



Unlocking SSD Potential With Software Innovations

A Look at the Philosophy, Features, and User Benefits
of Solidigm Synergy™ Software 2.0

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SOLIDIGM™

Table of Contents

Table of Contents.....	1
Introduction	2
What's in It for You?	4
Everyday Users	5
Gamers	6
Content Creators.....	7
Solidigm Synergy™ Toolkit	8
Key Features	9
Solidigm Synergy™ Driver	10
Fast Lane (formerly Host-Managed Caching).....	10
Smart Prefetch	11
Dynamic Queue Assignment.....	13
The Path Ahead	14

Introduction

When Solidigm opened for business in December 2021, it promised “a new paradigm in solid-state storage” - a new way of thinking that would unlock solutions to the industry’s intractable problems and offer an unprecedented user experience.

With the launch of Solidigm Synergy™ software 2.0, a free software suite that supports and empowers our client SSDs with a host of innovative features, the company is continuing to deliver on that promise. The new software layer closes the communication gap between the SSD and the host system, enabling greater responsiveness and personalization than even the best hardware alone can provide.

Solidigm Synergy™ Software Components



	Solidigm Synergy™ Toolkit	Solidigm Synergy™ Driver
User Benefits	Enables users to view drive health and utilization reports and provides useful tools, such as Diagnostics and Secure Erase	Enhances user experience by closing the gap between PC and SSD, automatically optimizing performance “under the hood” of the system
SSD Compatibility	All PCIe and SATA SSDs	Solidigm™ Client SSDs
Platform Compatibility	Microsoft Windows 10 or 11 on Intel or AMD CPU	
Required for Solidigm SSDs?	No, but highly recommended	
Cost	Free	

Hardware innovations have led the way to improved performance, higher capacities, and lower costs in client SSDs over time. These include:

- Higher NAND media speeds and densities (bits per cell)
- Evolution of the PCIe interface
- Architectural innovations, such as host memory buffer (HMB)

At the same time, firmware advancements have contributed to a better product in a variety of ways. A great example is SLC caching (both static and dynamic implementations), which allows an SSD to store recently written data in a portion of the drive reserved for quicker access when needed by the user again later.

Despite all the improvements and refinements to the conventional client SSD, it remains innately limited in some important ways. It relies on one-size-fits-all policies that might not be optimal for different kinds of users. An office worker, for example, could benefit from different storage settings than a gamer using the same device.

And, critically, even the highest-end SSD is completely unaware of what it's actually storing for you. It sees the world in terms of logical block addresses (LBAs), with zero awareness of whether they might represent a photo, a text file, or that kazoo tribute to Nickelback you've been working on.

Why Software?



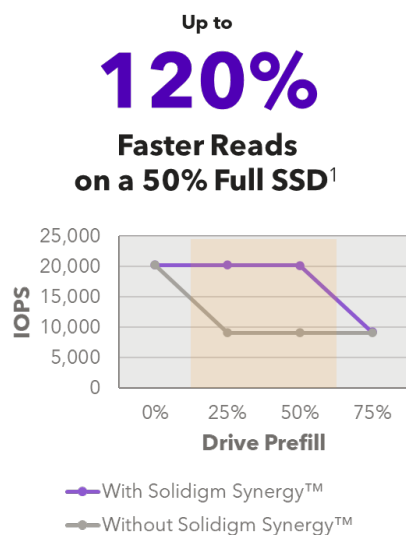
That's where software - and, specifically, the storage driver - comes in. By bridging the gap between host and storage device, software can provide actionable insights to the SSD that weren't possible before.

What's in It for You?

What follows in this white paper is a detailed discussion of the innovations and features that Solidigm has put into its latest release of Solidigm Synergy™ software, including both the toolkit and the driver.

But let's start with the punchline: Why does any of this matter to you, the end user? How does it improve your experience in the course of your daily PC work and play? After all, if there are no concrete benefits to the kinds of things you're doing most often on your PC, then this is all a lot of marketing fluff.

Consistent Performance



Responsive Experience

Up to
20%
Faster
Random Writes²

Application Launch

Up to
14%
Faster Microsoft
PowerPoint Launch³



Gaming » Up to **350%** Faster QD1 4KB Sequential Reads⁴



PC Boot Time » Up to **7%** Faster System Boot⁵



PCMark 10 Storage » Up to **7%** Higher Test Score⁶

As it turns out, there *are* significant, specific benefits for users of all types. Let's break them down into a few high-level categories and talk about each in turn.

Everyday Users

- Office workers, students, and others who use their PCs for a variety of common activities, from web browsing to using productivity software such as the Microsoft Office suite.

Gamers

- Those who are frequently pushing their systems with AAA games that include huge installations and heavy loading of large asset files.

Content Creators

- Those who do a lot of media manipulation—be it photos, videos, audio, or otherwise—place unique demands on their PC with a mix of large and small files, reads and writes, frequently while multitasking.

Everyday Users

Daily PC usage is as varied as the people at the keyboard. This includes things like starting up the PC, browsing the web, light productivity work (think Microsoft Office applications), and so forth.

For these kinds of activities, a valuable feature of Solidigm Synergy™ is **Fast Lane**, which optimizes the use of your SSD's cache space (the "fast access" area of the drive). We'll go deeper into the mechanics of Fast Lane when we explore the Synergy Driver since many users can relate to the general slowdown in their PC experience as their storage fills up.



The main benefit of Fast Lane is that your drive's read performance will remain consistent for much longer. And the difference is significant: We have measured an increase in QD1 random read speed of **up to 120%** on drives that are already half full of data¹.

Another key improvement for most users is in reduced time to boot up your PC. Nobody likes to sit and wait for system loading tasks to complete. You want to get to the desktop and begin doing whatever it is you set out to do. The goal of responsive storage is to get the technology out of the way and enable you to be at your most productive.



In our testing, systems with Solidigm Synergy™ software booted up from a powered-off state **up to 7%** faster than the same systems using the default Windows disk driver⁵.

Additionally, there are storage benchmarking tools that are useful indicators of overall PC user experience. One such highly regarded tool is PCMark 10, an application by UL that outputs a standardized score based on, critically, runs of real-world workloads from common applications including the Microsoft Office and Adobe Creative Cloud suites.

PCMark 10 has the additional advantage of offering a subset of tests to measure the performance of specific system resources, such as storage devices. That's the idea behind the tool's Full System Drive and Quick System Drive benchmarks.

While not all self-purported storage benchmarking tools are equally useful for evaluating real-world user experience, it is our opinion that the PCMark 10 storage tests are among the best in terms of indicating actual user experience.



Systems with Solidigm SynergyTM software fared **up to 7% better** in PCMark 10's Full System Drive Benchmark when compared to the same configurations without Solidigm software⁶.

Gamers

PC gaming, particularly of the big-budget, AAA "blockbuster" variety, tends to place a relatively narrow, but more intense, set of demands on your SSD than general usage. Gaming workloads tend to involve significantly more reading from the disk than writing to it, after initial install. This makes intuitive sense: Most of the I/O operations come from launching games, loading save states, and loading new levels within a game.

These game workload reads tend to be:

- Mostly reads
- Mostly sequential in nature
- Mostly at very low queue depth (QD)

It's in precisely this area that a new feature of Solidigm SynergyTM software called **Smart Prefetch** can help. This feature operates by detecting highly predictable data streams, of the kind described above, and delivering the next items in series before the user application (in this case, your game) asks for it. In this way, Smart Prefetch reduces latency and improves load times, particularly in cases where games rely on a lot of sequential reads of small transfer sizes.

In the detailed discussion of Smart Prefetch later, we'll look at a specific workload and how this feature addresses the specific demands of PC gaming.



Solidigm SynergyTM software can significantly accelerate low-QD sequential reads, particularly at small transfer sizes. We have measured improvements at 4 KB of **up to 350%**. Note the bottom-line impact to game load times is dependent on how each particular title loads its data⁴.

Content Creators

Content creators, those who routinely deal with media production of video, audio, or photo material, present a unique set of challenges to even the hardest storage devices. Depending on project phase, the work may involve much more writing than reading, or vice versa. And depending on the nature of the individual project, it may require lots of small I/O operations (typically random in nature), or a smaller number of large, sequential reads or writes.

Consequently, small improvements across all performance vectors contribute to an overall sense of “responsiveness” or how snappy your system feels in many small ways over the course of a workday.

To that end, **Dynamic Queue Assignment** is a feature that yields improvements in both read and write performance, specifically among those operations that are random in nature. This feature works by dynamically optimizing the number of CPU cores used to complete I/O requests. In other words, if there are some cores that are less busy than others, the driver can redistribute work to avoid a bottleneck at the CPU.



Dynamic Queue Assignment has shown to improve random reads by up to 20% in Solidigm testing, relative to the same system running the same workload without Solidigm Synergy™ software².

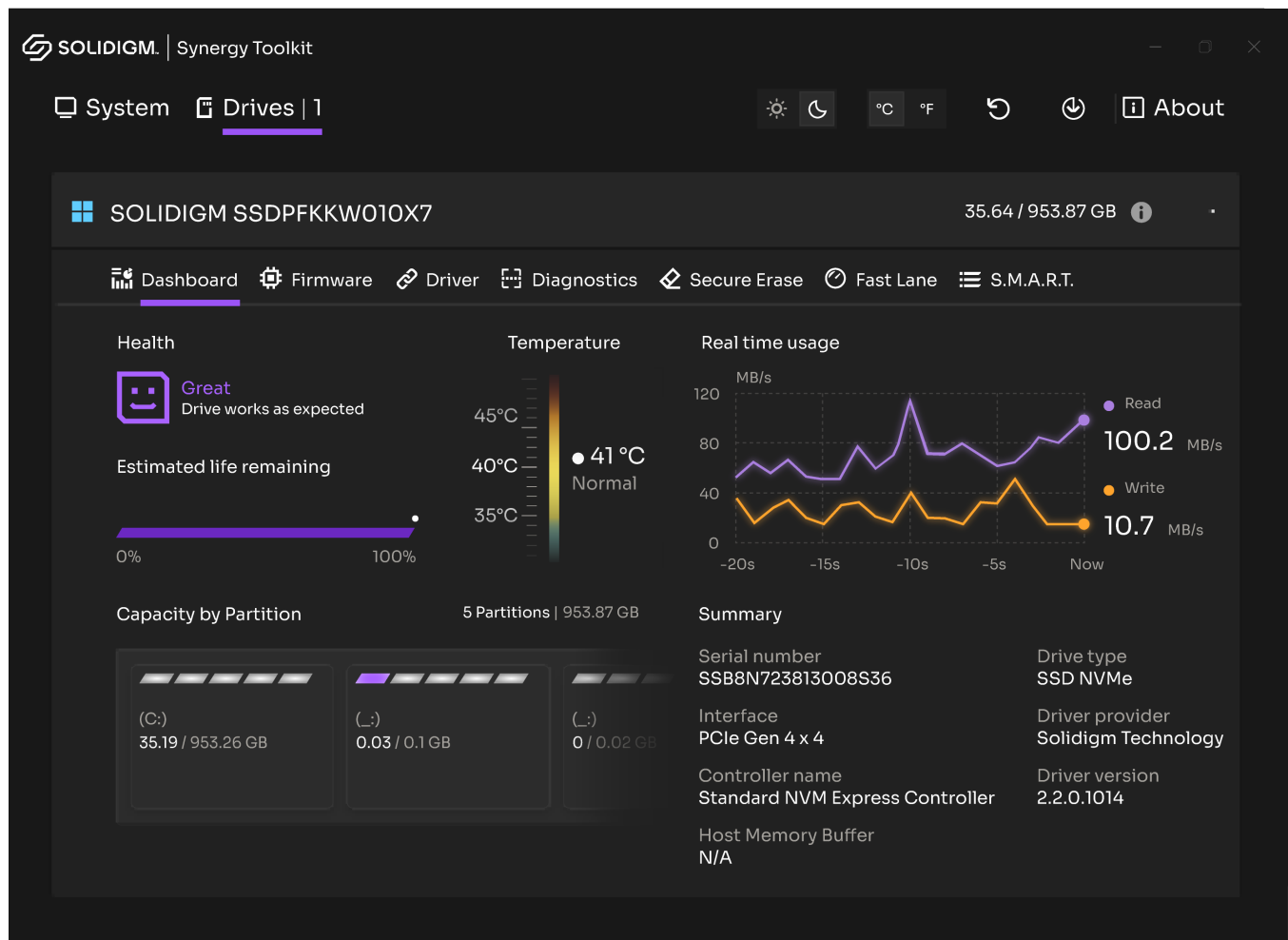
Application launch is one of the most common-and most important-events during which storage performance drives user experience. Everyone has had the experience of clicking an icon on the desktop only to be greeted with a loading screen (or, worse, nothing at all) while the application loads and becomes available to the user.



The combination of optimizations in the Solidigm Synergy™ Driver can positively impact many application loads, depending on how those programs are designed. In one example, we loaded Microsoft PowerPoint up to 14% faster with Solidigm Synergy™ than with the default Windows driver³.

Solidigm Synergy™ Toolkit

Our toolkit is the half of the software suite with which users will routinely interact. For that reason, we focused on good design to make your user experience better. With the release of Solidigm Synergy™ 2.0, we have redesigned our Windows application from the ground up, spending many extra cycles ensuring that the UI is best-in-class so all tools and drive reporting features are intuitive and accessible.



Whether you are using a Solidigm SSD or an SSD from one of our competitors, you can still benefit from the Solidigm Synergy™ software feature set. We have opted to open up *virtually every feature* in the toolkit to third-party SSDs in addition to our own. The lone exception in Synergy 2.0 is Fast Lane management, which relies on specifics in the drive firmware that are not available to non-Solidigm drives.

Key Features

For detailed discussion toolkit features, check out our Solidigm Synergy™ Toolkit User Guide. Here is a brief summary:

Feature	Description	Availability
Dashboard	The home screen, full of useful drive information.	<p>Solidigm SSDs: Real-time health, capacity, temperature, R/W activity, and product summary data, such as serial number and interface.</p> <p>Third-party SSDs: All features available.</p>
Firmware and Driver Update	View current versions and update, if available.	<p>Solidigm SSDs: View current firmware and driver versions, receive notifications about relevant updates, and install with a click.</p> <p>Third-party SSDs: View current firmware and driver versions.</p>
Diagnostics	Test your drive's integrity.	<p>Solidigm SSDs: Quick (~3 minutes) and full (>1 hour) diagnostic scans, which involve writing data to the drive and reading it back for errors.</p> <p>Third-party SSDs: All features available.</p>
Secure Erase	Permanently delete old data.	<p>Solidigm SSDs: Available on any secondary drive (i.e., any drive not in use as the main system drive).</p> <p>Third-party SSDs: All features available.</p>
SMART	View extensive drive self-reporting data.	<p>Solidigm SSDs: View all SMART attributes in a handy searchable table.</p> <p>Third-party SSDs: All features available.</p>

Solidigm Synergy™ Driver

We have already discussed some of the performance improvements available to users of Solidigm Synergy™ software. Now let's pop the hood and see how they work.

Fast Lane (formerly Host-Managed Caching)

Fast Lane remedies an issue as old as the first generation of SSDs capable of storing multiple bits per cell. With those drives came the advent of the SLC (single-level cell) cache. The architecture of NAND caching is outside the scope of this white paper, but virtually every SSD sold today uses a cache of this kind as a sort of "fast access" area on the drive.

Things in the relatively small cache can be loaded most quickly, while others stored in the larger area outside of the cache tend to load more slowly.

From a user experience perspective, these are the relevant factors:

- As your SSD fills up, the cache space shrinks to make room for additional files. This is an industry-standard behavior called "dynamic" caching.
- Without the benefit of Fast Lane, SSDs are simplistic in their use of cache space: Every new thing written to the drive (i.e., every file saved) goes straight into the cache, where it stays until newer things eventually kick it out. We call this the "data treadmill" effect.

Consequently, when your drive is 50% or more full, two things are compounding: 1) There's more data on the drive that you (presumably) will want to access at some point, and 2) There's less cache space available to serve it up quickly. This leads to a general storage slowdown over the life of a typical SSD.

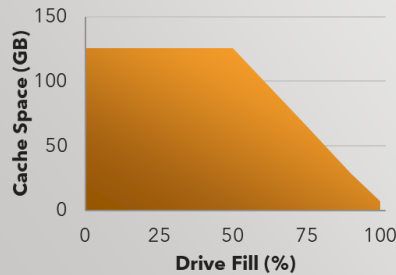
For those reasons, it's increasingly important to make better use of your limited cache space. That's what Fast Lane is all about. It observes your actual usage to determine which files and applications are most important to you, and then prioritizes keeping those items in the cache.

The main benefit to you in this approach is performance consistency. By optimizing what's in your cache, you increase the likelihood that your most important data will be available quickly. That likelihood goes up relative to conventional caching as the drive fills—and your cache size consequently decreases—because the conventional approach was already making sub-optimal decisions about what to cache (based solely on write recency) and is now doing so in an increasingly smaller cache space.

With Fast Lane, we see improvements of up to 120% in QD1 random read speed (a key driver of responsiveness) on drives that are 50% full compared to the same systems without the feature.

The Problem

As your SSD fills up, cache space (the “fast access” area) is reduced to make room for new data, leading to general storage slowdown.



Example: Dynamic cache sizing on a 1TB SSD

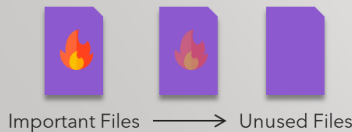
The Solution

Fast Lane tracks which files and applications you use most often - and prioritizes those within the cache.

WITHOUT FAST LANE

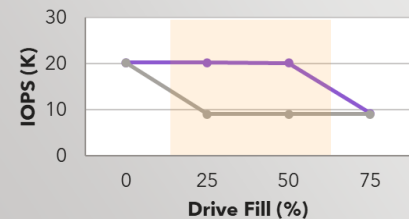


WITH FAST LANE



The Result

Access to important files and applications remains fast, even as the drive fills up and the cache shrinks.



Up to **120% Faster Reads** on a 50% Full SSD¹

One thing to note: Fast Lane has little to no effect when the drive is close to completely full, because the dynamic cache has shrunk so much that making intelligent decisions about what to store there matters little. Likewise, as you may have guessed, the feature does not significantly improve user experience on empty drives because cache space is so abundant that even the conventional approach manages to keep every bit of data stored on the drive inside the cache.

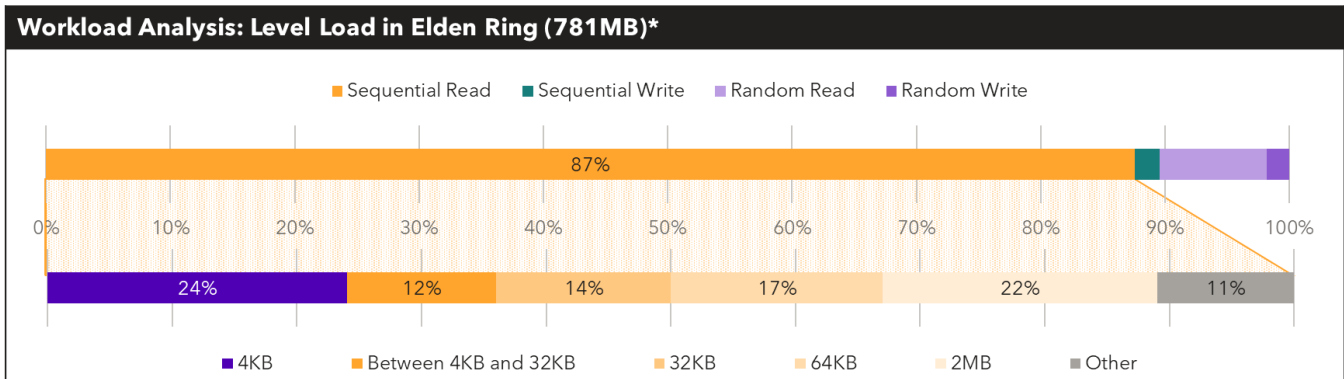
Fast Lane benefits are most valuable for drives that are between 25% and 75% full, which Solidigm believes to be true in a majority of cases in the real world.

Smart Prefetch

Within read operations, we can characterize each as sequential or random.

- **Sequential operations** are so called because they involve contiguous “chunks” of data on the storage device, and often (but not always) occur during the transfer of large individual files.
- **Random operations** occur when the drive is jumping from one place to another within your stored data to service I/O requests, often (but not always) involving smaller files.

The gaming realm, with its massive models, textures, audio files, and other assets, leans more heavily on sequential operations than any other I/O type based on our internal workload analyses. For example, consider this breakdown of operations while loading a new level in Elden Ring:



* Workload analysis based on internal Solidigm research.

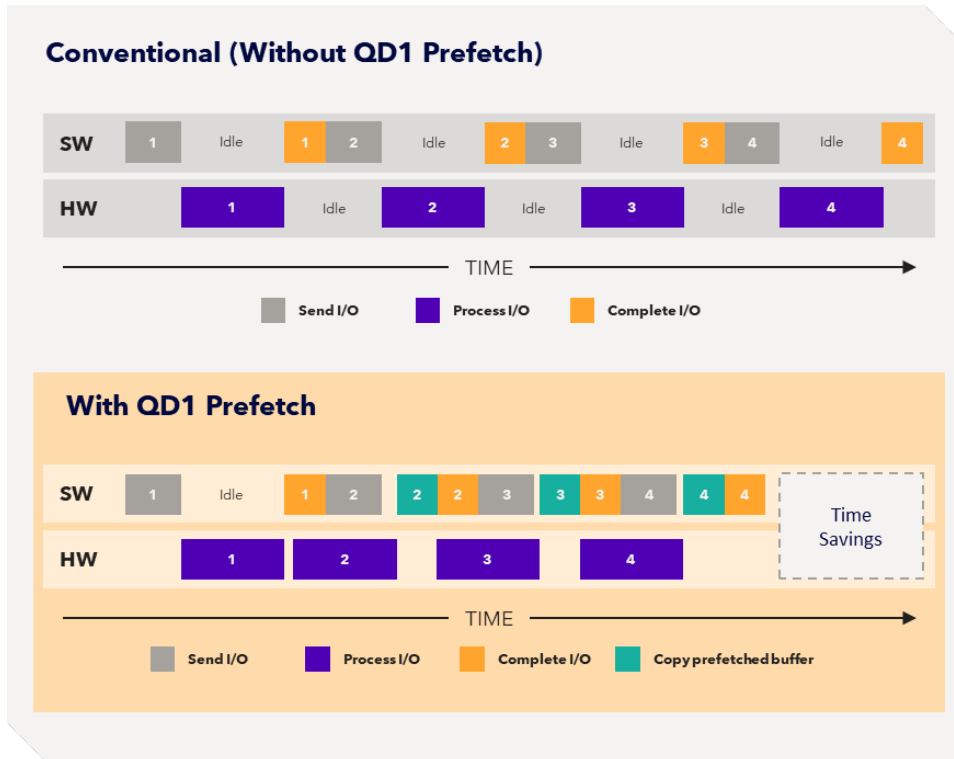
Key takeaways:

1. Of the 781MB of data transferred during the level load, fully 87% was moved in the form of sequential read operations.
2. Within those sequential reads, a variety of transfer sizes were represented, with very small (4 KB) and very large (2 MB) being the most common by operation count.

Another factor to consider in our gaming discussion is **queue depth (QD)**, which is a measure of how many outstanding I/O commands are pending at the SSD controller at any one time. It's important to understand that the vast majority of real-world activity takes place at a queue depth of one (QD1) or, in other words, there is no queue and the SSD is processing requests just as quickly as they come in.

In our Elden Ring example, the mean QD was 1.2 across the entire level load, which took 7 seconds and comprised tens of thousands of I/O operations.

This is where a new feature of Solidigm Synergy™ software called **Smart Prefetch** comes in. Using this feature, the driver can detect when a highly predictable stream of read operations is occurring, that is operations which are sequential in nature at a low queue depth. It uses this information to "prefetch" data before the user application asks for it.



Essentially the SSD, with the help of the Solidigm Synergy™ Driver, says to the PC, “I see you’ve already asked for A, B, C, and D. I bet you’ll want E, F, and G next, so let me get them to you before you ask.” The effect is a *significant* improvement in sequential read speeds, especially at low transfer sizes where the number of requests can soar into the thousands, with each one introducing a split-second of latency to the overall completion time.

Dynamic Queue Assignment

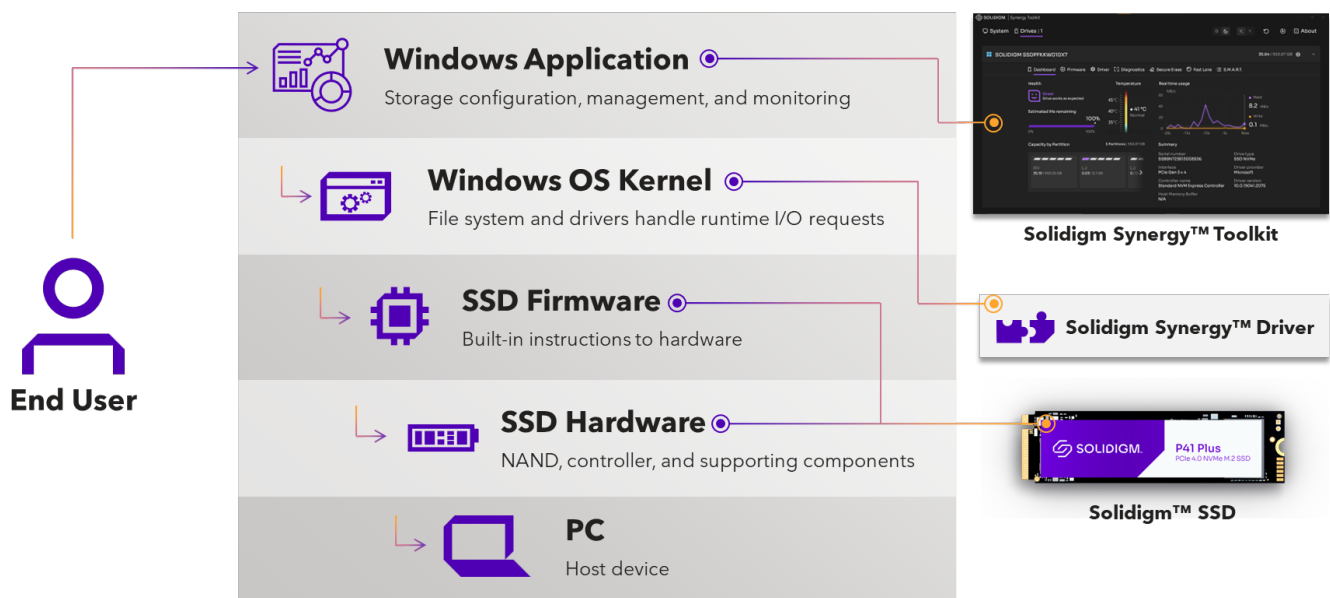
In addition, the driver seeks to optimize user experience by identifying where storage-intensive workloads are potentially creating system resource bottlenecks outside of the SSD itself. As I/O requests are received, serviced, and routed for completion, it’s possible to create a bottleneck at the CPU if, for example, too many completions are sent to an already-busy core.

Dynamic Queue Assignment relieves this problem by dynamically routing I/O completions to less-busy CPU cores. Today’s PCs ship with processors usually having eight or more cores. This feature makes better use of those cores to ensure you aren’t waiting for an unusually large number of operations to complete on a single busy core while others sit idle.

The Path Ahead

When we released Solidigm Synergy™ 1.0, we promised you that it was the beginning of a journey. Our company's mission to "deliver a new paradigm in solid-state storage" is more than just a catchy marketing phrase.

The 2.0 release builds on that promise with the introduction of a modern UI and exciting performance optimizations. We are proud of the technical innovations present in this version and the close collaboration between our engineering teams (hardware, firmware, and software) and planning and marketing teams - not to mention our customers, who have guided us from the start with critical feedback - that makes them possible.



But we're not finished yet. This is the second step of a multi-year expedition challenging the limits of what's possible. We believe there are significant improvements and optimizations yet to be made, and we will continue developing and refining them in passionate pursuit of the ideal user experience.

Stay tuned - there's more to come.

Appendix: Performance Claims

All comparisons are based on PC systems with Solidigm Synergy™ software, as compared to systems using the default Windows disk driver with otherwise identical hardware and system images running Windows 11 (21H2). Testing completed by Solidigm in March 2023.

1. Consistent Performance: Up to 120% Faster Reads on a 50% Full SSD
 - Iometer 4K random read test (8GB span, 300 seconds) with drives at 50% full. Configuration: Intel Core i7-11700K, 16GB RAM, P41 Plus 1TB.
2. Responsive Experience: Up to 20% Faster Random Writes
 - CrystalDiskMark 8.0.4 RND4K Q1T1 write test. Configuration: Intel Core i7-11700K, 16GB RAM, P41 Plus 1TB.
3. Application Launch: Up to 14% Faster Microsoft PowerPoint Launch
 - Microsoft PowerPoint launch test; median time of 5 runs. Configuration: Intel Core i9-11900K, 64GB RAM, P41 Plus 1TB.
4. Gaming: Up to 350% Faster QD1 4K Sequential Reads
 - CrystalDiskMark 8.0.4 SEQ4K Q1T1 read test. Configuration: Intel Core i7-11700K, 16GB RAM, P41 Plus 1TB.
5. PC Boot Time: Up to 7% Faster System Boot
 - PC full boot time. Configuration: Intel Core i7-12700T, 16GB RAM, P41 Plus 512GB.
6. PCMark 10 Storage: Up to 7% Higher Test Score
 - PCMark 10 Full System Drive Benchmark test. Configuration: Intel Core i7-12700K, 32GB RAM, P41 Plus 1TB. Note: Reported performance improvement occurs when the SSD is connected to the system via a PCH-attached M.2 slot.

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