that it's a tool intentionally shaped for professional workloads, where other machines are tailored to meet different priorities.

meet different priorities. So the recommended configuration for a P1 or other mobile workstation targeting CAD applications will very deliberately offer a higher-GHz, six-core CPU (or even eight-core) that would pay off in higher performance for their typical workloads.

Conversely, while you might search one out, there's little reason for a corporate-grade laptop to push a CPU like the Core i7-9850H, simply because it's overkill for most applications run on such machines. Furthermore, such a CPU would likely be counter-productive for mainstream corporate and consumer applications, because the tradeoff to this CPU's increased performance is higher power consumption — 45-watt TDP (thermal design power, versus the PC's Core i5 at 15 watts<sup>5</sup>). Intel specifically designs and manufactures the H-series (standing for *High* performance) for performance-first applications, and the U-series (for *Ultra-low* power) for battery life-first usage. So not only would OEMs and end users configuring a corporate or consumer notebook go unrewarded with a workstation's higher-performance CPU, they would be penalized with shorter battery life to boot. Add it all up, and both machines feature appropriate CPUs optimized for their intended purposes — but woefully unfit for each other's.

**Graphics-stressed workloads.** The difference in hardware components is more stark when considering the workloads that truly separate applications like CAD and digital media creation from the rest: 3D graphics. Consider that fewer and fewer mainstream corporate notebooks are integrating discrete GPUs today, and for the same reasons that are guiding CPU choices. For the applications that notebook PCs are typically designed for, there's little need for the additional performance of a discrete GPU — and building it in imparts additional cost, power consumption, and thermal output. So no surprise, the NVIDIA Quadro T2000 within the ThinkPad P1 mobile workstation outperformed our general-purpose notebook PC with CPU-integrated graphics by an order of magnitude: It was 11 times faster (overall average across viewsets, or 7 times faster on trimmed mean with outliers removed).

Furthermore, even if that commercial or gaming PC notebook does come outfitted with a discrete GPU as a companion of the default, CPU-integrated graphics hardware, it's not going to be the optimal performance solution for CAD professionals in two critical respects: the design and testing of the driver, and the manner in which the system balances performance and power consumption.

For example, in the NVIDIA product world, workstation-caliber Quados and gaming- and consumer-focused GeForces are not one and the same. While they leverage a common foundation in core 3D graphics architecture and technology, they don't share drivers, and that's much of where the order-of-magnitude-better performance running those SPECwpc viewsets comes from. Why? Simply because the respective drivers are optimized to perform best on most of the common visual workloads that a Quadro or GeForce might see. The types of rendering that CAD modelers and Quadro will most commonly deal with differ from those in the consumer and corporate realm, especially in the domains of

<sup>5</sup> A modern higher-wattage CPU can be scaled down in power (e.g., lowering frequency, voltage, or number of cores in use), but will not be as power-efficient as a CPU intended for that purpose.

More so than sluggish throughput, the most obvious way a computing tool can sabotage productivity is simply to fail outright.

product design and architecture. Consider just a couple of examples in 3D lines and pencil-style shading: These drawing modes are still common in CAD, but virtually absent in gaming or other mainstream 3D applications. The result? As the respective test results indicate, the P1's Quadro T2000 can draw those SPECwpc 3D viewsets representative of Creo, Solidworks, Siemens NX, and CATIA far faster than the notebook PC's mainstream-focused CPU-integrated graphics can.

Second, even if a mainstream notebook PC did configure a discrete GPU alongside CPU-integrated support, the manner in which those two resources are managed is fundamentally different than in a mobile workstation like the P1 — again, for good reasons that align with the platforms' respective target usage. In a conventional notebook, OEMs typically implement NVIDIA's novel Optimus technology, which automatically switches between integrated and discrete graphics to optimize power consumption. While perfectly sensible for lower-demand commercial applications where battery life often outweighs performance, such autonomous control isn't ideal for visually intensive CAD workloads where time-to-completion more often outweighs all. Accordingly, the hardware and firmware engineered in a mobile workstation like the P1 allows users at their discretion to select Discrete Mode, which temporarily suspends Optimus Mode to wholly and unilaterally leverage the discrete Quadro GPU for maximum workflow throughput.

### **Workstation Reliability: A Critical Deliverable That's Far More Challenging in a Mobile Form Factor**

More so than sluggish throughput, the most obvious way a computing tool can sabotage productivity is simply to fail outright. While it might be a drag waiting seconds or minutes longer than necessary for your machine to complete a simulation or render to complete, consider the impact of being without the machine at all, for hours or even days. Accordingly, for a mobile workstation, reliability sits right at the top of the priority list with performance, a priority supported by the hallmarks of workstation breeding: robust construction, testing, and ISV certification.

It's anything but a trivial exercise to deliver reliability in a conventional deskbound computer, but, managing the same in a mobile form factor increases the challenge considerably. Far and away, the most prominent threats to a computer's reliability are thermal overload and shock, and engineering for thermal and shock tolerance becomes much more challenging when that machine comes in a laptop form factor. Deskside towers aren't likely to be dropped, or at least not often. And as for thermals, deskside workstations have more space and many more engineering tools in use to efficiently cool the machine.

Mobile workstations, in contrast, will certainly take their share of falls, and chassis volume is intentionally scarce, which puts an even higher onus on shock tolerance and efficient cooling. Accordingly, mobile workstations are engineered with more robust materials

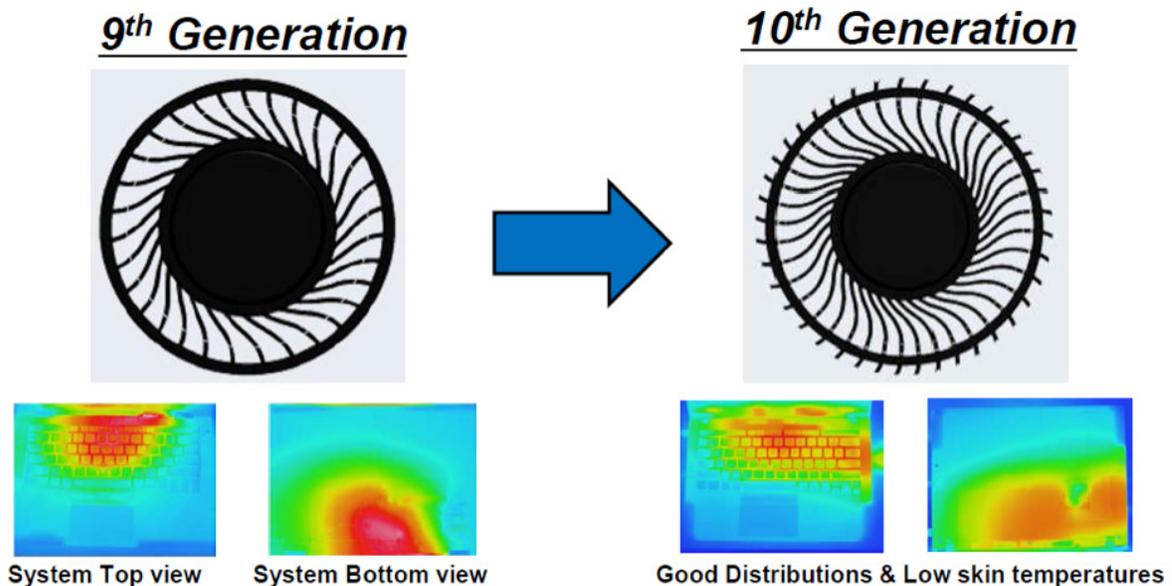
and more secure retention mechanisms. Lenovo's ThinkPad P1, for example, comes built and tested to meet rugged military grade MIL-STD-810g specifications for shock and environmental tolerance. The P1 also comes constructed with a carbon lid to improve structural integrity (as well as aesthetics).

Comprehensive thermal engineering ensures workstation components stay cool under the pressure of running compute-intensive software, as hot parts are more vulnerable to failure. For its ThinkPad P1, Lenovo engineers integrated new technologies to dial up cooling efficiency. Novel fan blades, for example, improve system cooling while reducing turbulence. Inspired by the effortless flight and sleek aerodynamics of its namesake, the P1's Owl Wing blades incorporate an enhanced shape and micro-spoilers that improve airflow volume by 15% without increasing noise. The result? Higher performance (via higher tolerated frequencies) with heat better dispersed throughout the chassis, and lower skin temperatures, all accomplished with stealth-quiet efficiency (figure 4).

Furthermore, consider the risks for any computer reliant on a single fan for cooling. Should that fan fail, the system will follow right behind. In the pursuit of maximum system reliability, the P1 comes outfitted with dual fans: Should one fail, the system will press on (though power consumption may be throttled down to adapt to reduced airflow).

While tangible physical and structural constructs may be the first things that come to mind when thinking about system integrity, robust and deterministic software operation is just as critical to eliminating downtime. A workstation-caliber GPU like Quadro runs exclusively on its own driver, specifically engineered, tuned, and tested to run target CAD applications like AutoCAD, Solidworks, Siemens NX, and CATIA. And in conjunction with the respective ISVs — including Autodesk, Dassault Systèmes, and

» **Figure 4.** *Lenovo integrates innovative Owl Wing technology to improve cooling, quietly and efficiently.*



Often overlooked by potential buyers, conscientiously designed ergonomics can contribute as much to end-user productivity as outright performance.

Siemens — the combination of Quadro hardware and software undergoes rigorous testing to ensure an ISV-certified level of reliable execution that gaming and commercial solutions do not. More robust hardware designs combined with ISV certification yield increased uptime thanks to reduced chances of crashes, bugs, memory errors, and repairs.

### Professional-Caliber Ergonomics

Often overlooked by potential buyers, conscientiously designed ergonomics can contribute as much to end-user productivity as outright performance. Acoustics, heat, and image fidelity are a few criteria that can turn an otherwise pleasant day of progress into a frustrating one of drudgery and missteps.

**Acoustics.** Nobody likes a noisy machine or one that runs excessively hot when literally atop your lap, but it's a bigger concern when running high-demand professional computing applications. Why? Well, office applications aren't particularly taxing on a machine — the CPU and GPU in particular — but professional visual computing applications in CAD and media creation are, and will crank up those resources. You've heard the jump in decibels when the fans kick up shortly after kicking off some computationally or visually intensive job, right? The jump is noticeable in a desktop, but particularly pronounced in a laptop form factor, one that's both more airflow-challenged and produces that noise closer to your ears. Run jobs like that only now and then, and the noise might be tolerable. Run them all day, and you might be reaching for some earplugs or looking to head home early.

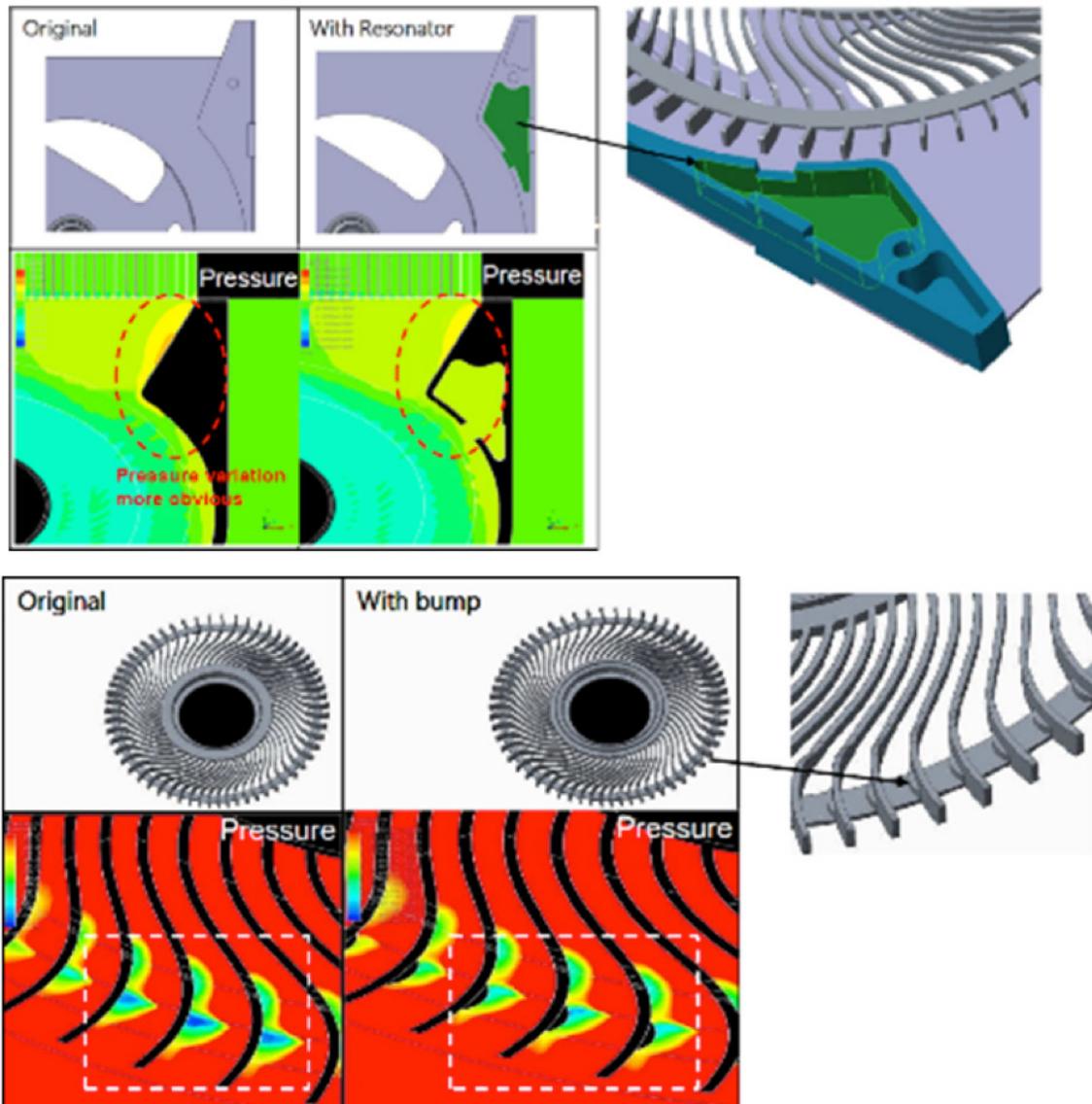
There's no pressing need for designers of a mainstream consumer or commercial notebook to spend time and money on acoustic engineering and efficient cooling (which, to a large degree, go hand in hand). But there is when creating a mobile workstation, which may be maxed out in simulation or rendering for extended periods, enough to turn a conventional notebook chassis into a sizzling racket. First off, the mobile workstation's cooling designs serve up dual benefits, not only reducing the chances of a problematic hot spot but keeping the fan speeds and air turbulence down. And second, the design of the fans, airflow, and chassis can cut decibels even further. Consider the deliberate design of the P1: Those spoilers not only improve the efficiency of airflow by dampening turbulence, the reduced turbulence cuts down decibels. Last but not least, the P1 includes a resonant chamber as well, which performs destructive interference on resulting high-frequency noise (think of it as a muffler with high-frequency acoustic cancellation; see **figure 5**, p.11).

**Maximum image fidelity.** Relying on a professional-tailored GPU will certainly deliver the goods when it comes to generating real-time interactive 3D graphics for developing CAD models. But how those colors are reproduced on screen is beyond the control of the GPU or application. Not all monitors will look the same when displaying the same RGB color that a GPU would produce, an unfortunate fact resulting from both the characteristics of different display technologies and variances in manufacturing the same display

technologies. So not only will two panels relying on different technologies — IPS LCD versus OLED, for example — produce a different shade and/or intensity as perceived by the eye, but two units manufactured with the same process can also vary (though to a lesser degree).

The remedy — one found exclusively in mobile workstations — is color calibration, in which sensors visually sample a particular panel's output and compare it to expected color gamuts and profiles. Lenovo's ThinkPad P1 is an example, giving customers the option to have X-Rite Pantone color calibration performed at the factory for the exact unit purchased, creating an accurate color profile unique to that specific panel. Desirable in virtually any CAD or digital media application where professionals visualize designs prior to committing to expensive prototypes, color calibration can be outright mandatory in applications requiring strict adherence to standard, accepted libraries of materials and textures.

» **Figure 5:** The ThinkPad P1's fan comes designed with resonating chamber (top) and mini-spoilers (bottom) to improve airflow cooling efficiency and mitigate noise levels. Image source: Lenovo.





**Commercial Laptop**

### A Common Story: Different Tools for Different Purposes

Exploiting a common base of engineering and technology investments makes sense in any modern industry. Consider Toyota, which designs and markets a broad range of cars and trucks for a diverse customer base. The company created the Sequoia SUV for families and personal use, and Tundra pickup trucks for businesses and commercial work — two different solutions for different customer needs — yet they share a common pool of investment in engineering and manufacturing the chassis, engines, and parts. Precisely the same principle applies in computing, as evidenced by today's notebook PCs and mobile workstations.

Along with virtually the entire computing landscape — from handheld phones to massive supercomputer installations — notebook PCs marketed for consumer and corporate applications tap into a common pool of hardware and software technologies, as do today's mobile workstations. But from that shared foundation, the breeds evolve separately, based on a different set of guiding principles and priorities. Whether peeking under the hood, or carefully considering its choice in components, chassis, body, and design intent, you can see how the mobile workstation sets itself apart from the typical corporate- or consumer-class notebook PC. It could be the inclusion of a Xeon or high-performance Core CPU, or of an NVIDIA Quadro GPU; selecting error resilience in ECC memory or RAID storage; taking unique tacks in engineering the enclosure, thermal, and acoustic characteristics ... or it could be all of the above.



**Lenovo ThinkPad P1**



In that sense, and despite its shared DNA, the mobile workstation has never lost sight of its primary mission: to encapsulate features, reliability, testing, and certification custom-tailored to the needs of engineers, designers, architects, and construction staff on the move. Even better, that common investment in technology means that the mobile workstation's benefits can now be had at a fraction of the cost of its workstation predecessors. With purchase prices competitive to corporate-class notebooks, and given its focus on reliability and CAD-focused visual and computing throughput, the better measure of price — the ultimate total cost of ownership (TCO) — falls in the mobile workstation's favor. Today more than ever, the mobile workstation is the logical choice for visual computing professionals on the move. ◆

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*\*The ThinkPad P1 mobile workstation outperformed the commercial laptop by a wide margin on the Product Development suite of SPECwpc tests, and particularly on graphics-focused workloads, which ran about 7 to 11 times faster. (See figure 3, p.6 for more details.)*