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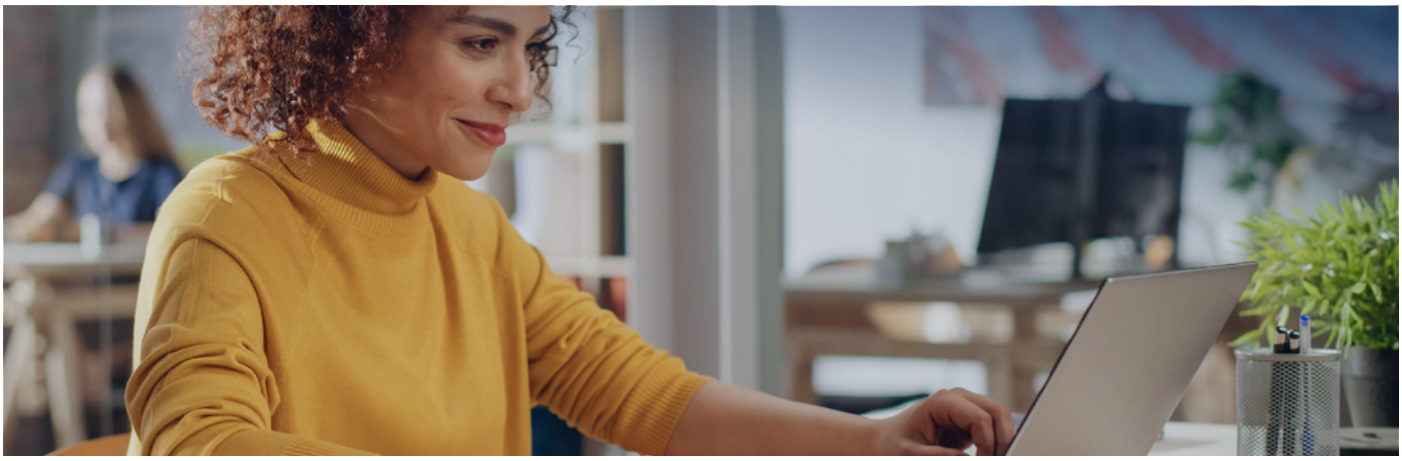

Technical Research Report

Windows® on x64 or Windows on Arm®: Which Architecture Offers the Best User Experience?

Prowess Consulting performed research and testing to determine which underlying architecture provides the best performance, application compatibility, and support for drivers, support files, and peripherals.

Executive Summary

For decades, consumers and businesses have relied on the stability and vast ecosystem of Windows® applications running on x86/x64 architecture from Intel and AMD. Over the last several years, a handful of companies have tried to shake up the market by releasing devices with Arm®-based processors that require a completely redesigned version of Windows. But those Arm-based Windows devices have struggled to take hold due to many issues related to software compatibility, driver and hardware support, poor performance, high latency, and frequent crashes.

Now, Qualcomm is hoping to turn things around with its recent release of Qualcomm® Snapdragon® X and Snapdragon X Elite processors for Windows on Arm. Early online reviews look promising, demonstrating far fewer issues and much greater performance than Qualcomm's predecessor chips and the previous iteration of Windows on Arm. But are the improvements enough? And do they overcome the compatibility challenges that plagued earlier releases of Windows on Arm?

Prowess Consulting, sponsored by Intel, performed testing and research to answer that question. We found that despite the improvements, devices powered by x64 architecture–based processors offer much broader support for applications, games, drivers, and peripherals while providing exceptional performance for complex productivity, content creation, and AI workloads.

Highlights

Compared to a Windows® on Arm® device powered by a Qualcomm® Snapdragon® X Elite processor, an x64 processor–based Windows device powered by an Intel® Core™ Ultra processor offers:

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- Broader support for applications, drivers, and peripherals
- Wider compatibility and higher performance for popular games
- Greater performance for real-world productivity workloads

Industry Landscape: Architecture Comparison

Given the complexities and potential confusion for users, why are there two competing architectures for Windows? A brief look at the history of each of these architectures can help answer that question.

Note

The industry sometimes uses the traditional term "x86 architecture" to refer to modern systems built on 64-bit ("x64" or "x86-64") architecture, which supports both 64-bit and 32-bit applications. This paper uses "x64 architecture" to emphasize support for 64-bit applications. The Intel® processor–based Dell™ XPS 13 9340 devices used in our testing ran 64-bit (x64) architecture.

Competing Architectures for Windows

In the 38 years since its inception, Windows has become one of the most popular PC operating systems in the world. The x86/x64 architecture has been part of that journey from the beginning, allowing a rich ecosystem of software developers, applications, and tools to flourish. Today, Intel and AMD compete to provide x64 architecture–based devices offering performance, efficiency, and affordability in a wide variety of forms built for productivity, gaming, content creation, media consumption, and other types of workloads.

Arm architecture, in comparison, was originally developed in 1990 as a reduced instruction set computer (RISC) CPU.[1] RISC is designed to handle more, but simpler, instructions that can be processed quickly, which makes this architecture well-suited for use in smartphones. As a result, Arm-based solutions power about 99% of premium smartphones (according to Arm),[2] in addition to a wide variety of tablet devices.

More recently, several OEMs have brought Arm architecture to Windows and Google™ ChromeOS™ laptops. In early 2024, Qualcomm released its Snapdragon X and Snapdragon X Elite chipsets, which were built to run the latest release of Windows on Arm. The intent was to bring the efficiency benefits of these smartphone-based processors to Windows laptops while also meeting modern performance needs for AI-dependent workloads. The Qualcomm Snapdragon X release dovetails with a renewed effort from Microsoft and partner software vendors to provide native support for Windows on Arm. However, the ecosystem still lags behind x64-based applications, and Windows on Arm still presents challenges to many users—which we examine in this paper.

Emulation Impacts Performance

To help ease the transition to Arm architecture, Microsoft developed the Microsoft® Prism emulation engine. The Prism emulator translates software built for traditional x64 binaries to run on Arm architecture. This is particularly useful for running applications that have not been rewritten to be native for Arm. However, our testing found that this emulation layer can have an impact on performance.

Even applications that are built from scratch to support Arm architecture might have specific components or drivers that require emulation. And as our testing and research show, even fully native Arm architecture–based applications can lag in performance compared to apps designed for and running on devices built on x64-based architecture.

Testing and Research: Windows on Arm Versus Windows on Intel® x64 Architecture

Given the limitations of the Arm architecture discussed earlier, is it worthwhile for users to invest in devices running Windows on Arm? To help answer this question, we conducted extensive research and performed tests on devices running Windows on both Intel x64 architecture and Arm architecture in order to compare performance and functionality.

We focused our analysis on several sources:

- Published vendor statements on support for Windows on Arm
- Published findings and observations from press and reviewers
- Our own internal testing using benchmarks and real-world applications

We performed our testing on two Dell™ XPS 13 devices, one running Windows on Arm architecture on a Snapdragon X Elite X1E-80-100 processor and one running Windows on x64 architecture on an Intel Core Ultra 7 processor 155H. We specifically chose systems that were the same model and configuration, with a similar price, and from the same OEM to enable a fairer CPU performance comparison. (See Appendix A for full system configurations.)

Prowess Consulting's testing included several industry-standard benchmarks, in addition to real-world workloads covering productivity, AI, content creation, collaboration, and games. All the tested applications ran natively on the x64 device. For the Arm-based device, some of the tested applications were available with native Windows on Arm support, and some only ran in emulation mode. These are noted in the "Prowess Consulting Lab Testing" section of this paper.

Finally, we performed additional research to determine what differences users might encounter when working with various peripheral devices and third-party drivers on Arm-based PCs versus x64-based PCs.

A Comparative Review of Battery Life

Battery life is generally a key differentiator for users interested in purchasing devices powered by Snapdragon X Elite processors, so we ran several tests to compare battery life for the two Dell XPS systems in our study.

We first ran a local video file in a loop until the laptop battery died. For this test, we found that the Snapdragon X Elite processor–powered device provided longer battery life by almost 1.5 hours. The Intel Core Ultra processor–powered system provided a respectable 20+ hours of continuous video playback.

We also ran the UL Procyon® Battery Life Benchmark, which resulted in a median performance 6.5% higher for the Intel Core Ultra processor–powered device.

Because the Intel Core Ultra processor–powered device can provide exceptional battery life with higher performance, users will need to determine what is most important for their specific needs. In addition, Intel promises even higher efficiency and longer battery life from its Intel Core Ultra 200V series processors, with Dell offering an XPS 13 laptop as early as October 2024.[3]

Applications on Windows on Arm Compared to Windows for x86 Systems

We began our research by looking into application support for Windows on Arm. The number of supported apps has grown considerably since the previous release. However, there are still applications that do not install on Windows on Arm, that install but run only in emulation mode, or that install but run with errors or performance lag.

If you are considering a Windows on Arm device, you should check with both application vendors and hardware device vendors to determine if the apps you use are fully supported. Unfortunately, this is easier said than done because documentation is often unclear or missing from software provider websites. Based on our research, many vendors simply state that their application is supported on Windows 11 without specifying if that includes Windows on Arm (see Figure 1).

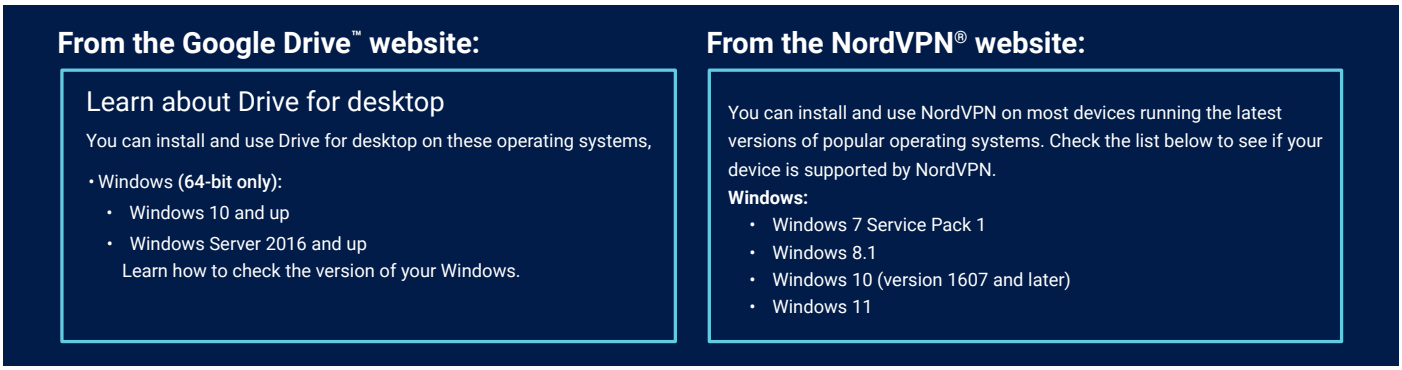


Figure 1 | The websites for many applications, including Google Drive™ (left) and NordVPN® (right), do not specify if Windows® support includes support for Windows on Arm® devices (last accessed September 13, 2024)

In cases where a software vendor doesn't explicitly state support for its application on Windows on Arm, users will have no choice but to install the app on their Windows on Arm system and hope for the best—but this can lead to installation errors and other problems. Throughout our testing, we discovered several popular applications and games that could not be installed on the Snapdragon X Elite processor–based device running Windows on Arm, as shown in Figure 2.

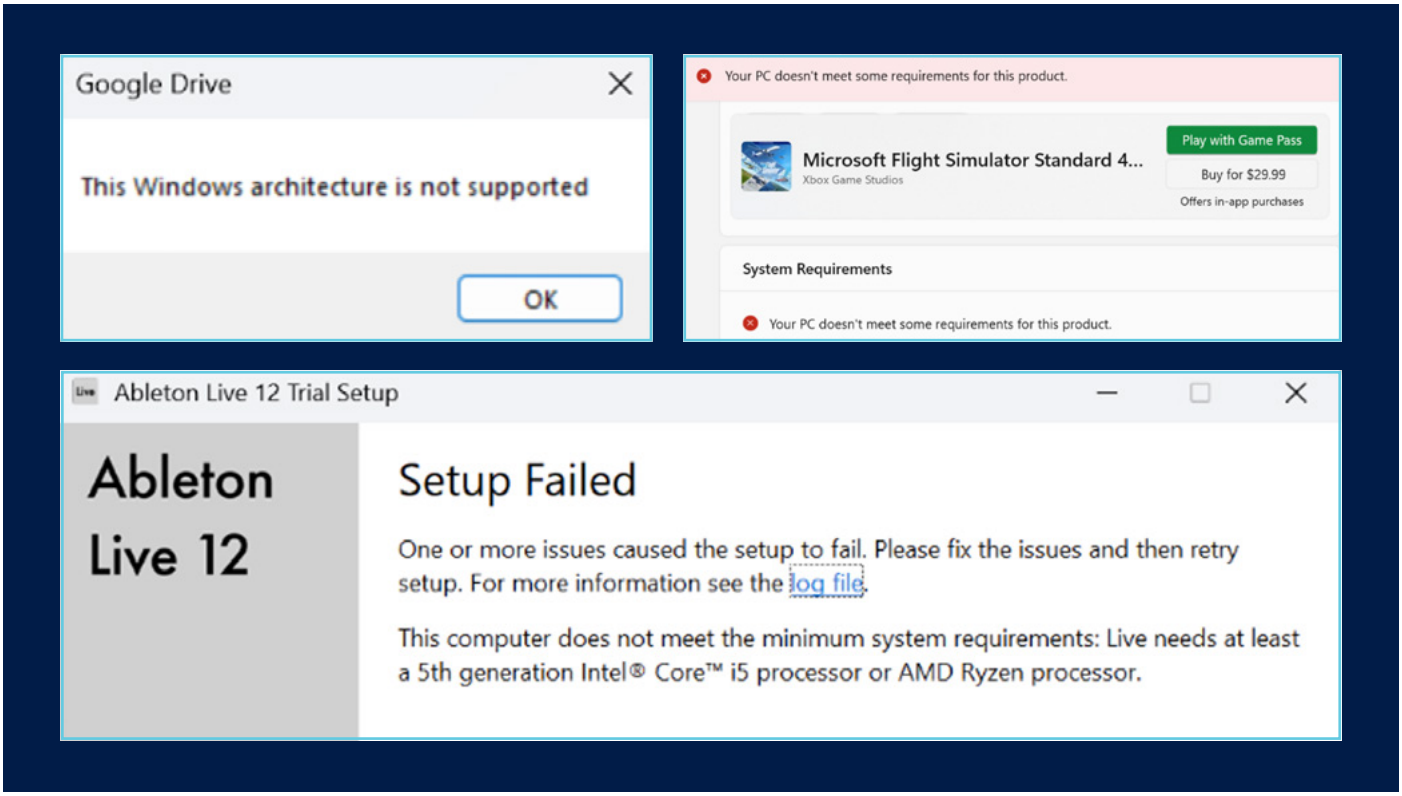


Figure 2 | Many applications and games generate errors when attempting to install them on a Windows® on Arm® device, even though there is often no compatibility information available on the vendors' websites

Some hardware vendors might provide additional compatibility information if you dig deep enough. We were able to find details from Samsung on its Korean-language website regarding the Samsung Galaxy® Book4 Edge (running Windows on Arm on a Snapdragon X Elite processor). As of July 2024, Samsung states that the following apps are not supported, which implies that the same apps would not run on any Snapdragon X Elite processor–powered device:[4]

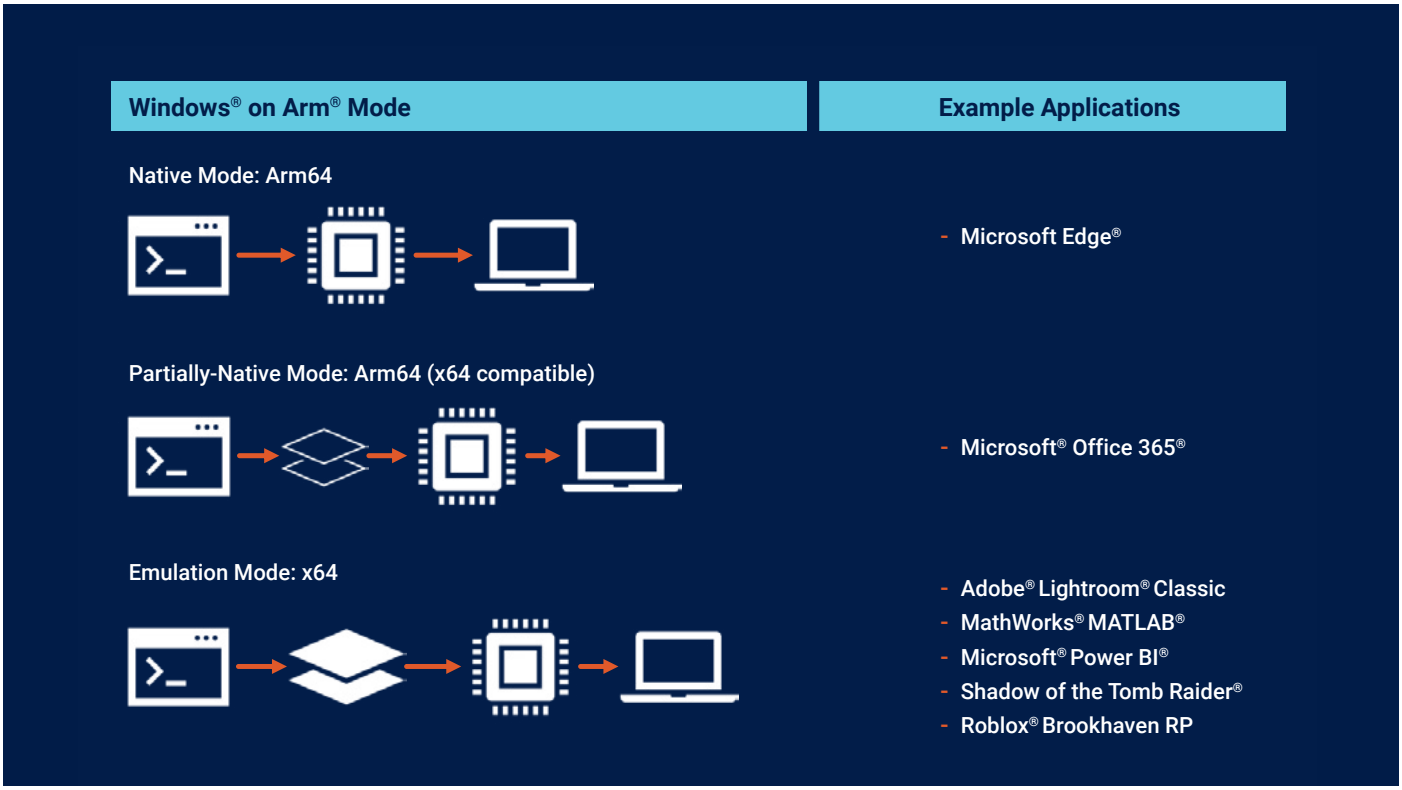
- **PC management and security apps:** Avast® Cleanup, Avast® Driver Updater, Avast SecureLine® VPN, Avast® Free Antivirus, and Avast® Security; Fortinet® FortiClient® VPN; Kaspersky® Antivirus; Webroot® SecureAnywhere® AntiVirus; VirtualBox® Headless Frontend; and ALYac Internet Security
- **Productivity (content creation) apps:** Adobe® InDesign®, Adobe® Illustrator®, Adobe® After Effects®, and Adobe® Premiere Pro®
- **Games:** League of Legends®, FC Online, PUBG®: Battlegrounds, Sudden Attack, Valorant®, Legends of Runeterra®, Dead by Daylight®, VRChat®, Apex Legends®, Fortnite®, Fall Guys®, Lineage™, Tales Runner, Call of Duty®: Modern Warfare® 3, and Halo Infinite®
- **Other:** Naver eBook Reader, LDPlayer, BlueStacks®, DMM Game Player, NoxPlayer, Google Play™ Games, Canon® IJ Scan Utility, Epson® FAX Reception, Epson® Status Monitor 3, and the Google Drive™ desktop app

Prowess Consulting Lab Testing

Despite the issues noted above, other apps are supported on Windows on Arm, either natively or through Microsoft Prism emulation. We ran several tests to evaluate performance for several content creation and productivity apps, and even some games.

Native or Partially Native Apps for Windows on Arm

We began testing on applications that have been rewritten to run natively or partially-natively on Arm architecture, which we verified by using Windows Task Manager.



For our testing, we used both benchmarks and real-world workloads, which uncovered some interesting findings. For example, when we ran the UL Procyon benchmark, we noted that the Snapdragon X Elite processor–based device scores ranged from on-par (plus or minus 3%) to 12% higher than the Intel Core Ultra processor–based device scores, as shown in Figure 3.

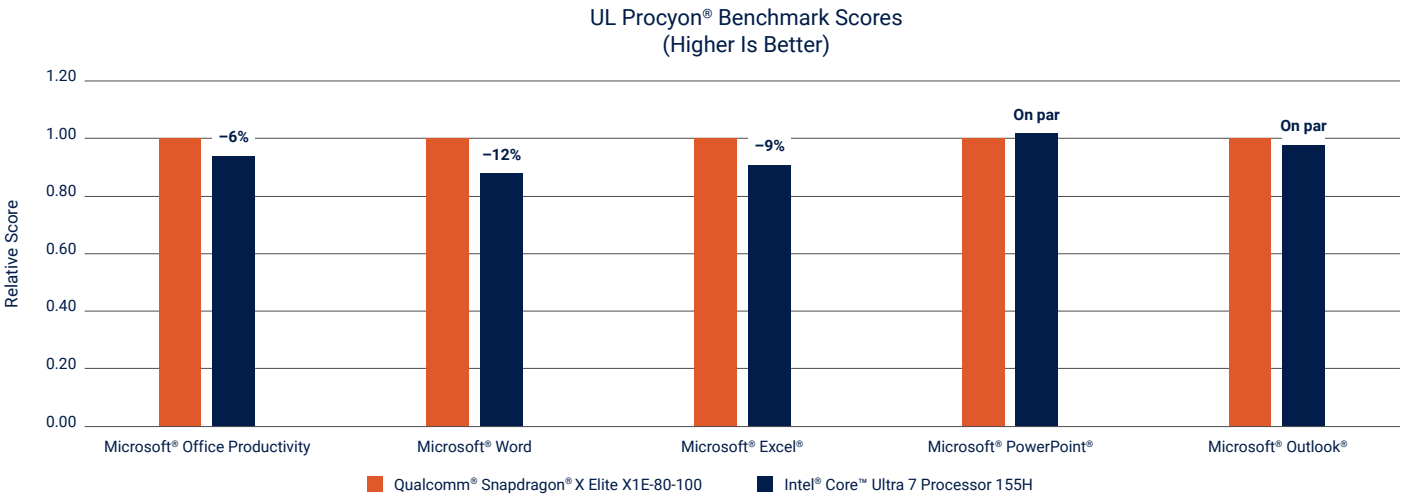
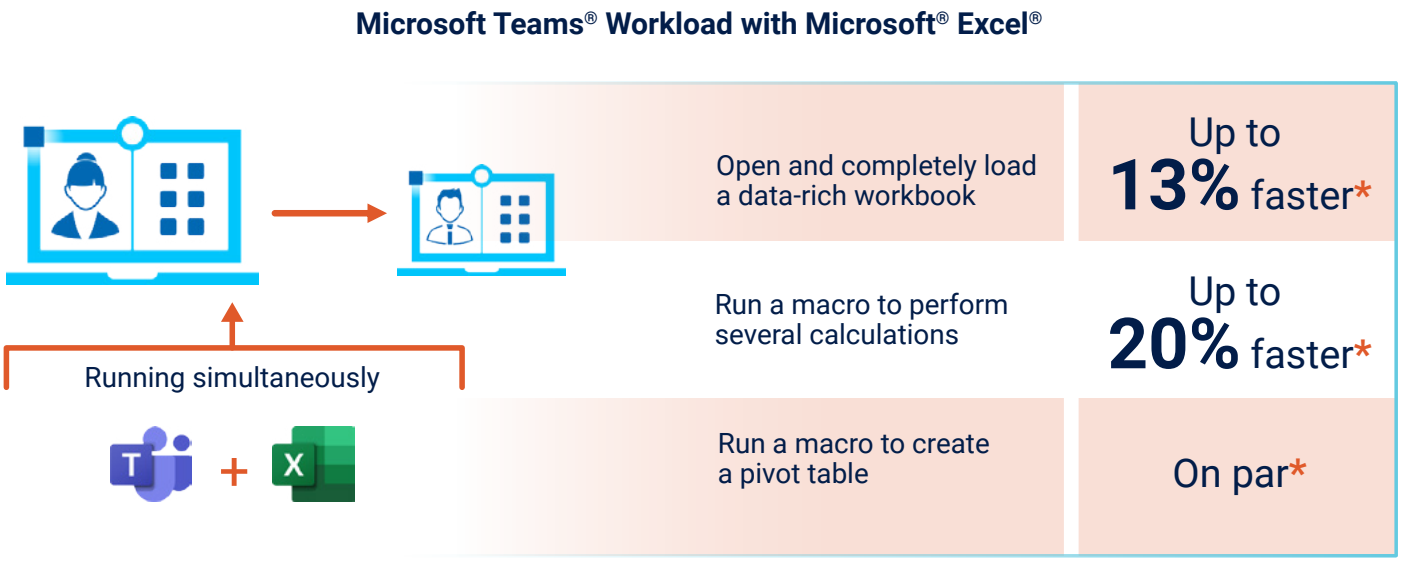


Figure 3 | UL Procyon® benchmark scores for the Qualcomm® Snapdragon® X Elite processor–based device versus the Intel® Core™ Ultra processor–based device

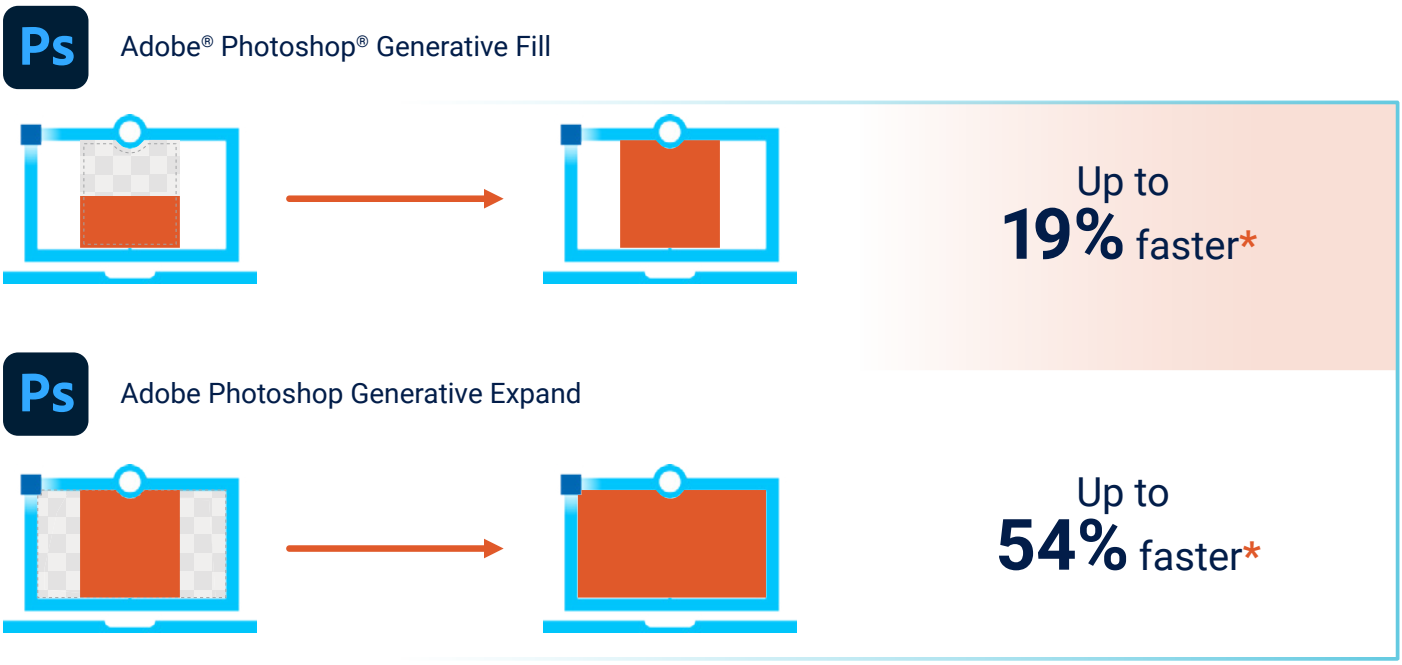
However, the results were quite different when we used Microsoft® Office applications in a real-world multitasking scenario. We initiated a Microsoft Teams® videoconferencing call and shared a Microsoft® Excel® workbook, as shown in Figure 4. In this testing, the Intel Core Ultra processor–based device completed functions up to 1.2x (20%) faster than the Snapdragon X Elite processor–based device.



*Device powered by an Intel® Core™ Ultra 7 processor 155H compared to a device powered by a Qualcomm® Snapdragon® X Elite X1E-80-100 processor

Figure 4 | The Intel® Core™ Ultra processor–based device performed a Microsoft Teams® and Microsoft® Excel® multitasking workflow up to 20% faster than the Qualcomm® Snapdragon® X Elite processor–based device

We ran a similar comparison using Adobe® Photoshop®. Photoshop has been rewritten to run natively for Windows on Arm. For this test, we first ran the PugetBench® for Creators Photoshop benchmark, which resulted in a score 14% higher for the Snapdragon X Elite processor–based device running Windows on Arm. However, when we ran a real-world workload that made use of two modern AI-based features in Photoshop—Generative Fill and Generative Expand—the tables turned, as seen in Figure 5.



*Device powered by an Intel® Core™ Ultra 7 processor 155H compared to a device powered by a Qualcomm® Snapdragon® X Elite X1E-80-100 processor

Figure 5 | An Adobe® Photoshop® Generative Fill workflow completed 19% faster, while the Generative Expand workflow completed 54% faster on the Intel® Core™ Ultra processor–based device, compared to the Qualcomm® Snapdragon® X Elite processor–based device

What would explain these results compared to the benchmark tests? One possibility is that the applications might have been running a mix of native and emulated components on the Windows on Arm device. Even though the primary applications (Microsoft Teams, Excel, and Photoshop) were all running natively, it's possible that drivers or features within those apps were running in emulation mode. Another possibility might be that running multiple apps in parallel (multitasking) affects performance more on the Snapdragon X Elite processor–based system. More detailed analysis would be required to better understand the underlying cause. Regardless, the tests showed the Intel processor-powered device as a clear winner when running a more complex multitasking workload.

Windows on Arm Apps Running in Emulation Mode

We ran tests using MathWorks® MATLAB®, a widely used application that engineers, scientists, and students rely on for creating complex AI models and simulations. We tested a workload that uses the MATLAB tool for motion-based multiple-object tracking. Detection of moving objects is important for many real-world computer vision applications, including activity recognition, traffic monitoring, and automotive safety. The workload ran up to 47% faster on an x64-based Windows system powered by Intel Core Ultra processors compared to a Snapdragon X Elite processor–equipped laptop, which ran the workload using emulation mode.

MathWorks® MATLAB®: **Up to 47% faster** on x64 Windows®, compared to Windows on Arm®

Microsoft highlights the exceptional performance capabilities of its Prism emulation mode, so we included emulated x64 apps in our testing. First, we compared the performance of running a popular content creation app, Adobe® Lightroom® Classic. Although the Adobe® Creative Cloud® version of Lightroom runs natively, Lightroom Classic only runs in emulation mode. Many photographers still run Lightroom Classic, however, because they prefer local storage of photos instead of a cloud-based option or because they want to use specific features only available in the classic version.

We relied on the PugetBench for Lightroom Classic benchmark for testing, which yielded a 1.13x (13%) higher overall score for the Intel Core Ultra processor–based device compared to the Snapdragon X Elite processor–based device, which is likely the result of overhead from the Prism emulation layer.

PugetBench® for Adobe® Lightroom® Classic: **Up to 13% higher** score on x64 Windows®, compared to Windows on Arm®

Next, we tested Microsoft® Power BI® Desktop, a free, commonly used application that lets you connect to, transform, and visualize data. We ran tests that measured the time it takes to change the data source for a Power BI dashboard and update the dashboard with the new data. Our test results demonstrated up to 66% faster performance for this workload on the x64 device powered by an Intel Core Ultra processor.

Microsoft® Power BI® Desktop: **Up to 66% faster** on x64 Windows®, compared to Windows on Arm®

Performance for Windows on Arm Games Running in Emulation Mode

Typically, devices powered by Snapdragon X Elite processors wouldn't be used for extensive gaming. Nonetheless, Qualcomm does call out the platform's ability to support light gaming, so we ran additional tests to see how the Snapdragon X Elite processor–based platform would perform compared to the Intel Core Ultra processor–based platform. First, we ran tests using 3DMark® Time Spy and 3DMark® Wildlife Extreme, two benchmarks that are commonly used to evaluate PC gaming capabilities.

As Figure 6 shows, the two devices performed on par when running 3DMark Wildlife Extreme, but the device powered by the Intel Core Ultra processor performed up to 2x (100%) faster running 3DMark Time Spy.

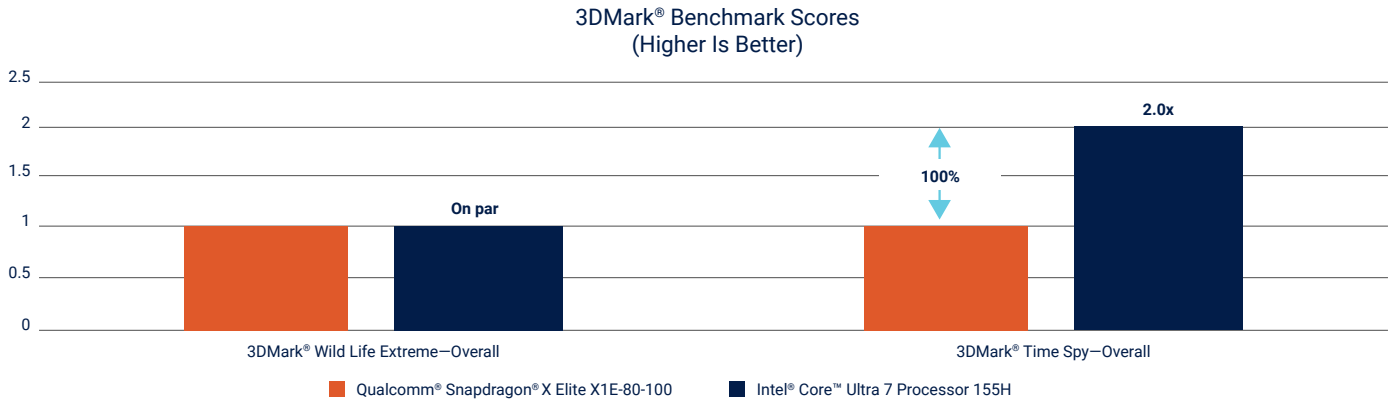


Figure 6 | 3DMark® benchmark scores for the Qualcomm® Snapdragon® X Elite processor–based device versus the Intel® Core™ Ultra processor–based device

As demonstrated earlier in this paper, benchmarks don't always tell the whole story. To get a better indication of real-world performance, we ran in-game benchmarks for Shadow of the Tomb Raider® and Roblox® Brookhaven RP, and we then recorded average frames per second (FPS).

As Table 1 shows, the Intel Core Ultra processor ran at 66% higher average FPS for Shadow of the Tomb Raider and 104% higher average FPS for Roblox Brookhaven RP. The significant performance gap shown in Table 1 was likely due to emulation. Both tested games relied on Prism emulation, which we confirmed by using Task Manager (see Figure 7).

Table 1 | Frames per second (FPS) for Shadow of the Tomb Raider® and Roblox® Brookhaven RP running on a Qualcomm® Snapdragon® X Elite processor–based device and an Intel® Core™ Ultra processor–based device

	Qualcomm® Snapdragon® X Elite X1E-80-100 (Windows® on Arm®)	Intel® Core™ Ultra 7 155H (x64 Windows)
Shadow of the Tomb Raider®	30 FPS	50 FPS
Roblox® Brookhaven RP	105 FPS	215 FPS

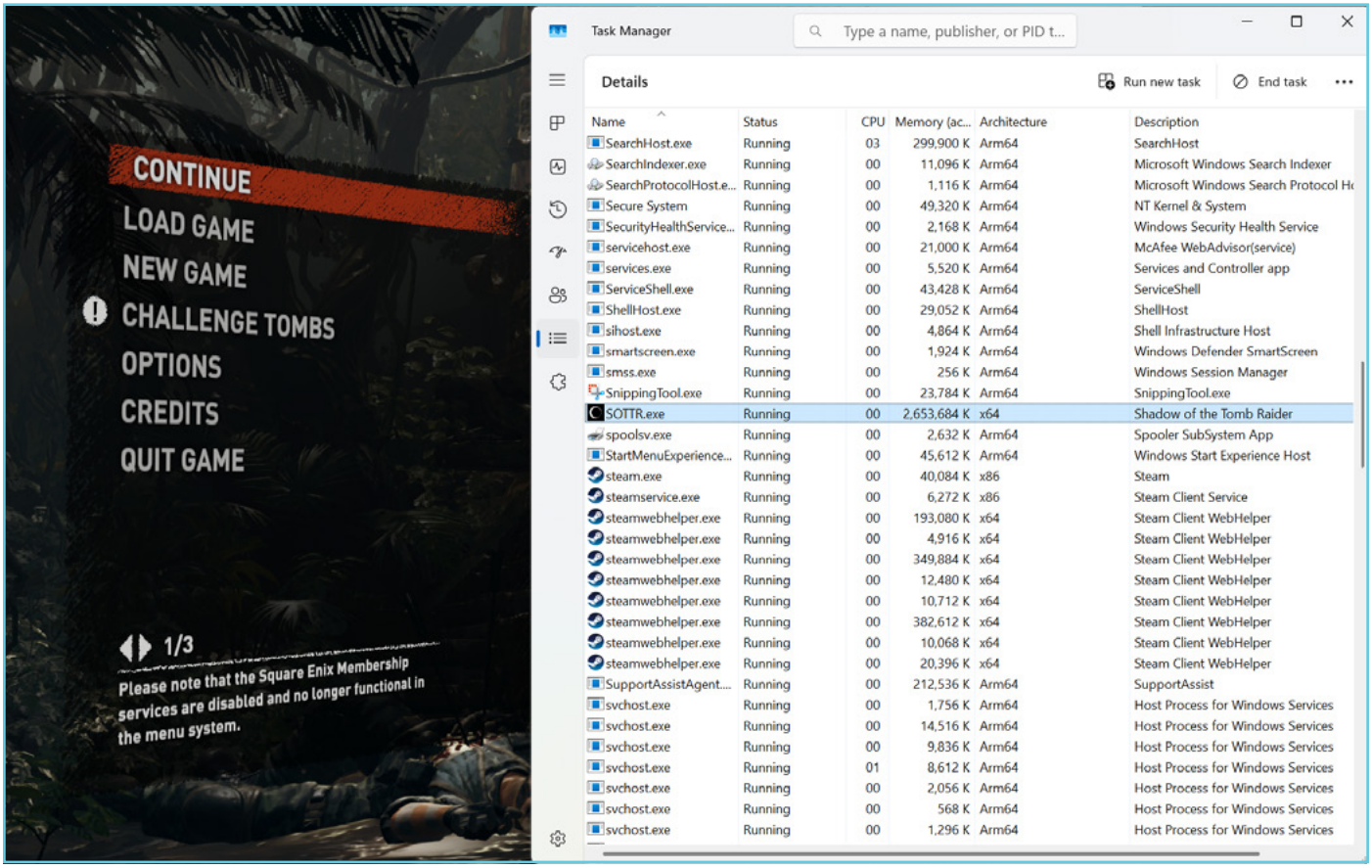


Figure 7 | Windows® Task Manager showing Shadow of the Tomb Raider® running as x64 binaries in emulation mode

Based on our research, most games currently run only in emulation mode on Windows on Arm devices, if they run at all. Unfortunately, it isn't always obvious to users if a game will run or even install without frustrating and potentially costly trial and error. For example, as of July 2024, the Steam® online store doesn't distinguish between x64 Windows and Windows on Arm, making it appear that games will run on either platform, as shown in Figure 8. Many of those games will successfully install on Windows on Arm, but they might then not run properly due to incompatibility issues with DirectX®, APIs, or other required files.

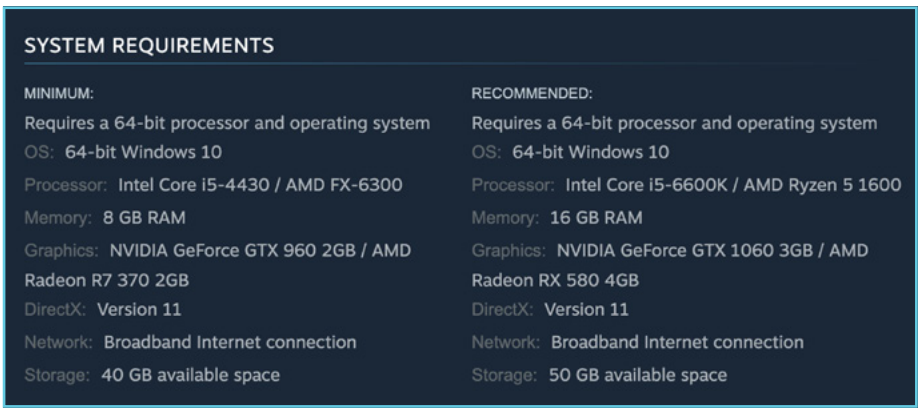


Figure 8 | Although PUBG®: Battlegrounds is not supported on Windows® on Arm® (due to incompatible anti-cheat software), the Steam® website does not make that clear because the site specifies only a "64-bit processor" as a requirement[5]

Some third-party websites, like one maintained by Linaro (shown in Figure 9), can help mitigate this issue by providing a list of games that are playable or unplayable on Windows on Arm.[6] Although this list isn't comprehensive, it does give users a good starting point for tracking down information that is otherwise often lacking.

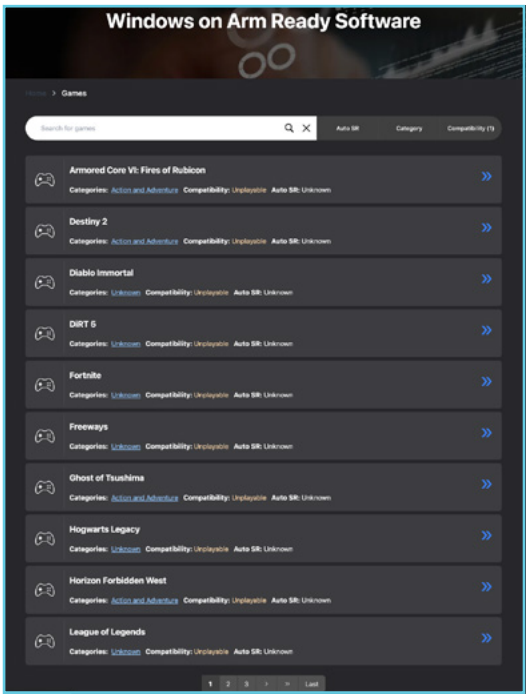


Figure 9 | A website by Linaro maintains a list showing games that are playable or not playable on Windows® on Arm® PCs

Other games might install on Windows on Arm but then demonstrate issues with crashing, stuttering, and framerate drops. Online reviewers have noted these concerns; for example, an article from June 2024 in *PCWorld* states, "Modern games simply don't run well on Qualcomm's chip … many titles experience hitching, stuttering, and/or extended framerate drops that drag down the experience with instability."[7] Another review from June 2024 in *Digital Trends* states, "Based on this first batch of reviews, none of these games seem playable due to crashing, low performance, and stutters."[8]

Because of these issues, we recommend choosing a device based on an x64-based processor for the greatest compatibility for gaming.

Drivers, Peripherals, and Support Files for Windows on Arm Devices

In addition to software applications, potential buyers of Windows on Arm devices also need to consider drivers and the hardware peripherals that they rely on. For example, a content creator might determine that the Adobe applications they need can be installed and used on a Windows on Arm PC, only to discover issues when trying to connect a printer or a drawing tablet.

Wacom, the manufacturer of a popular drawing tablet, states that its tablets are not currently compatible with Windows on Arm processors, including Snapdragon X processors.[9] According to the site 7P Drawing Tablets, several other tablets and stylus pens are also incompatible with Windows on Arm until drivers are updated. They call out XP-Pen® and Huion® devices, specifically.[10]

Users might encounter similar issues with other peripherals, including external storage devices, graphics cards, speakers, and so on. Check with the device manufacturer for compatibility and driver support details, but note that this information might be hard to come by until manufacturers perform testing and update their websites with more information.

User Experience for Windows on Arm Devices

User experience presents a less quantifiable but equally critical area to consider when comparing Windows on Arm to x64-based Windows software. The environment for Windows on Arm has improved considerably from the previous generation, with far greater app support and a much more responsive emulation layer. However, users should be aware of certain difficulties to consider.

A review by *The Verge* points out specific points that line up with our own observations and performance results. The author notes some occasional stuttering and lag with less demanding apps, and bigger performance and latency issues in more demanding apps, particularly when relying on the emulation layer: "For more heavyweight apps, Prism doesn't bring the experience up to what you'd find on an Intel- or AMD-powered laptop. Adobe's Premiere Pro running emulated was practically unusable for editing a 4K video on the Surface Laptop, which is probably why Adobe is now blocking the installation of the x64 version on Snapdragon X Elite and Plus processors."[11]

Android Authority also notes: "Asana and Discord run like an egg and spoon race—stopping, starting, pausing, and loading. This is where Prism's performance is a letdown; UI elements can temporarily freeze, sometimes system-wide, and I've even had music playback cut out for a split second. These issues don't crop up very often, but when they do, you're instantly reminded you're not receiving the best Windows experience out there."[12]

Your particular user experience will vary considerably, obviously, depending primarily on whether your apps are running natively or in emulation mode. But several other factors need to be considered as well, including the complexity of your workflows, how much multitasking you typically engage in, and your reliance on third-party drivers and peripherals.

AI PC User Experience

Evaluating a PC for AI capabilities can be complex, depending on your workloads and business needs. If you are looking for guidance on this topic, see our technical research study, "How to Understand and Evaluate AI PCs for Your Apps and Workloads."

Conclusion: Windows on Intel x64 Architecture Is Still the Best Choice for Most Users

Qualcomm processors and Windows on Arm have made big strides from the previous generation, with greater overall application compatibility and a better emulation layer. Unfortunately, compatibility issues still have an impact on many apps, drivers, and peripherals, making it difficult to know what is fully or partially supported or not supported at all.

Those unknowns can lead to frustrations for users. For example, imagine a content creator considering a move to a Windows on Arm device powered by a Snapdragon X Elite processor. They first need to conduct research to determine if all of their regularly used apps are supported. If the software vendor doesn't explicitly state compatibility for Windows on Arm, the user will need to resort to online reviews and user groups or cumbersome trial and error.

If the app is supported, the user might run into compatibility issues or slowdowns while using the app. Furthermore, the user might discover that a key peripheral that they rely on, like a Wacom® tablet, printer, or scanner, is not supported. These unknowns present a risky proposition if you are dependent on those apps and devices for your work. Additionally, Snapdragon X systems are priced at premium levels (more than $1,000), and users face compatibility and slowdown issues without clear guidance.

Based on these concerns and our own testing and research, we believe x64-based platforms like the Dell XPS 13 9340 to be a better option for most users because they offer:

- Similar or better performance across key workloads
- Broader support for software applications
- Greater support for third-party device drivers, support files, and peripheral devices, including many legacy devices
- Exceptional battery life

If you do not need to make an immediate purchase, we suggest waiting for upcoming offerings from Intel and AMD that are likely to provide exceptional AI performance and longer battery life without the compatibility issues that affect Windows on Arm devices.

Appendix A: System Configurations

We used the following configurations in our testing.

Table 2 | Configurations tested as of 7/15/2024

	Dell™ XPS 13 9345 Running Windows® on Arm® Architecture	Dell XPS 13 9340 Running Windows on x64 Architecture
CPU	Qualcomm® Snapdragon® X Elite X1E-80-100 processor 12 cores/12 threads	Intel® Core™ Ultra 7 processor 155H 16 cores/22 threads (6 Performance-cores [P-cores] + 8 Efficient-cores [E-cores] + 2 low-power E-cores)
Storage	512 GB NVM Express® (NVMe®) Western Digital® PC SN740	512 GB NVMe KIOXIA® BG6
Memory	16 GB LPDDR5x at 8,448 MHz	16 GB LPDDR5x at 7,467 MHz
Operating System (OS)	Windows 11 Home (for Arm-based processor)	Windows 11 Home (for x64-based processor)
OS Version	24H2 26100.1000	24H2 26100.1000
Browser Version	Microsoft Edge®: 126.0.2592.87 (arm64) Google Chrome™: 126.0.6478.127 (arm64)	Edge: 126.0.2592.87 (64-bit) Chrome: 126.0.6478.127 (64-bit)
Graphics	Qualcomm® Adreno® 8cx Gen 3	Intel® Arc™ graphics
Graphics Driver Version	31.0.56.0	31.0.101.5593
Resolution	1920 x 1200	1920 x 1200
Screen Size	13.4-inch	13.4-inch
Battery Size	55 watt-hours (Wh)	55 Wh
BIOS	Dell Inc. 1.6.0	Dell Inc. 1.6.0

Appendix B: Benchmarks and Workloads

We used the following benchmarks in our testing:

- **UL Procyon Office Productivity:** This benchmark uses Microsoft Office apps to measure PC performance for office productivity work. The benchmark workloads feature relevant, real-world tasks using Microsoft Word, Excel, PowerPoint®, and Outlook®.
- **UL Procyon Battery Life Benchmark:** The UL Procyon Battery Life profile provides a broad view of practical battery life across a range of real-world scenarios. Video playback, idle, and office productivity scenarios are available.
- **PugetBench for Photoshop:** This is a photo editing performance measurement benchmark, developed by Puget Systems, and it is a part of the PugetBench for Creators benchmark suite.
- **PugetBench for Lightroom Classic:** This is a photo editing performance measurement benchmark developed by Puget Systems, and it is a part of the PugetBench for Creators benchmark suite.
- **3DMark:** This is a benchmark from Futuremark® that measures DirectX® 10, DirectX 11, and DirectX 12 gaming performance. There are two main tests used: "Wildlife Extreme Unlimited" for Vulkan® graphics and "Time Spy" for DirectX 12 graphics.

We ran the following workloads in our testing:

- **Microsoft Teams and Excel data workflow:** This workflow measures the time to open a large Excel file and apply both calculations and pivot table macros while sharing the Excel application window in a Microsoft Teams videoconferencing call.
- **Adobe Photoshop Generative Expand and Generative Fill AI workflows:** This workload records the time it takes (in seconds) to apply the Generative Expand and Generative Fill features on image files within Adobe Photoshop.

- **MathWorks MATLAB workload:** MathWorks MATLAB is a widely used application that engineers, scientists, and students rely on for creating complex AI models and simulations. The workload measures the time in seconds to complete the "object tracking" feature on a 47-second AVI video file using MATLAB 2023b. The score is a median value for three runs, as output by the MATLAB workload.
- **Microsoft Power BI workload:** This test measures the time it takes to change the data source for a Power BI dashboard, and to then update the dashboard with the new data.
- **Battery rundown test:** This test involves running a local video file in a loop until the laptop battery dies.
- **Gaming tests:** This test consists of measuring average FPS at 1080p Low settings for the titles Shadow of the Tomb Raider and Roblox Brookhaven RP.

[1] Ben Walshe. "A Brief History of Arm: Part 1." Arm Community Blogs. April 2015.

[2] Arm. "Consumer Technologies: Smartphones." Accessed July 2024.

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Results have been simulated and are provided for informational purposes only. Any difference in system hardware or software design or configuration may affect actual performance.

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