Technical Whitepaper

RAID with HP G5 Workstations

Contents & Navigation

Technical Whitepaper

Contents & Navigation

Table of Contents

Technical Whitepaper

Contents & Navigation

Technical Whitepaper

Contents & Navigation

Technical Whitepaper

Contents & Navigation

Overview

This document is designed as an aid to understanding the support for RAID on HP G5 workstations. Workstation that use 4th-generation Scalable Processor architectures support Intel® VROC, and the Z6 G5A supports AMD™ RAIDXpert2. Details of what is supported are provided in a later chapter.

This is not a tutorial on RAID. What follows next is an overview to put Intel® VROC and AMD™ RAIDXpert2 in context with other RAID implementations. Please note that the details of Intel® VROC and AMD™ RAIDXpert2 are different. Be sure that you are consulting the information appropriate for your platform.

Basics of RAID

As computing systems evolved over the decades, using electromechanical hard drives (HDDs), engineers invented ways to arrange the drives to improve performance and to improve the data reliability of storage systems. Some of the schemes have continued to be used despite the gradual transition to solid state drives (SSDs) which are usually more reliable.

Modern computers accommodate various mechanisms for RAID (Redundant Array of Independent Disks), the name for many of these storage arrangements.

A few useful terms for the discussion that follows:

- Array: In a RAID implementation, a number of drives are grouped together in a set is called an array in this document. (Some implementations might call it a pool.)
- Member: A drive participating in an array is a member drive.
- Volume: From an array, a logical drive called a volume can be created that uses space on the array members in a particular way (striped, mirrored, etc.). Some implementations allow more than one volume to be created in the same array.
- Metadata: Information outside of any logical volume must be managed on each member of an array. This data tracks the organization and status of the array itself and of any volume(s).

RAID modes

Many different arrangements of the disks and the data on them have been devised, usually called RAID modes. Here is a summary of the ones relevant to RAID on HP G5 Workstations:

Basic geometry	RAID mode	Description
Striped	0	Data is sequentially arranged in stripes across all the drives in the array. Performance: Striping supports interleaved accesses for reading and writing and yields better performance than a single drive. Performance scales with more drives in the array, however not linearly. Data protection: Failure of any one drive is significant because there is no redundancy or recovery mechanism for data on the failed member. Effective capacity: The capacity of a striped volume is the total of the space it uses on all the member drives. For a single volume per array, that would be the total size of all the drives, minus some small allowance for metadata.

Technical Whitepaper

Contents & Navigation

Mirrored	1	The complete data image is replicated on two or more member drives. Writes must be done to all the members, otherwise they are out of sync and the volume status is degraded. Performance: Reads can come from any member that is in sync, so read performance can benefit. Data protection: There is complete data redundancy in case of a failure of one member drive. Effective capacity: Regardless of how many mirrors there are (normally just one duplicate), the volume only holds one drive's worth of data.
Parity	5	In this mode, data is laid out in stripes across the member drives, however in each stripe there is at least one drive where parity data computed on the rest of the stripe is recorded, instead of data. The parity data is usually scattered so not on the same member drive for each stripe. Performance: Because any write involves putting the data on one member drive and parity on another drive, writes require extra work, however reads benefit from interleaving just as in the striped geometry. Data protection: The striped layout with redundancy allows data and parity for a failed member to be reconstructed. Effective capacity: A typical RAID 5 of N drives has a capacity of N-1 drives worth of space.
Striped and Mirrored	10	This combines striping and mirroring to provide redundancy with some of the performance advantage of striping. Performance: Reads and writes both benefit from the striped geometry. Mirrors can get out of sync if not all writes are completed to each of them. Data protection: Complete redundancy just as in RAID 1. Effective capacity: For a RAID 10 that uses four drives, the useful data capacity is that of two drives.
Non-RAID	Volume	AMD™ RAIDXpert2 only. AMD™ RAIDXpert2 treats one or more disks, or the unused space on a single disk, as a single array. This provides the ability to link together storage from one or several disks, regardless of the size of space on those disks. This is useful for scavenging space on disks that is unused. Volumes do not provide a boost to performance or redundancy- disk failure will result in data loss.
Non-RAID	RAIDable or RAID Ready	AMD™ RAIDXpert2 only. This array allows a RAIDable disk to be later transformed into a RAID 0 or RAID 1 array. This provides flexibility when developing a storage solution.

Types of RAID Implementations

It is worthwhile to put the Intel® VROC and AMD™ RAIDXpert2 implementations in context with other RAID methods.
Here is one way to categorize them:

- Software RAID performs all the normal storage operation (reads, writes, and array maintenance) in OS drivers and services, executed by the CPU.
    - "Pure" software RAID also does management (array/volume creation and deletion) in a platform-independent way. Examples of this type include:

Technical Whitepaper

Contents & Navigation

        - Microsoft Windows **Storage Spaces**
        - Linux **mdadm** (when used with the default metadata format)
    - "Platform-assisted" software RAID uses a specific metadata format that is also supported by other management methods, e.g., in UEFI drivers and tools. The storage controller driver may be vendor-specific. Examples here include:
        - Intel(R) Architectures
            - Intel® **RST** (iRST) for SATA storage and NVMe prior to Intel® 12th-generation Core architectures
            - Intel® VROC for SATA storage
        - AMD™ Architectures
            - AMD™ RAIDXpert2 for NVMe Storage
    - "Hybrid" software RAID is platform-assisted and also includes hardware to consolidate the array members under an assisting controller. This requires a different driver in the OS to perform the basic read and write operations. Management of arrays and volumes can be supported via both OS-level and UEFI-level interfaces. Examples:
        - Intel® RST on Intel® 12th generation and later Core architectures, for SATA and NVMe storage
        - Intel® VROC, for NVMe storage
- Hardware RAID requires a controller "engine" that truly hides the array members and implements the RAID operations. Often this is an add-in card (a host-bus adapter, or HBA).
    - Simple hardware RAID adapters support RAID modes that do not require extra computations on the data being read or written; that is, simple striped and mirrored volumes.
    - More complex adapters include hardware support for parity computations such as those used for RAID 5. For good performance, these computations are done in a specialized processor, so this is often called RAID-on-chip (ROC).

All these types of RAID implementations may support all the common RAID modes (mirrored, striped, and parity). As you might guess, parity computation that must be done on the CPU has an impact on performance, including writes in RAID 5. Some of the simple hardware adapters cannot support the additional computation so they simply do not offer those modes.

What does "VROC" stand for?

The Intel® RAID software support for earlier generations of server-class architectures (used in HP Z4, Z6, Z8 Workstations models Zx00, Zx20, and Zx40) was called **Rapid Storage Technology enterprise**, or **RSTe**. As of the 6.x release for the 2nd-generation processors, in which NVMe support was first added, the software was rebranded as **Virtual RAID on CPU** (**VROC**). Though the new brand was originally connected mostly with NVMe RAID, it applies to both SATA and NVMe RAID.

Intel® Core architectures are supported by Intel® Rapid Storage Technology (RST, or sometimes iRST), which is NOT the same as VROC. This software stream also has a long history, originating as Intel® Application Accelerator and then called Intel® Matrix Storage Manager, before becoming Rapid Storage Technology.

Intel® VROC RAID Components, Supported Platforms, and Capabilities

Intel® VROC Components

As mentioned in the Overview:

- VROC SATA support is platform-assisted software RAID.
- VROC NVMe support can be considered hybrid software RAID, in that it relies on a special hardware function in the CPU called the Volume Management Device. (See below.)

VROC comprises multiple system elements:

1. Intel® SATA controllers with RAID "mode"

   The main SATA ports are implemented under controllers located in the Platform Controller Hub (PCH). In most platforms, the visible controller is the primary **SATA** controller. In some, it is the secondary **sSATA** controller. When the controller is in "RAID" mode, the appropriate Intel® VROC driver in Windows associates with the

Technical Whitepaper

Contents & Navigation

controller. When in "AHCI" mode, a Windows "in-box" driver is used. (The PCI express device IDs differ between these two modes.)

2. Intel® Volume Management Device (VMD)

   PCIe root complexes in the supported Intel® CPUs implement an optionally enabled device that provides a VMD controller that acts as an "umbrella" over NVMe (PCIe-based) storage devices. It is this special device that gives "one point of control" when the OS drivers are accessing NVMe RAID volumes.

   There is one VMD function available per architectural group of 16 PCIe lanes (root port), so each group is called a "VMD domain". The enablement of any particular VMD is controlled through the system BIOS settings on the PCIe slots or sockets in that domain.

   HP system BIOS allows VMD enablement to be managed by NVMe "location". For example, if two sockets on the mainboard are both in the same domain, VMD participation can be enabled on one and not the other. Examples of locations are individual M.2 sockets, PCIe slots that accommodate M.2 carrier cards, and connectors for specialized M.2 enclosures.

   HP BIOS does not support VMD enablement of PCIe lanes and slots hosted under the PCH.

   Important:

   - **A RAID volume used for OS boot must exist entirely within one VMD domain**.
   - A volume used for data (not OS) can "span" multiple VMD domains.

3. Human Interface Infrastructure (HII) implemented in UEFI drivers, accessible in HP Workstation platform BIOS "F10 Setup"

   Both SATA and NVMe arrays and volumes can be created and deleted via an interactive interface accessible in the system BIOS F10 Setup pages. Non-member drives can be collected into arrays or designated as spare drives (and for RAID 5, as a type of journalling drive).

   NVMe drives that are not in enabled VMD domains are not shown in this interface.

   The capability to create a RAID volume in the BIOS allows an operating system to be installed to the volume. Obviously, the correct driver must be available at installation time. This will be discussed more later.

4. Device drivers for the Microsoft Windows operating system

   Intel® provides Windows drivers for the primary and secondary SATA controllers and for VMD controllers.

   - It is important to know that the Windows in-box driver for primary SATA can access a single drive under a controller in RAID mode.
   - On the other hand, the in-box NVMe driver cannot support NVMe drives in VMD-enabled locations.

5. Intel® VROC applications for Windows
   a. Graphical user interface (GUI)

      A VROC RAID management application (Intel® Virtual RAID on CPU, executable name IAStorUI.exe) can be installed that makes most management actions possible from the operating system. Arrays and volumes can be created, and RAID migrations and rebuilds performed. A single OS drive can be migrated to be a boot RAID.

      A background task (IAStorIcon.exe) is also set up by the installer to support RAID health monitoring and notifications.

   b. Command line interface (CLI)

      The HP web package (SoftPaq) includes the Intel® VROC CLI (IntelVROCCLI.exe) and a user guide. The GUI installer does not add this to the system image.

   c. These applications must be run with Administrator privileges.

6. UEFI shell tools

Technical Whitepaper

Contents & Navigation

The HP SoftPaq includes a few tools that provide a command line interface useful in the UEFI shell.

Intel® User Guide and Other Documentation

Intel® provides a User Guide for VROC that can be found at the URL below. A version of the guide is included in the HP SoftPaq. The revision online might be more recent.

https://www.intel.com/content/www/us/en/support/articles/000094004.html

Sections of the guide that refer to BIOS interfaces are not appropriate to the HP Workstation BIOS. Please consult later sections of this document for equivalent information.

On the other hand, the guide shows well how to use the GUI in Windows. These topics will not be covered in this whitepaper.

At the same location, you can find other VROC-related documentation from Intel®, including some information about versions and architecture support.

When there is disagreement between Intel® and HP documentation, the HP-specific information takes precedence.

Intel® VROC Platforms

The VROC 8.x version stream is targeted to the 4th generation of Intel® Scalable Processor systems.

As of this writing, here are the HP Workstations that use this technology, including information on the storage controllers they provide and the Windows drivers that apply.

Platform Name	SATA controller	Number of SATA ports	Intel® SATA driver	Number of VMD domains useful for storage	Intel® VMD driver
Z4 G5	Primary (SATA)	5	iaStorE.sys	3	iaVROC.sys
Z4R G5	Primary (SATA)	1	iaStorE.sys	4	iaVROC.sys
Z6 G5	Primary (SATA)	5	iaStorE.sys	5	iaVROC.sys
Z8 Fury G5	Primary (SATA)	6	iaStorE.sys	6	iaVROC.sys
Z8 G5	Secondary (sSATA)	6	iaStorB.sys	3 (with one CPU) 6 (with two CPUs)	iaVROC.sys

The platform BIOS incorporates the UEFI code that provides the Human Interface Infastructure (HII) user interface and supports the VMD functionality in the PCIe complex.

Earlier versions of the VROC Windows drivers (that is, 6.x or 7x versions) are not supported with the 8.x UEFI code in the BIOS. This is important to know because a pre-existing OS image may malfunction if used normally on these platforms. It is critical to update the VROC software and drivers in such an image. New installations must use the 8.x software.

HP has not evaluated and does not support the 8.x Windows software and drivers on earlier generations of workstations. The BIOS on those systems incorporates versions of the UEFI code that are incompatible with the 8.x OS software.

Operating Systems

Microsoft Windows

The 8.x release of VROC Windows drivers and software is supported by HP on these platforms for:

- Windows 10 22H2
- Windows 11 22H2 and later

The 8.x release introduces a brand new Windows GUI style with new capabilities. Users will need to familiarize themselves with the new style. For the most part, the CLI options have not changed.

Contents & Navigation

Intel® VROC in Linux

Arrays and volumes created in the system BIOS are tagged with a metadata format that is called “imsm” in Linux software. Support in the kernel and in the mdadm tool to work with the 8.x UEFI code and the associated Intel® architectures is available in the open-source repositories. Containers and volumes can also be created in the operating system using a specification of that metadata format.

The following distributions are known to include the capabilities required and are supported by HP on these platforms:

- SLE 15 SP4 and later
- RHEL 8.6 and later
- Ubuntu 20.04 LTS and 22.04 LTS

Many others may also work correctly.

Hot Plug and Unplug

Intel® VROC does not provide a user interface to prepare an active array for wholesale removal. As a software designed to support servers, it accommodates some hardware hotplug and hot-unplug under server operating systems, with standard server backplanes and U.2 or U.3 NVMe form factors. HP Workstations do not implement those backplanes.

Individual members can be ejected from a redundant RAID in the VROC Windows GUI, if they are ejectable in Windows. Such a RAID will immediately go into a “degraded” mode and when the member is returned later or a spare is available, can start rebuilding.

In general, it is advisable to shut down the system when removing hardware that is part of a RAID.

Windows operating systems appropriate to Workstations have some support to eject or add NVMe drives that are marked as removable when they are being used individually. Removal of individual drives may succeed with unused spares and filed array members.

The User Guide from Intel® mentions allowing sufficient time between “events” when hotplugging new drives. It may be possible to bring a newly added drive into an existing array if the RAID mode allows that. Otherwise, a new drive can be made a spare and a rebuild of a degraded RAID will start if needed.

Linux operating systems can also tolerate an NVMe device removal. A software eject is advisable, e.g. by writing a value to a fiile in the sys filesystem. For example, if the device to be ejected is nvmeXn1, this command will notify the system:

echo 1 > /sys/block/nvmeXn1/device/device/remove

Of course there is risk if writes are active to the device when it is ejected.

Minima and Maxima

The following table captures various limits of VROC 8.x, as documented by Intel®. Please note that some of the maxima for NVMe are theoretical, in that is it not physically possible to mount that number of drives in the system.

To understand the practical maximum number of NVMe drives in the supported HP workstations, please consult the platform QuickSpecs. Only certain combinations of locations for M.2 modules are supported, and those combinations govern the total numbers of M.2 modules that can be installed.

	SATA		NVMe	
	Minimum	Maximum	Minimum	Maximum
Total drives		n_ports		96
Total arrays		n_ports / 2		24
Volumes per array		2		2
RAID 0	2	n_ports	2	48
RAID 1	2	2	2	2
RAID 5	3	n_ports	3	48
RAID 10	4	4	4	4

Contents & Navigation

AMD™ RAIDXpert2 Components, Supported Platforms, and Capabilities

AMD™ RAIDXpert2 RAID Components

The RAIDXpert2 solution consists of three components:

- **The AMD™ RAIDXpert2 UEFI component** comes included in the Z6 G5A BIOS. It enabled AMD™ RAIDXpert2 and provides an interface in the F10 setup menu for the creation and management of RAID arrays.
- **Device Drivers for the Microsoft Windows Operating System** enable the use of AMD™ RAIDXpert2 arrays inside windows for data or for OS installation.
- **The AMD™ RAIDXpert2 GUI** is a management suite that allows for array and disk management within Windows. The functionality provided by AMD™ RAIDXpert2 goes beyond what is possible in F10 setup.

AMD™ RAIDXpert2 User Guide

AMD™ provides a user guide for AMD™ RAIDXpert2 that can be found at the URL below. A version of the guide is included in the HP SoftPaq. The revision online may be more recent.

https://drivers.amd.com/relnotes/amd-raidxpert2_user_guide.pdf

Sections of the guide that refer to BIOS interfaces are not appropriate to the HP Workstation BIOS. Please consult later sections of this document for equivalent information.

When there is disagreement between AMD™ and HP documentation, the HP-specific information takes precedence.

AMD™ RAIDXpert2 Platforms

AMD™ RAIDXpert2 is only supported on the Z6 G5A platform.

The platform BIOS incorporates the UEFI code that provides the Human Interface Infastructure (HII) user interface.

Operating Systems

Microsoft Windows

The AMD™ RAIDXpert2 Windows Drivers and software is supported by HP on the Z6 G5A for:

- Windows 10 22H2
- Windows 11 22H2 and later

AMD™ RAIDXpert2 in Linux

AMD™ RAIDXpert2 is not officially supported by HP for the Z6 G5 A; however, the AMD™ RAIDXpert2 user guide provides guidance on using AMD™ RAIDXpert2 arrays in a Linux environment.

Hot Plug and Unplug

At this time, AMD™ RAIDXpert2 does not support hot-plug and hot-unplug under any operating system. In general, it is advisable to shut down the system when removing hardware that is part of a RAID.

Minima and Maxima

The following table captures various limits of AMD™ RAIDXpert2, as documented by AMD™. Please note that some of the maxima for NVMe are theoretical, in that is it not physically possible to mount that number of drives in the system.

To understand the practical maximum number of NVMe drives in the supported HP workstations, please consult the platform QuickSpecs. Only certain combinations of locations for M.2 modules are supported, and those combinations govern the total numbers of M.2 modules that can be installed.

Technical Whitepaper

Contents & Navigation

Please be advised that AMD™ RAIDXpert2 only supports a maximum of 8 arrays in any configuration. It is possible to create more arrays through the AMD™ RAIDXpert2 interface, but such configurations are untested and unsupported. Note also that SATA RAID is not supported on the Z6 G5 A at this time.

	NVMe	
	Minimum	Maximum
Total drives		n_ports
Total arrays		8
RAID 0	2	8
RAID 1	2	2
RAID 5	3	8
RAID 10	4	8
Volume (JBOD)	1	8
RAIDable	1	1

Hardware Requirements

Intel® VROC Upgrade Modules

When a VMD is enabled, the NVMe devices under it are by default in a "pass-thru" mode. The VROC driver for the VMD controller can support them as individual storage devices, much as the Windows in-box standard NVMe driver would for devices not under a VMD controller.

To create VROC arrays and volumes on NVMe storage, one of the following types of upgrade modules must be installed to a special header (labelled "VROC") on the system mainboard. Reference the label on the inside of the side cover to locate the connector. The modules are available both at system order time and as after market options.

Upgrade Module Name	Enables these capabilities
Intel® VROC NVMe SSD Standard Ctlr Module	NVMe RAID modes 0, 1, 10
Intel® VROC NVMe SSD Premium Ctlr Module	NVMe RAID modes 0, 1, 5, 10 plus write hole closure support for both SATA and NVMe RAID 5

Here is an image of an upgrade module and the header on the mainboard that receives it:

There is a method for a 90-day Trial Mode use of an NVMe RAID, without the presence of an upgrade module. The array and volume can be created via the VROC Graphical User Interface for Windows. The Intel® User Guide documents this feature.

Technical Whitepaper

Contents & Navigation

SATA arrays and volumes can be managed without an upgrade module. Only the RAID write hole closure feature depends on the presence of the Premium item.

Note: Intel® VROC Upgrade modules are not required on AMD(TM) Workstations (e.g. - Z6 G5 A) to enable AMD™ RAIDXpert2.

Drive Types

SATA Hard Drives

Recording Methods

The Enterprise-class SATA hard drives supported by HPI in these workstations use Conventional Magnetic Recording (CMR) as the means of recording data. HP does not recommend or support use of HDDs that utilize Shingled Magnetic Recording (SMR) in VROC arrays.

Platform Support

SATA RAID is supported on all G5 platforms.

Self-Encrypting Drives (SEDs)

Self-encrypting drives can exist in two states: unprovisioned or provisioned. Provisioned drives have a defined passcode that must be provided before they can be accessed. Unprovisioned drives operate much the same as non-SED drives; they can be read and written however do not have a passcode. HP system BIOS prevents unauthorized definition of a passcode, which could make all the drive contents inaccessible.

BIOS in the HP platforms don't have a mechanism for unlocking SEDs so that they can be recognized as array members during system start; therefore, provisioned SEDs are not supported by HP in VROC arrays.

Solution Design Considerations

Recommended Minimum BIOS and Driver Versions

HP Recommends updating to the latest BIOS and RAID Driver versions. The table below shows lists the recommended minimum required BIOS and Driver versions for each platform. On Intel® platforms, when using a BIOS less than the recommended version listed below, it is necessary to disable "Pre-boot DMA Protection." The instructions to do so are listed in the Chapter titled, "Configuring Intel® VROC RAID in BIOS" in the section titled "Security Settings.

Platform	Minimum BIOS Version	Minimum Driver Version
Z4 G5	01.01.27	VROC 8.2.0.1985
Z4R G5	01.01.14	VROC 8.2.0.1985
Z6 G5	01.01.27	VROC 8.2.0.1985
Z8 Fury G5	01.01.27	VROC 8.2.0.1985
Z8 G5	01.01.27	VROC 8.2.0.1985
Z6 G5 A	01.01.30	AMD™ RAIDXpert2 932-00294

Capacity Planning

When considering possible designs for the storage solution in a system, these factors must be included:

1. **How many physical devices can be installed?**
    a. For SATA HDDs, this is the total of internal bays plus any supporting mountings in available external 5.25" bays. The number of available SATA ports is also a factor.
    b. For NVMe (M.2 modules), the maximum count derives from some combination of internal sockets and carriers, plus any supported external enclosure types. However, one must be mindful of the restrictions in location combinations as documented in the platform QuickSpecs.

Contents & Navigation

2. **For a RAID volume, can the desired mode and capacity be achieved using supported devices?** From the general discussion in the Overview, plus the specific VROC limits discussed in the chapter on supported configurations, this table can be generated:

RAID mode	Drives required in array (N)	Effective capacity for N (equally-sized) drives in array
0	Min=2, Max based on available locations	N
1	2	1
5	Min=3, Max based on available locations	N-1
10	4	2

3. **For an NVMe RAID boot volume, can the desired mode and capacity be supported using only one VMD domain?** See the subsection below showing the VMD domain map for each of the supported platforms. Since a boot volume cannot be spanned across domains, the choice of which domain to use interacts with the number of drives needed in the boot volume.

Drive Matching

Use of the same or functionally equivalent storage devices for all members of a given RAID array is recommended; therefore, it is recommended to use drives that have the same HP model numbers. Using different model numbers may limit the capacity of the RAID, reduce RAID performance, or reduce RAID reliability. Space will be wasted if some member drives are larger than others since RAID volumes are built with uniform space usage on all the members.

The exception is RAID 5 with the Journaling RAID Write Hole (RWH) closure mode. The Journaling disk can be smaller than RAID members, however Intel® does not specify a minimum capacity requirement.

RAID volumes require at least 5MB of free space at the end of the disk for metadata. RAID creation will fail if the source disk does not have enough free space at the end of the disk. When using the VROC GUI, a pop-up will appear with the following error:

Not enough disk space for Metadata, please reduce the source partition by 5 MB.

AMD™ RAIDXpert2 does not support the creation of a RAID using existing volume data. When creating a RAID from existing data, the size of the last partition on the disk may need to be reduced by 5MB to accommodate metadata. Most Windows OS installations consume the entire disk and will require size reduction of the last partition on the disk.

Intel® VROC Considerations

Intel® VROC VMD Enablement

As mentioned earlier, the VMD device enablement (or “VMD mode”) for a particular PCIe slot or socket is enabled in the BIOS F10 Setup dialog, in the Advanced->Slot Settings pages. Examples will be shown in the next chapter.

It is important to make sure the VMD enablement for each slot is as desired before booting to Windows. Here are some behaviors to be aware of:

- The option to enable VMD is only available for a slot if NVMe storage is present, otherwise it will be grayed out.
- The setting is not retained and automatically restored if the NVMe storage is removed and the system rebooted, and then the storage reinstalled later. You will need to re-enable VMD after such a procedure.
- Resetting the BIOS to factory defaults will also disable VMD on all slots.

Here is the risk if VMD is unintentionally disabled for a boot storage device or boot RAID volume:

- During the setup of the Windows boot from a VMD source, the Windows **boot storage driver** is switched to the Intel® iaVROC.sys driver.
- However, if Windows successfully boots to the same storage device when VMD is later disabled, it may revert to its default NVMe driver. A successful boot after disablement may occur if the storage was configured either as a standalone “pass-thru” VMD drive, or as a RAID 1 member where the entire boot image is on each drive.

Contents & Navigation

- A later re-enablement of VMD does not always cause Windows to automatically reinstate the VMD-capable driver. Instead, it is possible the boot will fail with a message such as INACCESSIBLE_BOOT_DEVICE.
- This problem is more likely to occur with a boot RAID than with a single drive in VMD pass-thru.
- If this inadvertent reversion to the in-box driver occurs, it may be possible to reactivate the VMD driver using the method described below in "Migrating a boot image from non-VMD to VMD"

Intel® VROC VMD Domains

To understand how to combine NVMe devices into arrays, either in a single domain or spanning multiple domains, a "map" of the domains on the platform is needed. This subsection provides a table for the domains available on each of the platforms listed in the Supported Platforms and Capabilities chapter.

Please note that only data RAID Arrays can span multiple VMD domains. Boot RAID arrays cannot span multiple VMD domains; every disk in the boot array must be under the same VMD domain. The domain numbers shown here are what you can see in the BIOS Human Interface Infrastructure(HII). In the Windows VROC GUI, different "VMD numbers" are shown, due to the way Windows enumerates buses. You can match the BIOS domain numbers in the "Drives" dialog in the GUI, by expanding the properties on a particular drive and noting the "VMD Controller Number".

Platform: Z4 Rack G5

VMD domain number as shown in HII	Locations in the domain	Total number of PCIe x4 M.2 modules possible	Notes
3	PCIe slot 1	2	HP Remote System Controller or single-wide graphics
0	PCIe slot 2, PCIe slot 3	4	Each of these locations can be independantly enabled for VMD.
1	MB Socket M.2 SSD0, MB Socket M.2 SSD1, MB connector NVME0	4	Each of these locations can be independantly enabled for VMD.
2	MB Connector NVME1	2	

Platform: Z4 G5

VMD domain number as shown in HII	Locations in the domain	Total number of PCIe x4 M.2 modules possible	Notes
3	MB Socket M.2 SSD0 MB Socket M.2 SSD1 MB connector NVME0	4	Each of these locations can be independently enabled for VMD.
1	PCIe slot 4	4	
2	PCIe slot 5	4	

Contents & Navigation

Platform: Z6 G5

VMD domain number as shown in HII	Locations in the domain	Total number of PCIe x4 M.2 modules possible	Notes
3	MB Socket M.2 SSD0 MB Socket M.2 SSD1 MB connector NVME0	4	Each of these locations can be independently enabled for VMD.
5	MB connector NVME1	2	
1	PCIe slot 4	4	
2	PCIe slot 5	4	
6	PCIe slot 6	4	

Platform: Z8 Fury G5

VMD domain number as shown in HII	Locations in the domain	Total number of PCIe x4 M.2 modules possible	Notes
5	Personality slot 0 Personality slot 1	4	Each of these locations can be independently enabled for VMD.
3	MB connector NVME0 MB connector NVME1	4	Each of these locations can be independently enabled for VMD.
2	PCIe slot 7	4	
1	PCIe slot 5	4	
4	PCIe slot 1	4	
6	PCIe slot 6	2	

Platform: Z8 G5

CPU number	VMD domain number as shown in HII	Locations in the domain	Total number of PCIe x4 M.2 modules possible	Notes
0	3	Personality slot 0 MB connector NVME0	4	Each of these locations can be independently enabled for VMD.
0	0	PCIe slot 1	4	
0	2	PCIe slot 5	2	
1	0	Personality slot 1	4	
1	1	PCIe slot 2	4	
1	2	PCIe slot 6	4	

Intel® VROC: Migrating a Boot Image from Non-VMD to VMD

This section describes a procedure for migrating a Windows boot image that is initially using the in-box NVMe storage driver, on one NVMe device in non-VMD mode, to instead boot from one NVMe device under VMD in pass-thru mode. After that, migration to an NVMe RAID involving other drives in the same domain is possible, using the VROC graphical user interface.

In general, Windows does not gracefully handle changes of the boot storage driver. If you are installing Windows directly, you can avoid this procedure by installing to a drive already in VMD mode. You simply need to manually load the Intel® VROC driver for VMD (iaVROC.sys) during the installation or inject it into the image using deployment tools.

Technical Whitepaper

Contents & Navigation

Required for this procedure:

- A “scratch” NVMe device (which will not actually be modified).
- An available M.2 location in the same or another VMD domain. The important attribute is that it must be capable of being independently enabled for VMD. The terms boot location and scratch location will be used.
- Any needed device carrier to place that second NVMe in the scratch location.

Procedure steps:

1. Shut the system down and unplug the line.
2. Install the scratch NVMe into the scratch location.
3. Boot up to BIOS F10 Setup.
4. Navigate to Advanced->Slot Settings. Select a slot to be the scratch location. Set Intel® VROC NVMe RAID to “Enabled” for that location.
5. Boot to the Windows OS.
6. Install the VROC driver for VMD if not already done. This is most easily done by running the application installer, however it can be added via Device Manager if you have access to the .inf and other files for iaVROC.
7. After the driver installation, you should be able to see the VMD controller as a **Storage controller** in Device Manager. You should also be able to see the scratch device in **Disk drives**.
8. Reboot to BIOS F10 Setup.
9. Navigate to Advanced->Slot Settings. Select the slot corresponding to the boot location. Set Intel® VROC NVMe RAID to “Enabled” for that location.
10. Boot to Windows again. Because Windows already has loaded the VMD-capable driver, it should be able to install the iaVROC driver for boot storage access.
11. Shut down the system and remove the scratch NVMe.
12. Boot to Windows again. Now you should see the boot drive in the VROC GUI as a pass-through device, and it should be tagged as the “system device”.

Intel® VROC: How VMD Presents in Windows Device Manager

Each NVMe SSD has an integrated controller and shows up as an individual controller under the **Storage controllers** category in Windows Device Manager when VMD is not enabled. Each Intel® VMD Controller will manage up to four x4 NVMe SSDs. When VMD is enabled on a PCIe slot, and the Intel® driver is loaded, the NVMe SSD controllers will be hidden behind the Intel® VMD Controller assigned to the location. (If the Intel® driver is not loaded, VMD devices will appear as **RAID Controller** in another category.)

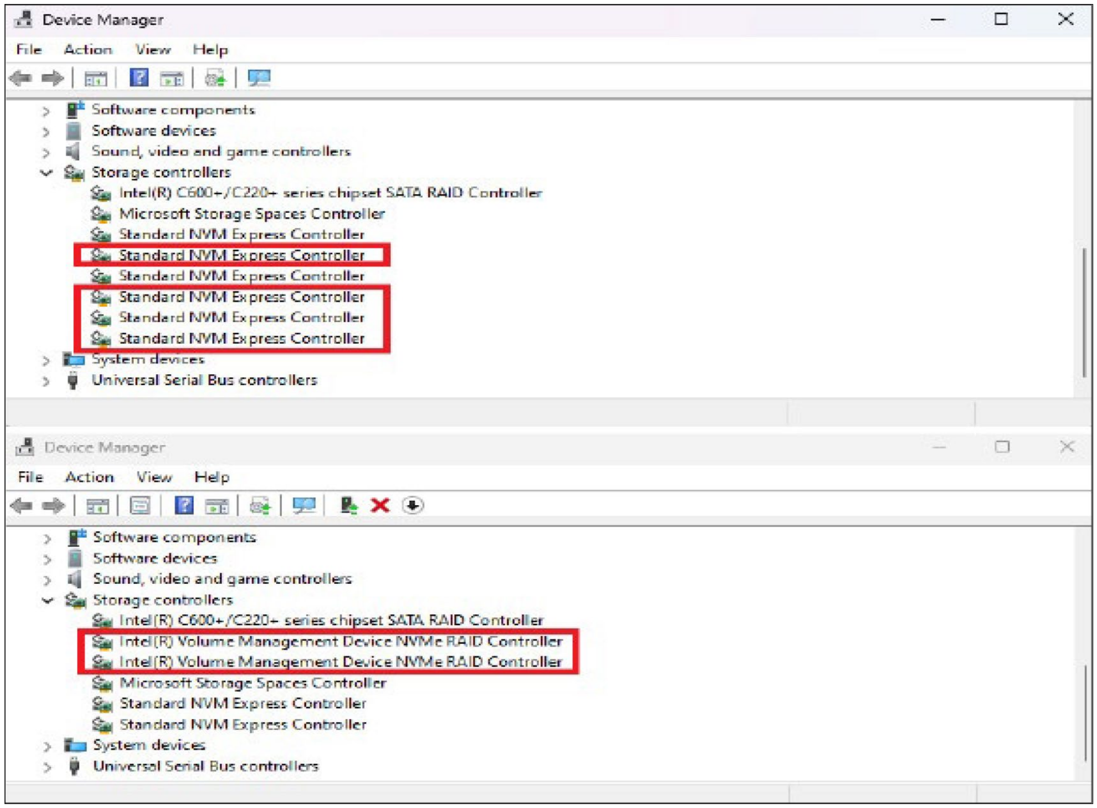
In the first Device Manager image of **Storage controllers** shown below, VROC is not enabled on any location. Devices using the Microsoft inbox driver will show up as “Standard NVM Express Controller” unless a vendor-specific device is installed.

In the second image below, all slots are VMD-enabled except one x4 PCIe location, in this case an M.2 socket on the system board holding the boot drive; and one x8 PCIe slot hosting one M.2 drive. Four other NVMe SSDs are now behind two instances of “Intel® Volume Management Device NVMe RAID Controller”.

Disk names shown in **Disk drives** will also change when a NVMe SSD is managed by VROC but not in an array, i.e. in pass-thru mode. VROC will truncate the SSD manufacturer’s string and insert NVMe in front.

Technical Whitepaper

Contents & Navigation



AMD™ RAIDXpert2 Considerations

AMD™ RAIDXpert2: Limitations with NVMe RAID Enablement

Configuring AMD™ RAIDXpert2 in BIOS discusses how to enable NVMe RAID with AMD™ RAIDXpert2 for Z6 G5A. It is important to consider the following when designing and setting up a storage solution.

AMD™ RAIDXpert2 enables NVMe RAID across all NVMe slots. This is unlike VROC, where RAID can be enabled or disabled on a per-slot basis. NVMe storage devices that were configured with NVMe RAID disabled, such as an NVMe drive with an OS installed on it, cannot be used once NVMe RAID is enabled. Such disks will be marked as legacy and must be formatted before they can be used with NVMe RAID enabled; therefore, NVMe RAID should be enabled before OS installation to a single disk if:

- The boot disk will later be migrated to a boot RAID array. In this case, the boot disk needs to be configured with a "RAIDable" array Windows must then be installed as described in the chapter entitled "Installing Windows to a RAID Boot Volume.
- An additional NVMe RAID array (boot or data) will later be installed alongside the boot disk.

Configuring Intel® VROC RAID in BIOS

This chapter illustrates some settings in the BIOS F10 Setup interface that enable VROC functionality, plus management of arrays and volumes in the VROC Human Interface Infrastructure (HII). Please consult this chapter in preference to the Intel® User Guide chapter "Pre-Operating System", which illustrates the interfaces using a completely different system BIOS style.

Security Settings

On certain BIOS versions, it is necessary to disable "Pre-boot DMA protection" to allow these functions:

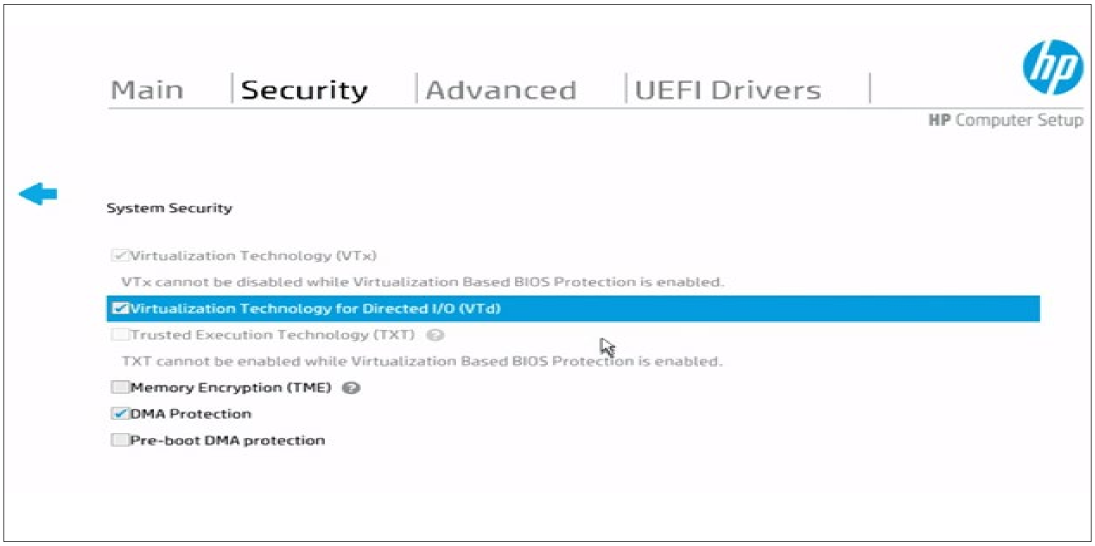
1. Manage NVMe arrays and volumes
2. Boot to an NVMe RAID volume

Uncheck the box in the Security->System Security dialog:

Technical Whitepaper

Contents & Navigation

Please refer to the table “Recommended Minimum BIOS and Driver Versions” in the Chapter “Solution Design Considerations” to see which BIOS versions are affected.



Controller Enablement

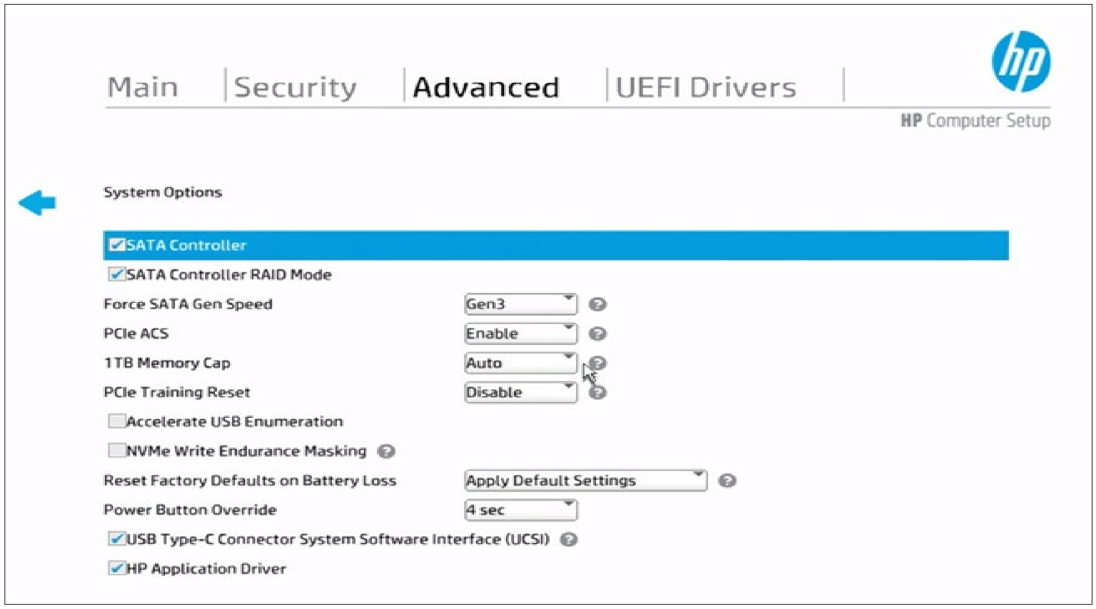
Both SATA and VMD controllers are enabled or disabled through subordinate pages of the Advanced section of the F10 Setup interface. Here’s the top-level view of the Advanced section. (This might vary by platform.)

SATA Controller Enablement in System Options

The SATA controller and RAID mode must be enabled via the checkboxes shown below, for VROC RAID to be available on SATA drives.

Technical Whitepaper

Contents & Navigation



VMD Enablement in Slot Settings

Previous sections have discussed how VMD can be enabled independently for each "location", where that may be a mainboard socket, a PCIe slot, or a connector for a front enclosure or other type of storage carrier. All the PCIe lanes in that location are enabled together, even if there are enough to support more than one 4-lane M.2 module.

All such locations are enabled through the Advanced->Slot Settings interface, which provides a separate subordinate page for each location.

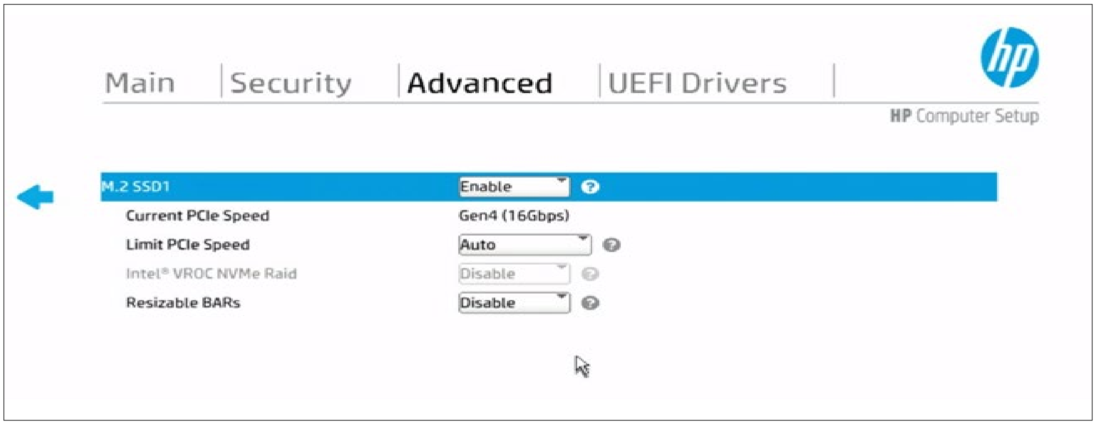
Here's an example of choices under Slot Settings. The exact choices vary by platform; this is from a Z6 G5 workstation. Some details:

- Not all PCIe slots are valid for storage devices. See the tables earlier that document the VMD domains.
- NVME0 and NVME1 are connectors on the mainboard to support front-accessible enclosures.
- SSD0 and SSD1 are mainboard single-M.2 sockets.

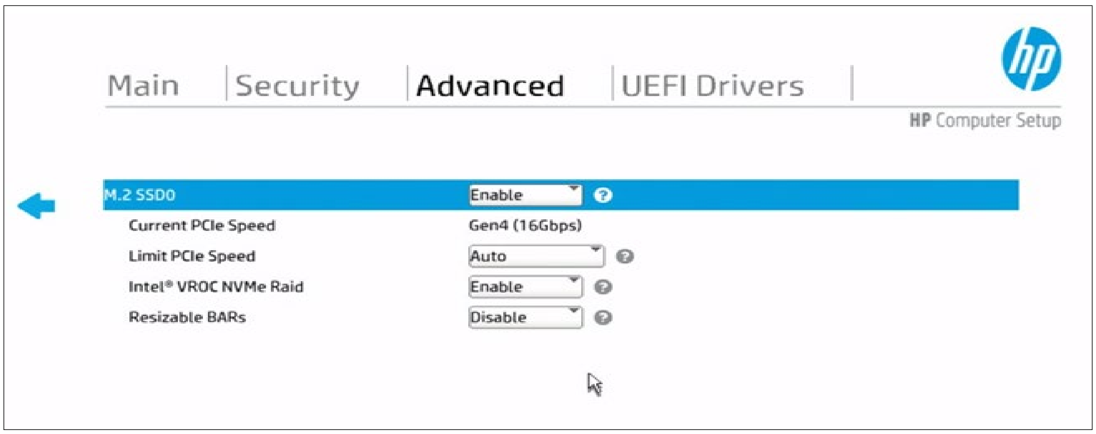
Below is the Slot Settings page for the mainboard M.2 socket. Note that the "Intel® VROC NVMe Raid" box, which would enable VMD for this location, is grayed out. That is because this socket doesn't have a NVMe device inserted. Remember that the system will "forget" that VMD was enabled for a location, if it is booted without a storage device present.

Technical Whitepaper

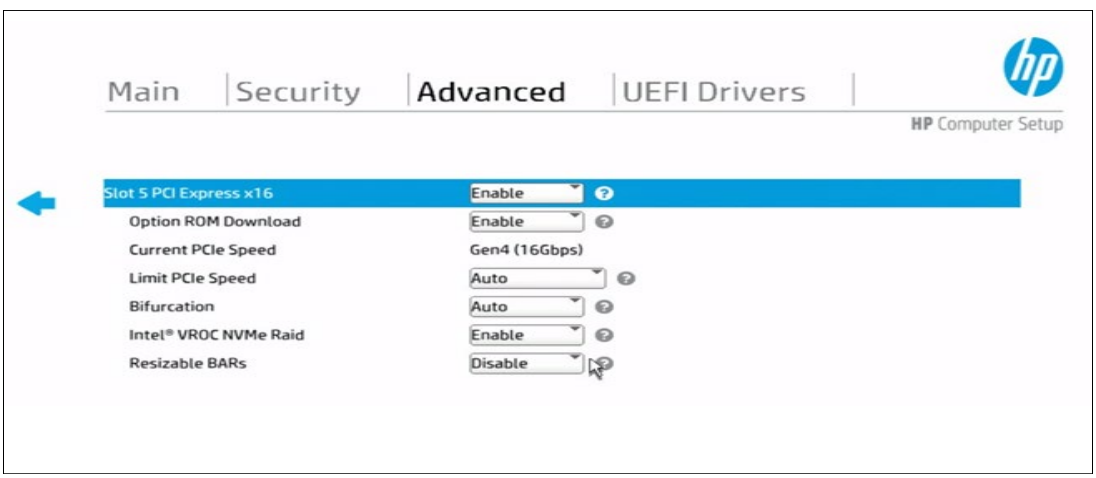
Contents & Navigation



Now here is a page for a mainboard M.2 socket that does have a device present:



This is an example of a page for a PCIe slot, that does have a card present hosting one or more NVMe devices:



UEFI Drivers Section: Intel® VROC Human Interface Infrastructure

Here's the view at the top level of the **UEFI Drivers** section of the F10 Setup interface. The exact set of choices may vary. Some you might see are not VROC-related, however at least two are:

- The **Intel® Virtual RAID on CPU** option (for NVMe management) will only appear if at least one VMD is enabled by enabling Intel® VROC NVMe RAID in Slot Settings.

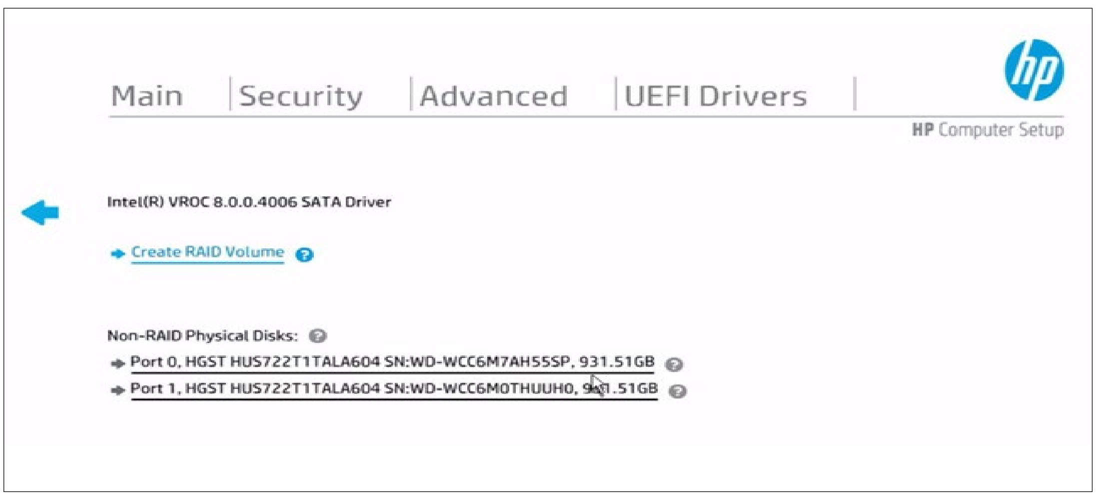
Technical Whitepaper

Contents & Navigation

- The **Intel® VROC SATA Controller** option will appear when the SATA controller is enabled for RAID mode. (On some platforms it may be the sSATA controller instead.)

SATA Volume creation and deletion

If the **Intel® VROC SATA Controller** option is chosen from the top level, you might see a page like this, if there are no SATA volumes in existence. This is the "SATA main page":



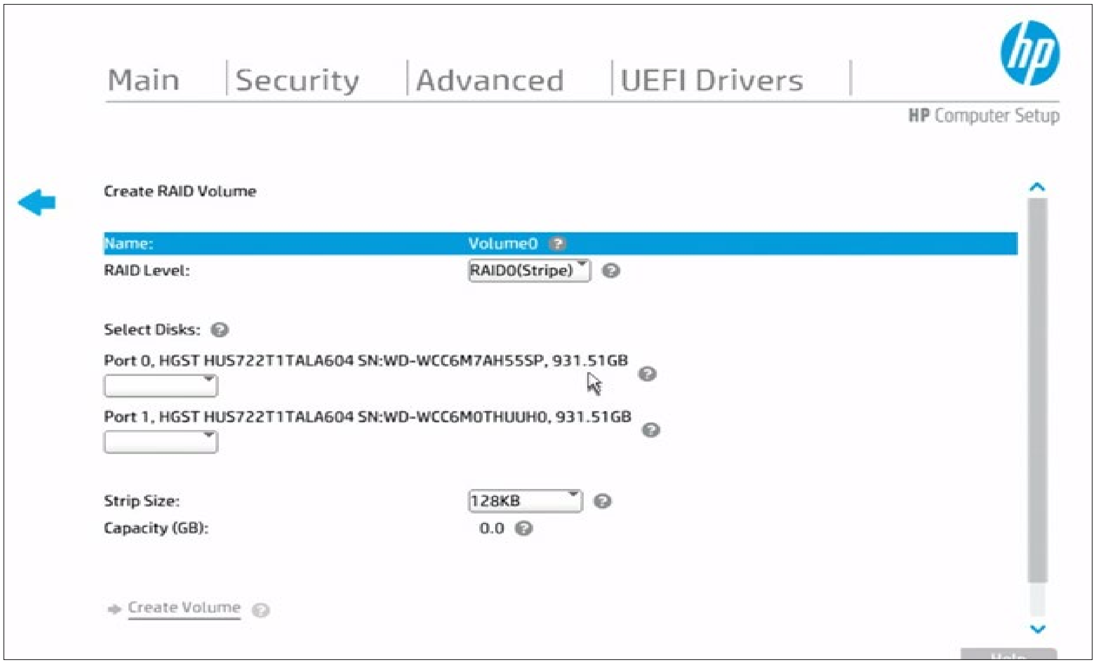
Creating a SATA volume

The following sequence of images step through the process of creating a SATA RAID0 volume (which implicitly creates an array). Choosing the **Create RAID Volume** option in the image above leads here.

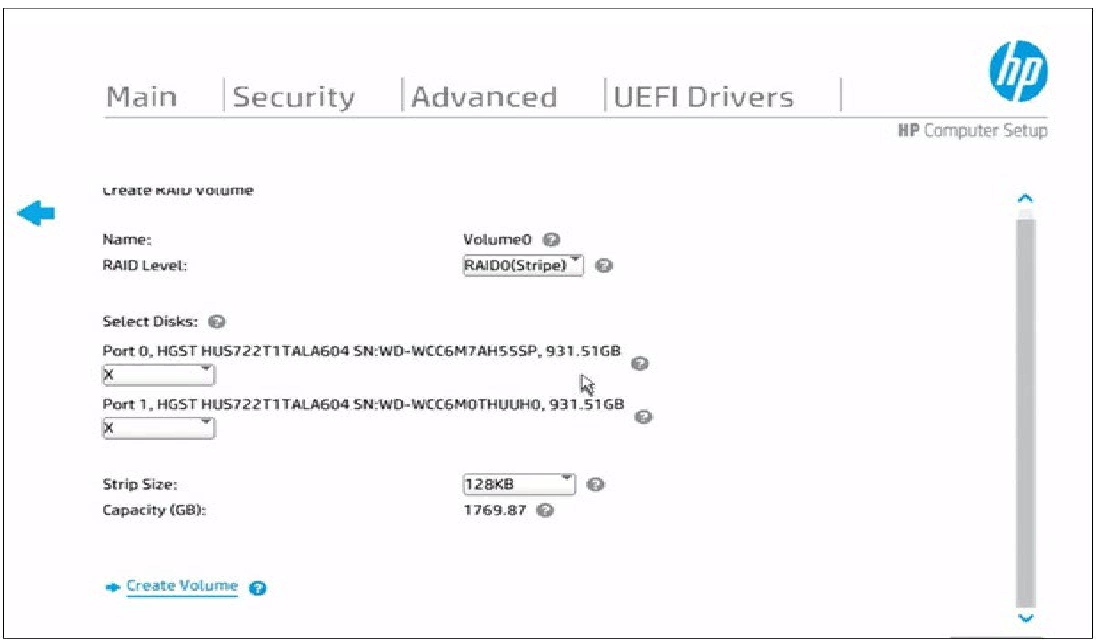
First, one can choose a volume name (or let it default), and the RAID mode.

Technical Whitepaper

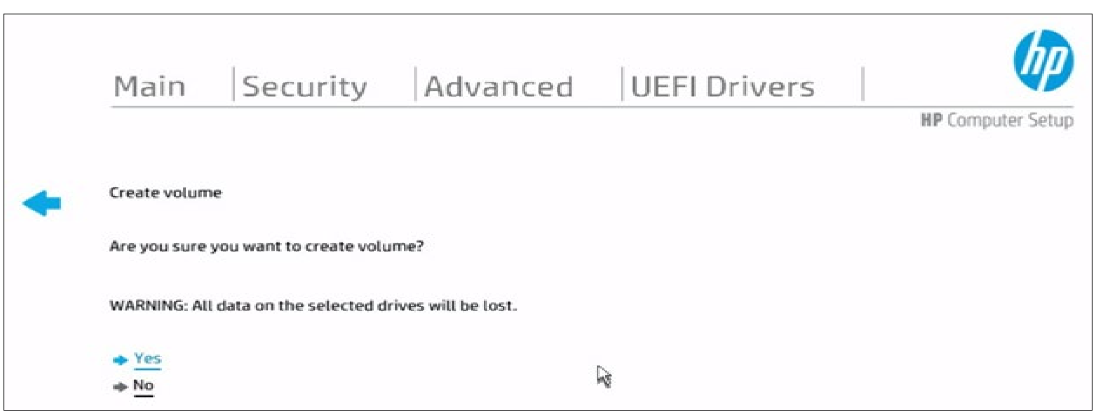
Contents & Navigation



Next, the drives that will be members of the array are chosen. VROC will assume you are using the full capacity of the drives unless you set the volume capacity:



When you choose **Create Volume**, you will get a confirmation screen to verify the action.



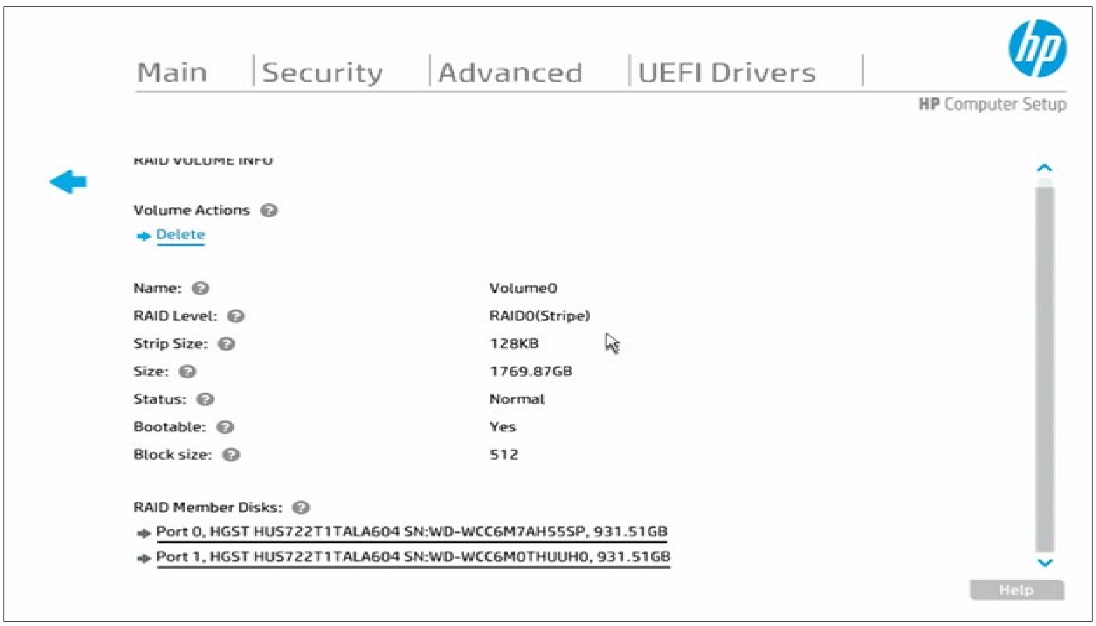
Technical Whitepaper

Contents & Navigation

After the volume is created, you'll return to the SATA "main page" and now your new volume is listed:

Deleting a SATA volume

By choosing a listed volume, the system will go to the information screen, however the only action that can be performed is deletion:



Again, there will be a confirmation screen before the volume is removed.
After confirmation, the interface will return to the "SATA main page".

NVMe Volume creation and deletion

If the **Intel® Virtual RAID on CPU** option is chosen from the top level **UEFI Drivers** page, you might see a page like this, if there are no NVMe volumes in existence. Since there may be more than one enabled VMD controller, the name for the link to "all" controllers makes sense.

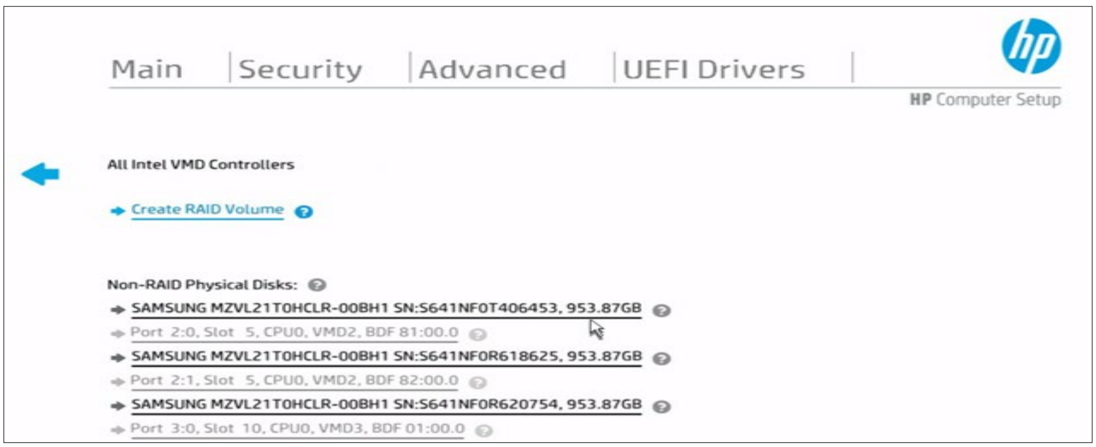
Technical
Whitepaper

Contents & Navigation

Creating an NVMe volume

Following the link to **All Intel® VMD Controllers** leads to the following page. All the non-member drives under enabled VMD controllers are shown, with their VMD numbers, PCIe "slot numbers" (which are assigned even for on-board sockets and connectors), and PCIe bus/device/function numbers. This is the "NVMe main page".

Choosing **Create RAID Volume** starts the process. Examples for Simple, Spanned, and Matrix volume creation will be shown in the following pages.



Simple Volume Creation

Choosing **Create RAID Volume** leads to this starting page.

In this example, a simple RAID 0 will be created on the two drives in VMD domain two. Note the option to create a "spanned" volume has not been selected. The drives that will be members are identified in the center of the page. The volume capacity could be modified or allowed to take the default of all the available space.

Technical Whitepaper

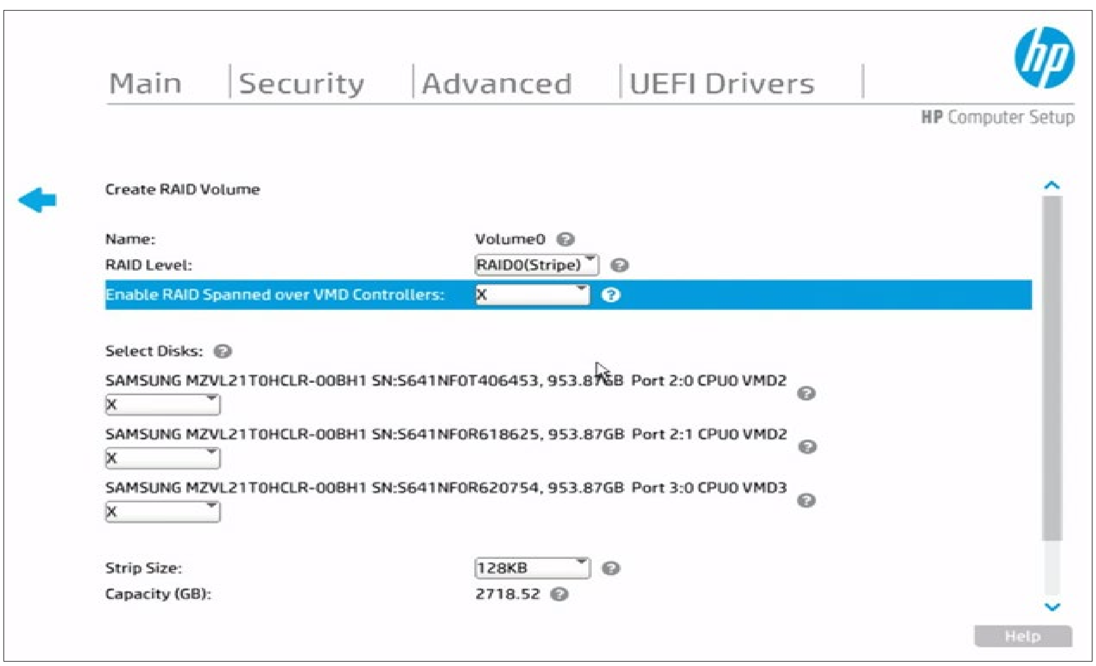
Contents & Navigation

Choosing **Create Volume** leads to the confirmation page:

After creation, the system returns to the “NVMe main page” and shows the created volume along with the remaining available drives:

Spanned Volume Creation

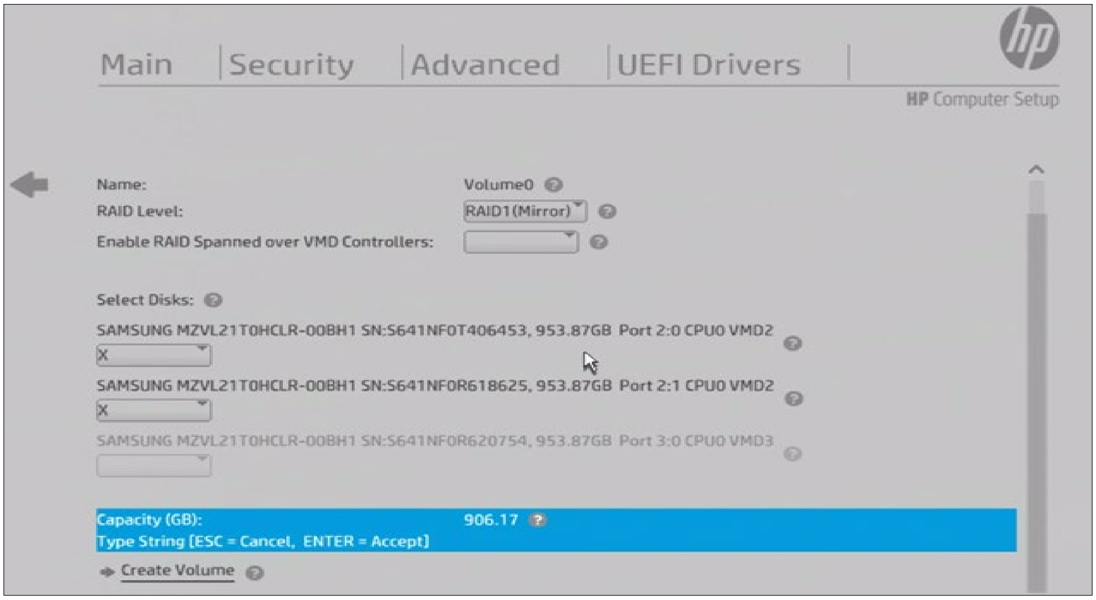
To create a volume that spans domains, start at the same place as for a simple volume and, Enable RAID Spanned over VMD Controllers. Now all the unused drives under VMD controllers are available.



Creation of a spanned volume posts a warning about usage, since such volumes are not supported as boot volumes:

Technical Whitepaper

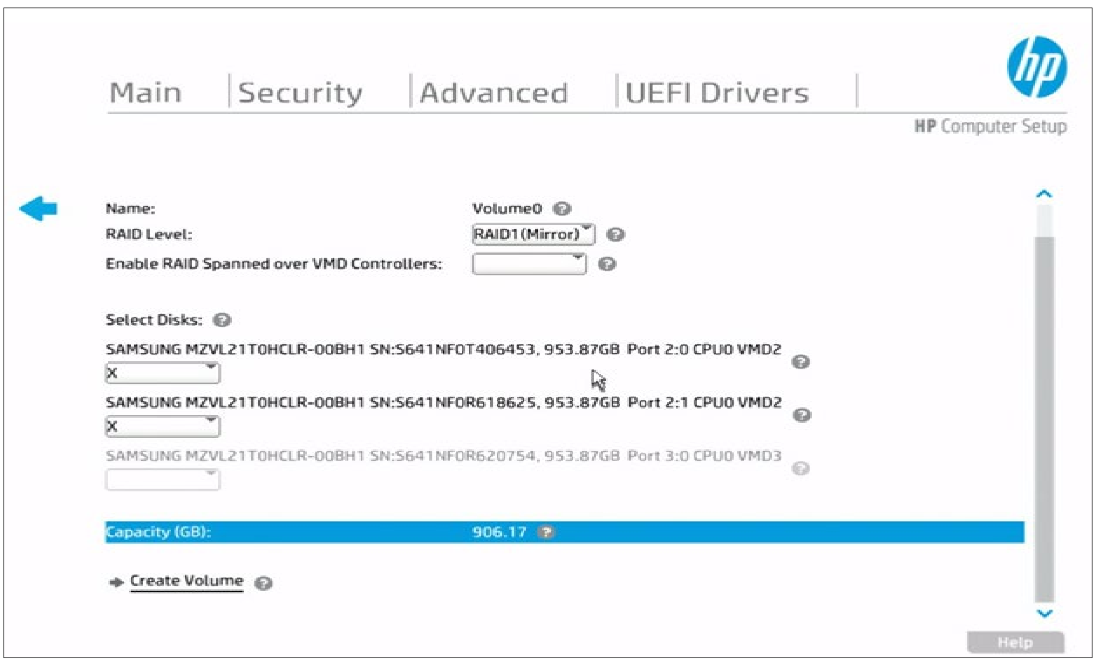
Contents & Navigation



Matrix Volume Creation

A "matrix" array hosts two RAID volumes rather than one. For there to be space to use for the second volume, the capacity of the first one needs to be set.

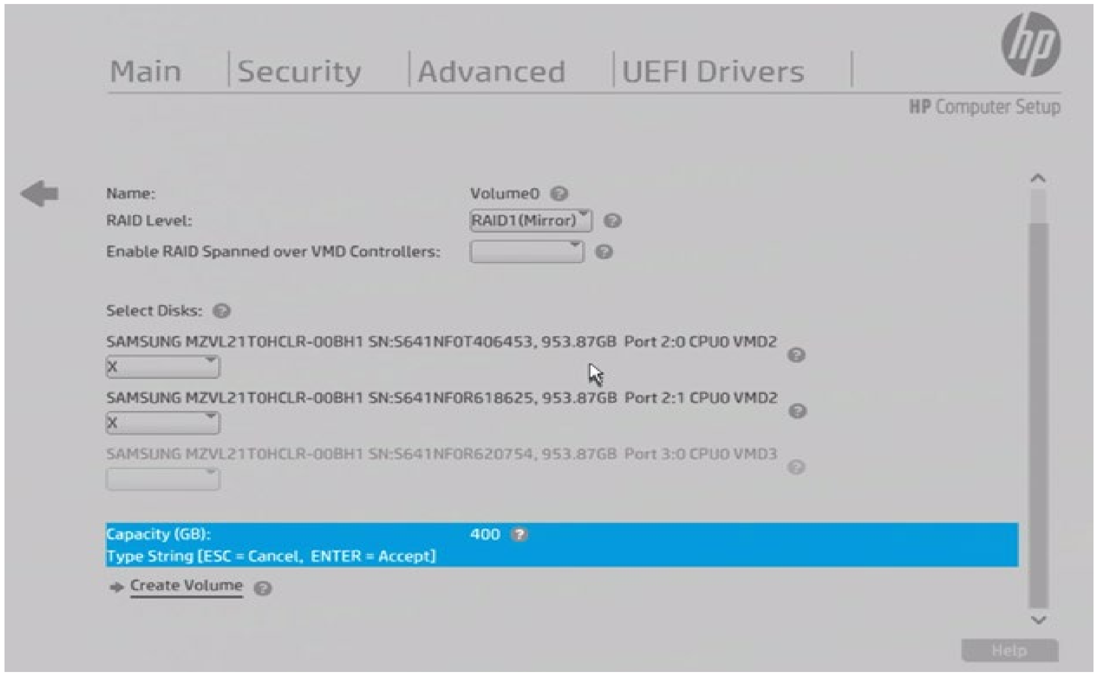
In this example, make the first volume a RAID 1 and set the volume to 400GB, as shown in the next three images.

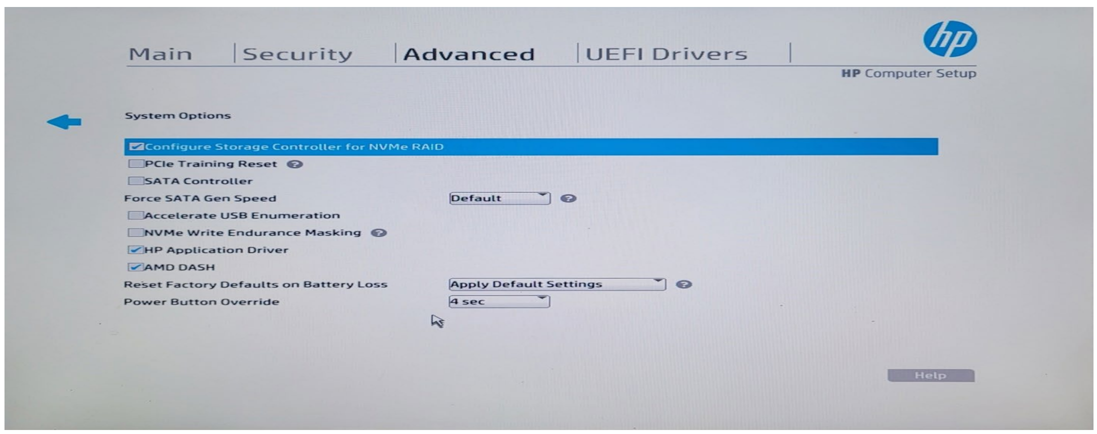


By choosing the Capacity line, you can interact with it to change the value. The gray background indicates the interface is waiting for the value change to be completed.

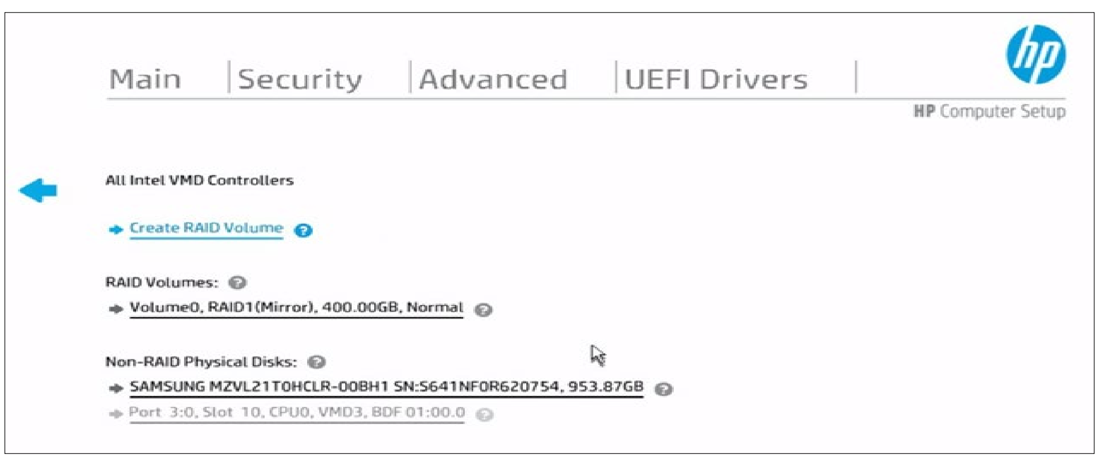
Technical Whitepaper

Contents & Navigation





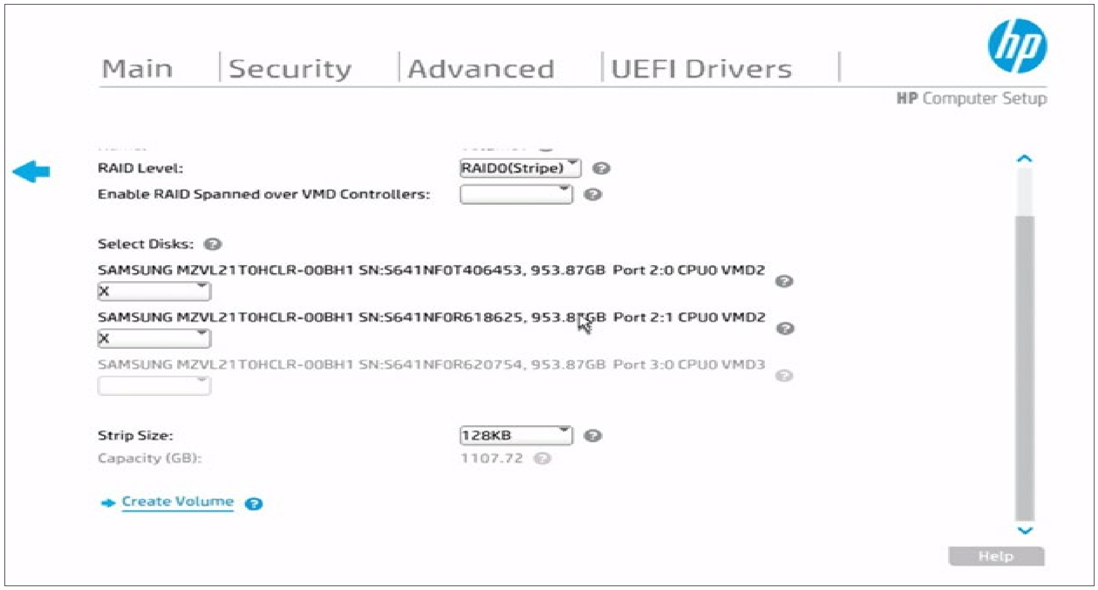
This image shows the "NVMe main page" after the first volume has been created:



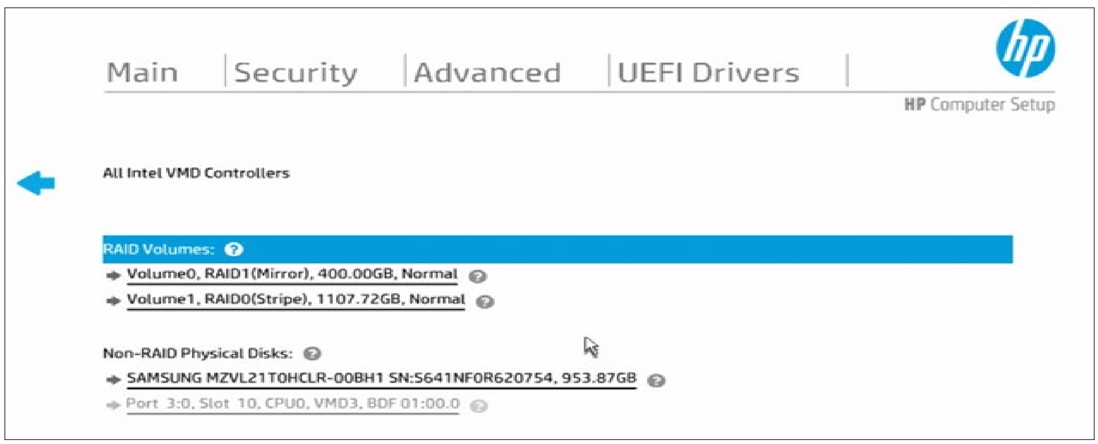
To create the second volume, one re-enters the **Create RAID Volume** dialog, and choose the same drives again. A RAID 0 volume is being created as the second.
VROC automatically uses the rest of the available space in the array.

Technical Whitepaper

Contents & Navigation

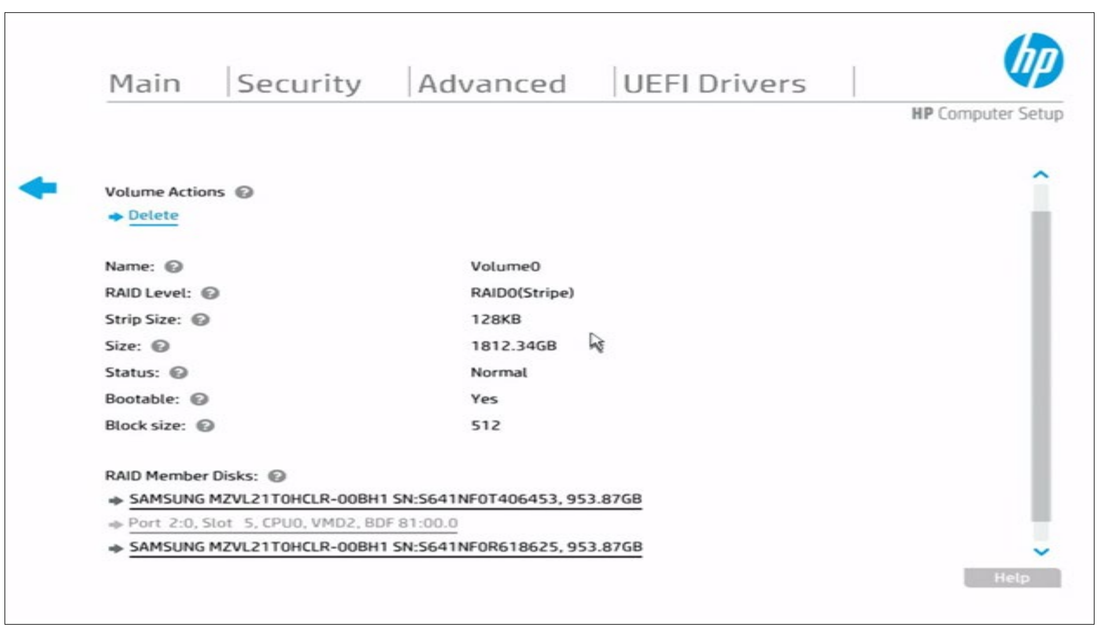


Here's the “NVMe main page” again after both arrays have been created:



Deleting an NVMe volume

By choosing a particular volume listed on the main page, an informative page is shown with the **Delete** action available:



Contents & Navigation

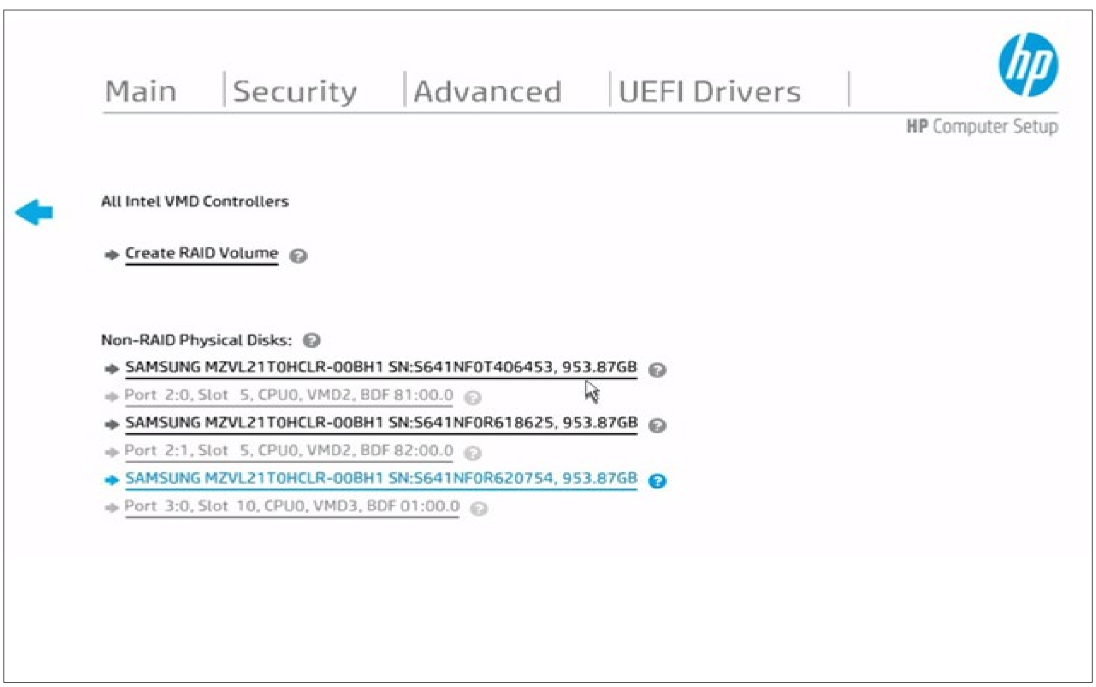
Starting a deletion leads to a confirmation screen. After confirmation, the volume will no longer appear on the "NVMe main page".

Drive Information

By choosing one of the unused drives on the "NVMe main page" or choosing a volume and then one of the member drives, the system will show information about the drive model number, serial number, capacity, and so on.

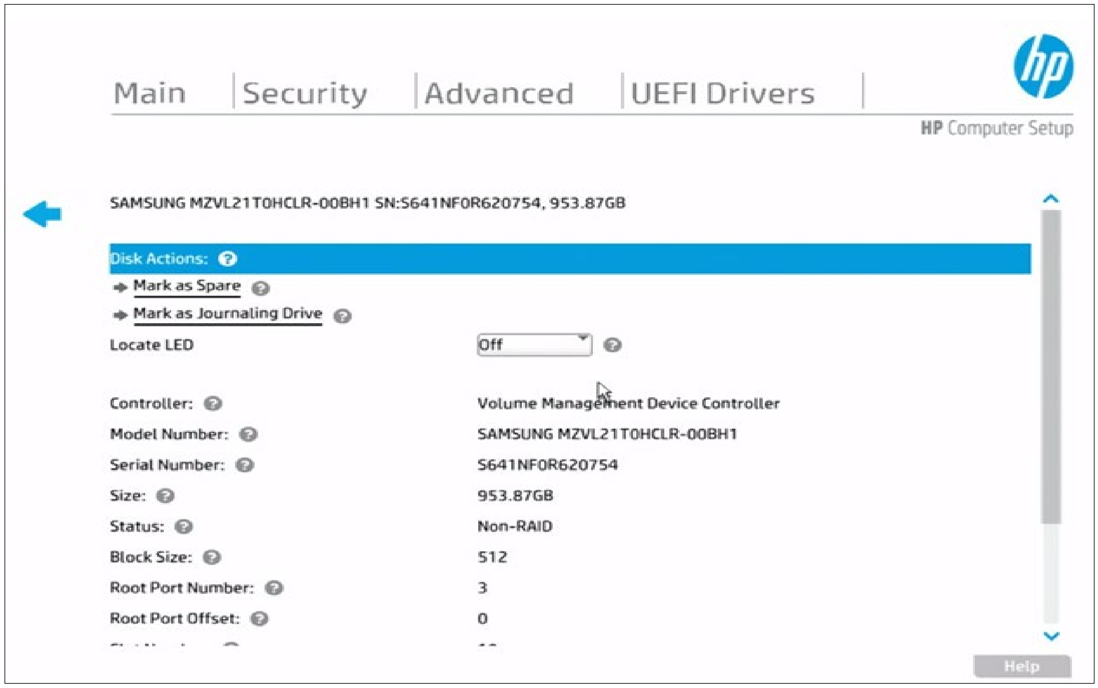
- In the case of an NVMe device, information about residence in a VMD domain is shown.
- For a SATA drive, the controller port number is visible.
- As you can see, special designation is possible as a "hot spare" drive, or as a journalling drive for RAID 5 write hole closure (only available with the Premium upgrade module).
- Some server backplane features in VROC, include LED control, are not supported on HP workstations.

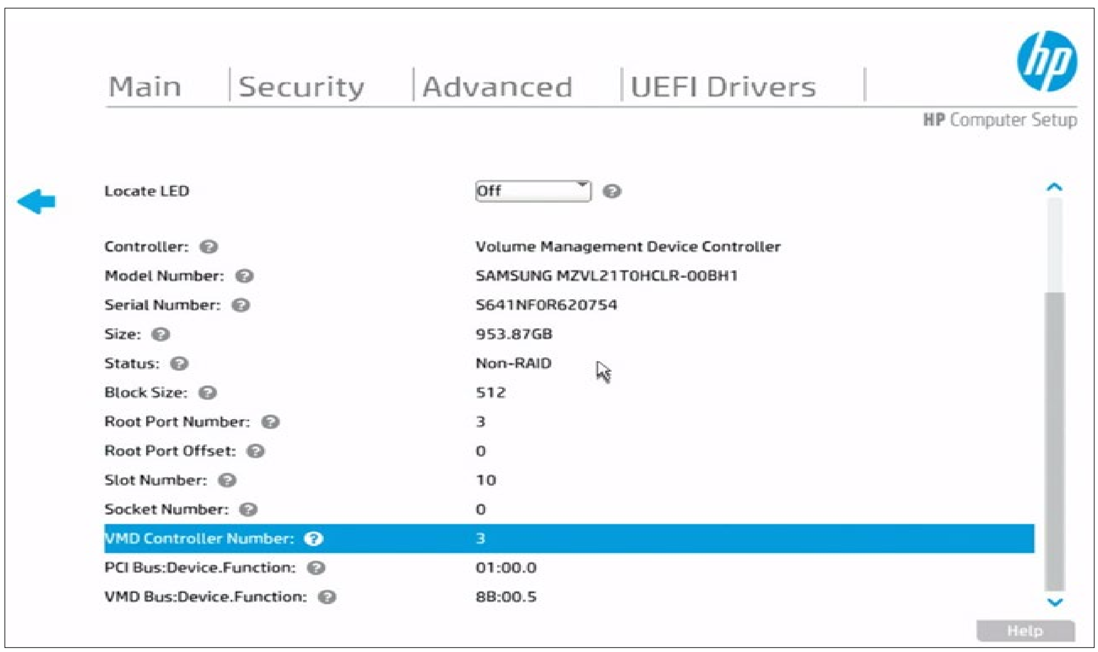
The drive information is shown in the images below:



Technical Whitepaper

Contents & Navigation



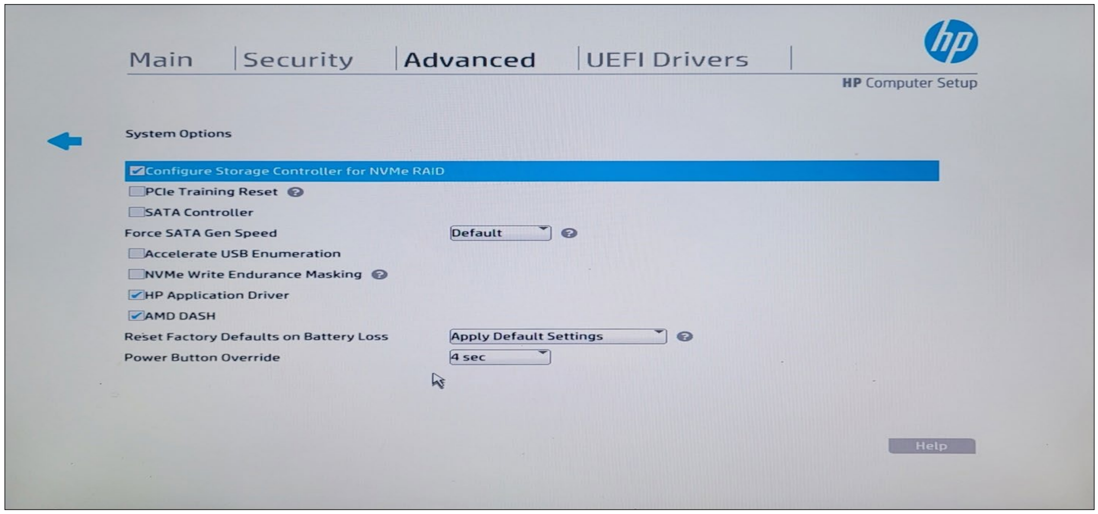


Technical Whitepaper

Contents & Navigation

Volume Status

Volumes can have different status values, as documented in the Intel® User Guide. You may have noticed in earlier images of the "main pages", that existing volumes are tagged with a status. Here's an example from the Matrix setup with two volumes both in Normal status.



Other values for status (documented more fully in the Intel® User Guide section "Drive States and Recovery") are shown below.

A very important thing to understand first: While the Human Interface Infrastructure (HII) can show you the current volume status value, no progress is made in initialization or rebuilding unless the OS is booted. All that work to move forward is done by the OS drivers. Don't leave the system sitting in BIOS if you want a rebuild to complete.

- Initializing: VROC is doing the initial part of a migration to a RAID volume, usually from a single source drive to the members of an array. Migrations from some RAID modes to others are also possible.
- Degraded: A redundant RAID volume is compromised, so data protection is currently relying on the redundant storage.
  - You will not see this status for RAID 0 since it has no redundancy. A problem in RAID 0 goes straight to Failed.
  - In the case of a redundant volume that is currently Degraded, and other non-member drives are available, then when you choose the volume from the "home page", you may see a **Rebuild** option in addition to **Delete**.
  - If you choose **Rebuild**, you will get to choose, from the available non-member drives, which one to bring into the array. As usual there will be a confirmation check, and then the home page will show the volume in Rebuilding status.
  - A transition to a rebuild is also possible in the OS.
- Rebuilding: A RAID volume that is currently not redundant is in the process of restoration.
- Failed: This means one or more members are not visible in the array. The critical number of members depends on the RAID mode. It does not necessarily mean that data is lost.
  - Missing members could be due to drives having been removed or the locations disabled. Adding them back in may restore the volume. That's true even for RAID 0.
  - On the other hand, if too many drives failed due to malfunction (writes not completed, SMART errors, etc.) then data has probably been lost. There's only one layer of redundancy in VROC volumes; that is, one mirror or one parity block per stripe.
  - In the Windows GUI or CLI, it is possible to set a drive and an array that includes it to "Normal" if the status is due to an improper Windows shutdown or drives have been brought back and you believe everything is intact. This does not magically bring back lost data.

Technical Whitepaper

Contents & Navigation

Configuring AMD™ RAIDXpert2 in BIOS

This chapter illustrates some settings in the BIOS F10 Setup interface that enable AMD™ RAIDXpert2 functionality, plus management of arrays and volumes in the AMD™ RAIDXpert2 Human Interface Infrastructure (HII). Please consult this chapter in preference to the AMD™ RAIDXpert2 User Guide, which illustrates the interfaces using a completely different system BIOS style.

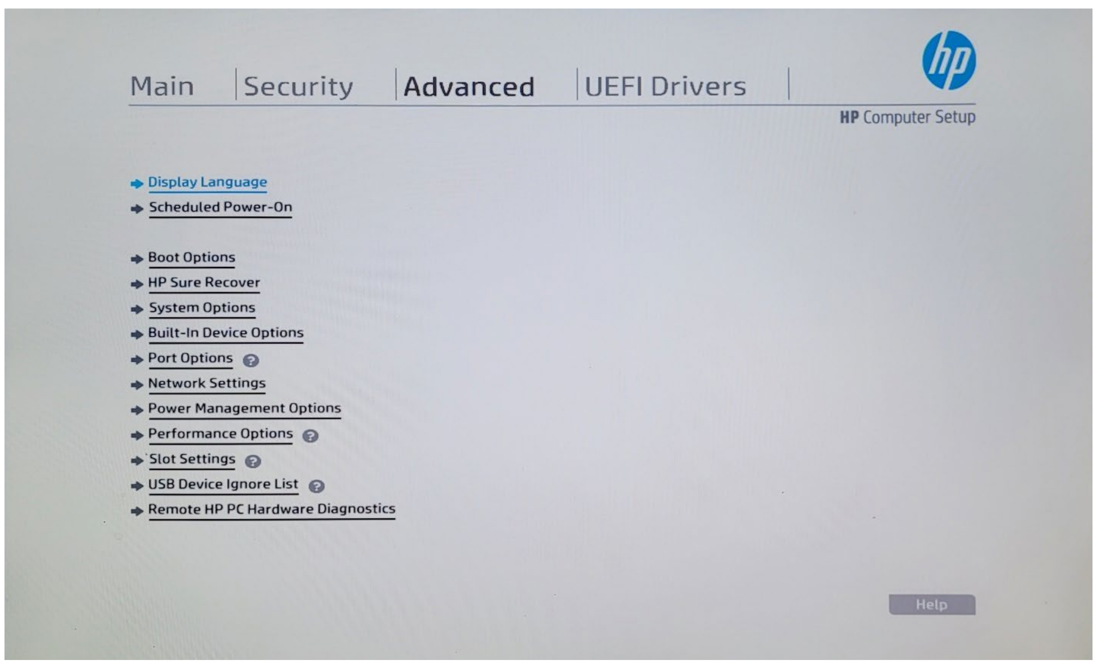
Controller Enablement

It is important to consider the following when setting up AMD™ RAIDXpert2.

AMD™ RAIDXpert2 enables NVMe RAID across all NVMe slots. This is unlike VROC, where RAID can be enabled or disabled on a per-slot basis. NVMe storage devices that were configured with NVMe RAID disabled, such as an NVMe drive with an OS installed on it, cannot be used once NVMe RAID is enabled. Such disks will be marked as legacy and must be formatted before they can be used with NVMe RAID enabled; therefore, NVMe RAID should be enabled before OS installation to a single disk if:

- The boot disk will later be migrated to a boot RAID array. In this case, the boot disk needs to be configured with a “RAIDable” array as described in Windows must then be installed as described in Installing Windows to a RAID Boot Volume.
- An additional NVMe RAID array (boot or data) will later be installed alongside the boot disk.

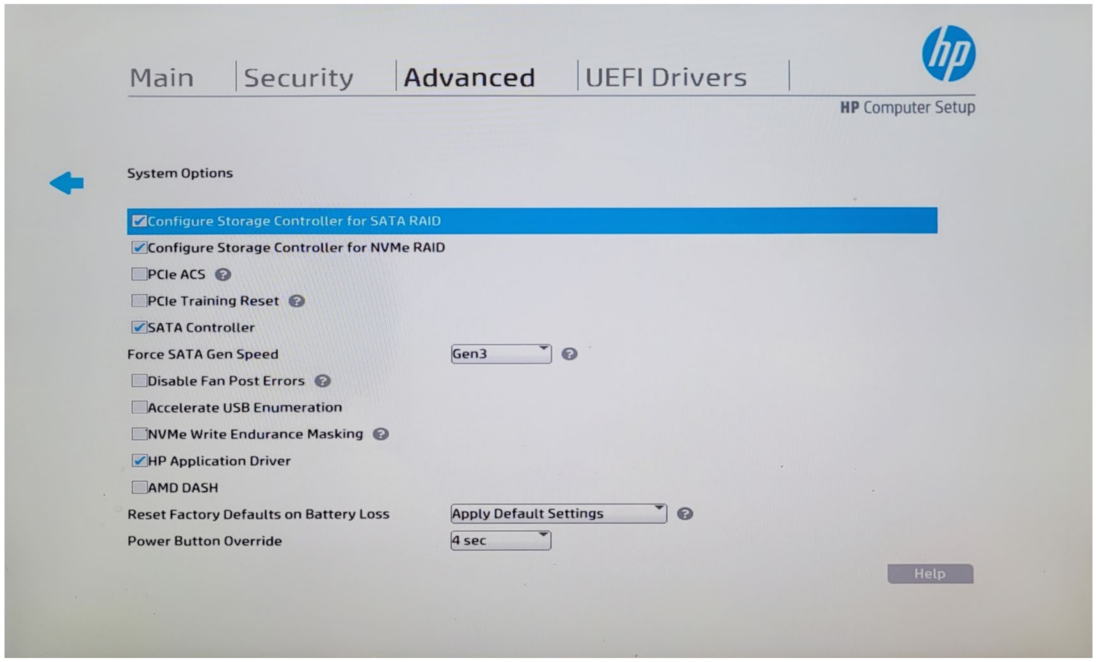
The NVMe and SATA RAID controllers are enabled or disabled through subordinate pages of the Advanced section of the F10 Setup interface. Here’s the top-level view of the Advanced section. (This might vary by platform.).



In the System Options menu, NVMe RAID can be enabled by checking the box next to “Configure Storage Controller for NVMe RAID.” Similarly, SATA RAID can be enabled by checking the box next to “Configure Storage Controller for SATA RAID”.

Technical Whitepaper

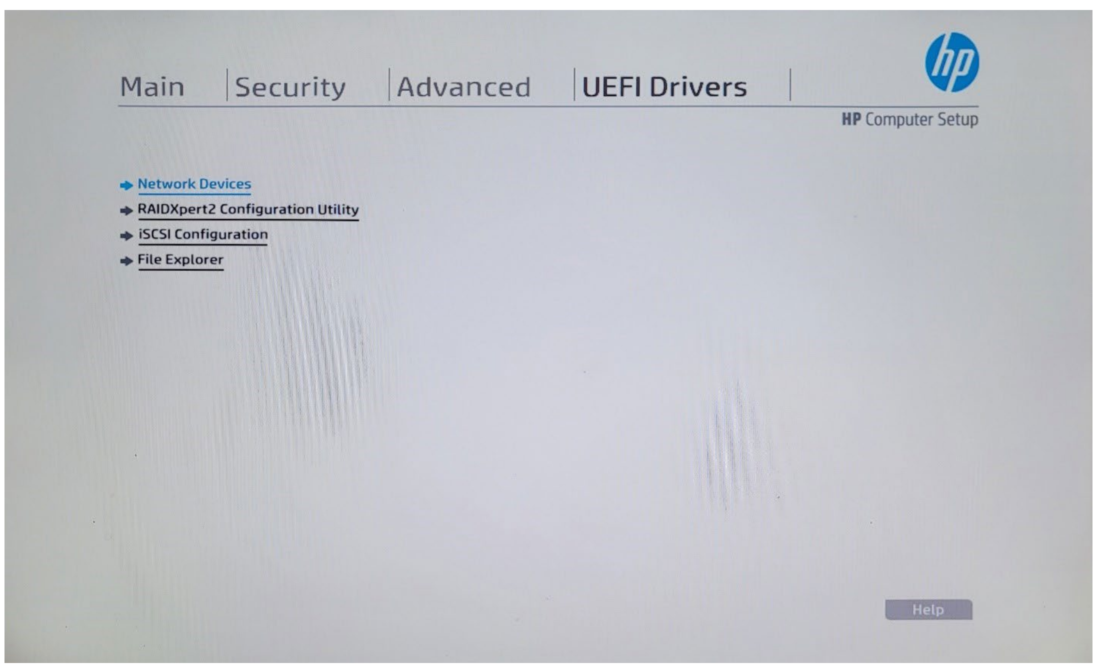
Contents & Navigation



Unlike the VROC solution, there isn't a per-slot enablement necessary for NVMe RAID to be enabled. After making changes in F10 setup, it is necessary to save, exit, and reboot back into F10 to continue RAID Configuration.

UEFI Drivers Section: AMD™ RAIDXpert2 Human Interface Infrastructure

Here's the view at the top level of the **UEFI Drivers** section of the F10 Setup interface.The exact set of choices may vary. Some you might see are not AMD™ RAIDXpert2-related. RAID configuration utilities are available in the AMD™ RAIDXpert2 **Configuration Utility** menu.

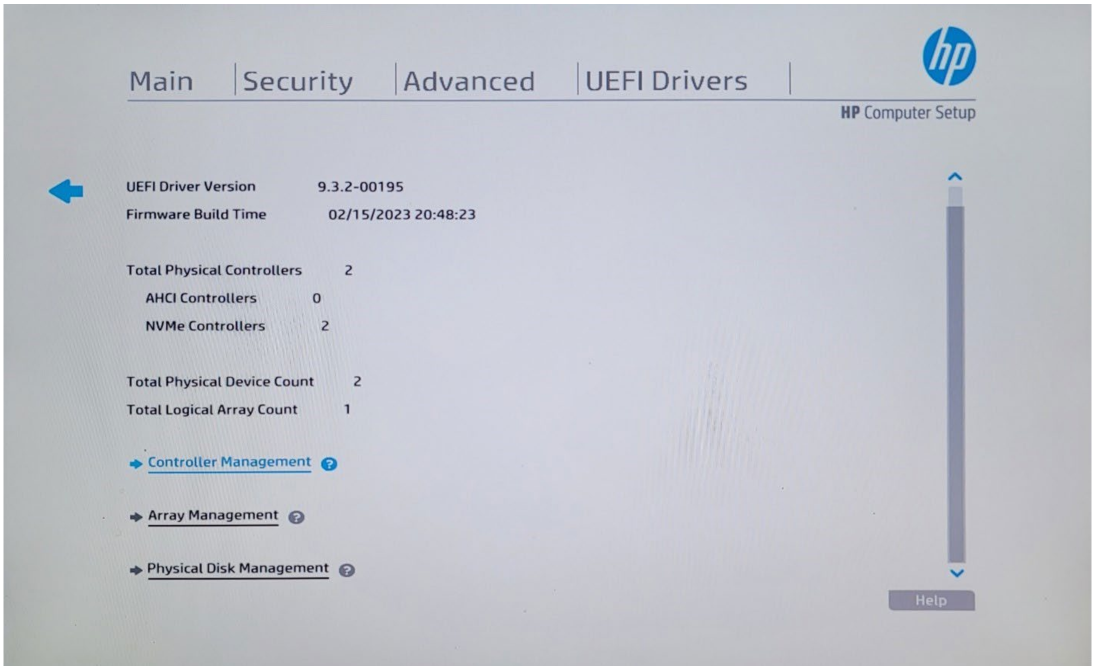


You will be presented with the top-level interface for AMD™ RAIDXpert2 configuration. There are options for the following sub-menus:

- Controller Management.
- **Array Management** for the creation and configuration or RAID arrays.
- **Physical Disk Management** for operations on individual storage disks. You may need to scroll down to see this option.

Technical Whitepaper

Contents & Navigation

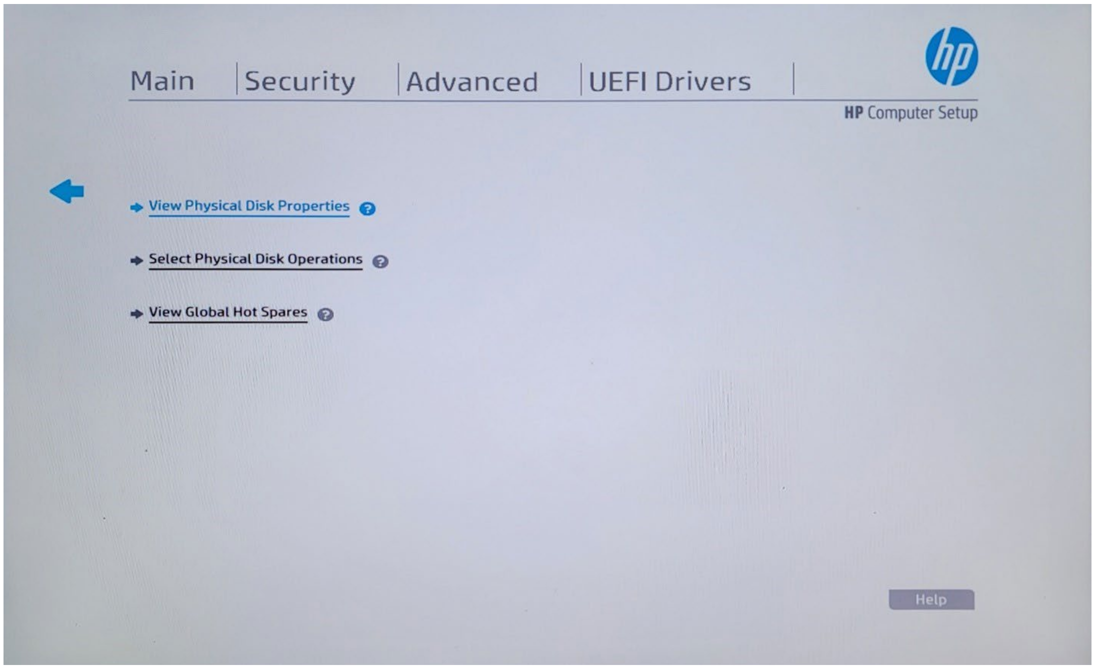


Physical Disk Initialization

It is necessary to initialize disks through the AMD™ RAIDXpert2 interface before adding those disks to a RAID array. It may be possible to create an array without first initializing the disks, however doing so may lead to issues further down the line. Please note that initializing disks in this way will erase all existing data on the disk.

Some disks may have legacy non-raid arrays already. These arrays must be deleted before proceeding with disk initialization. The steps for deleting an array are presented in the section RAID Volume Creation and Deletion below.

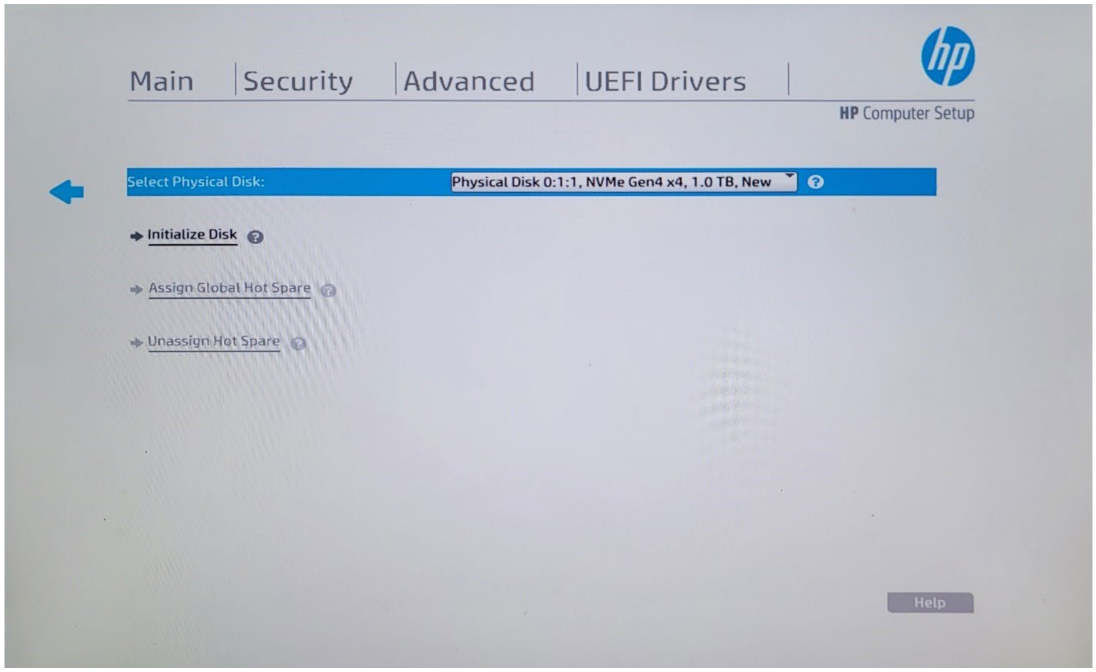
Navigate to **Physical Disk Management** and then to **Select Physical Disk Operations**



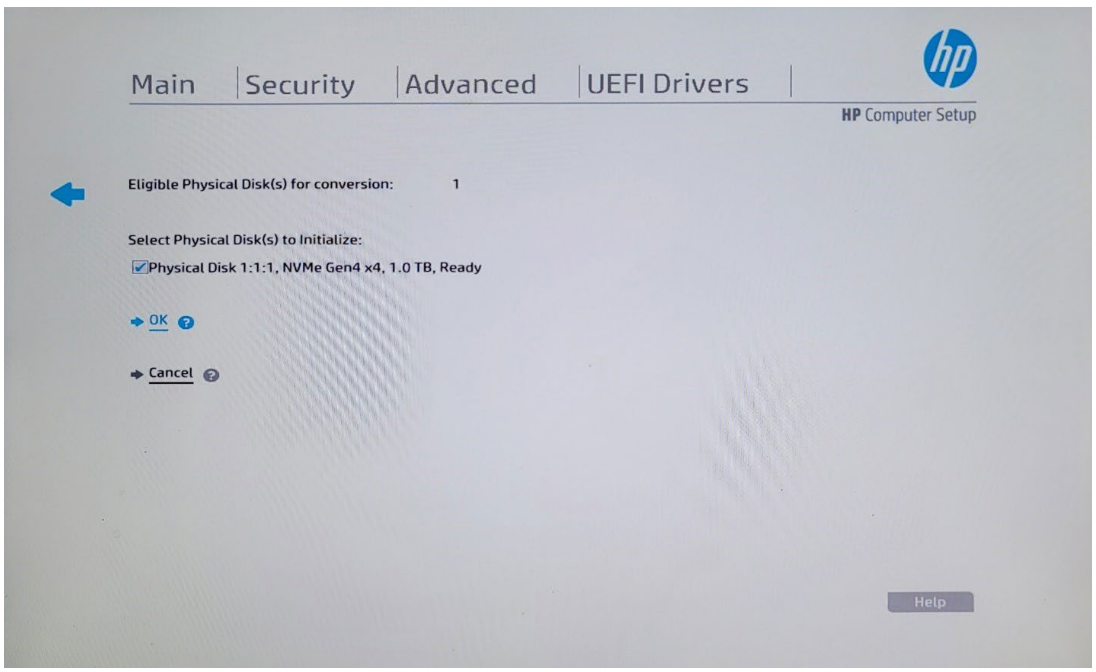
You will be presented with a drop-down menu for the selection of a physical disk. It is not necessary to select a disk here as you will be asked to select disks on the next menu. Instead, select Initialize disk.

Technical Whitepaper

Contents & Navigation



You will be presented with a list of disks eligible for conversion to RAID Arrays. Check the box next to each disk to be initialized, then press OK.



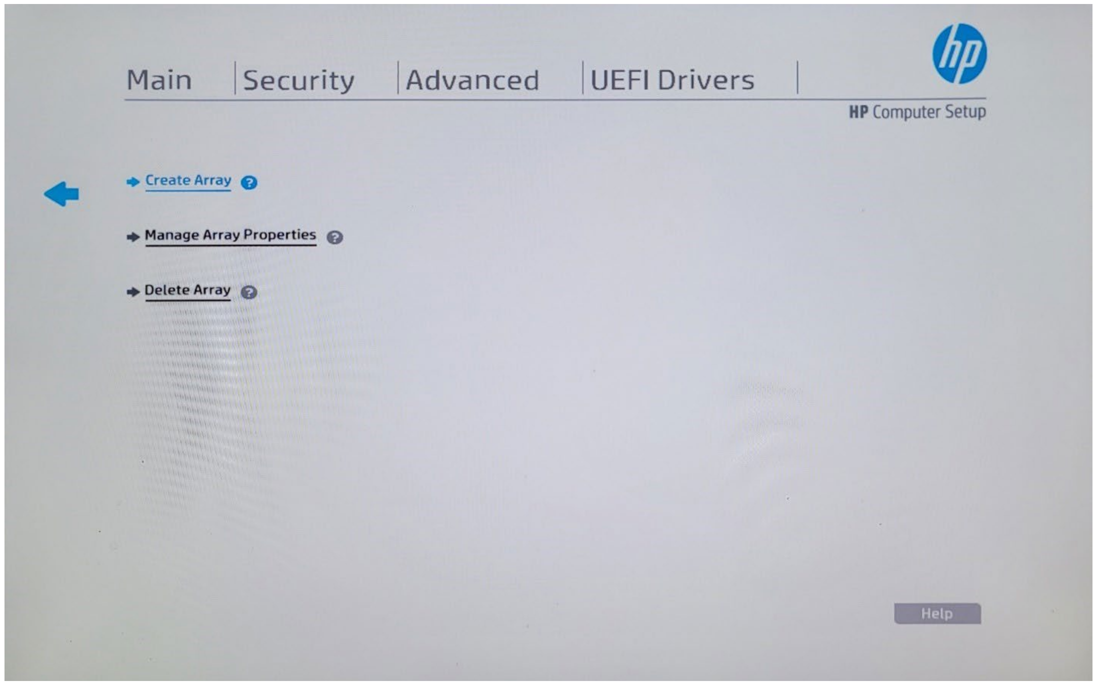
Once the disks are initialized, they are ready to be added to a RAID Array.

RAID Volume Creation and Deletion

From the AMD™ RAIDXpert2 Configuration Utility menu, select Array Management. Here you will be presented with the options to Create Arrays and to Delete Arrays.

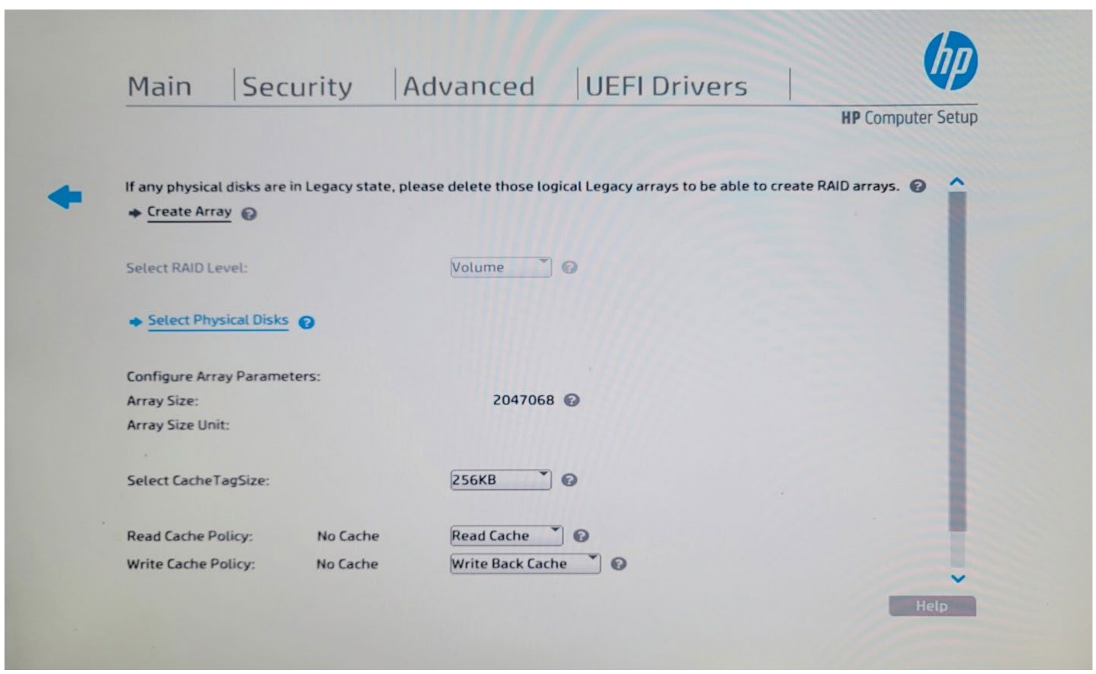
Technical Whitepaper

Contents & Navigation



Creating an Array

Please note that it is necessary to initialize all disks that will be added to an array before array creation. The steps for initializing disks are above in the section entitled "Physical Disk Initialization".
Select **Create Array**. You will be presented with an interface to select the desired RAID level, the target physical disks, and desired Cache settings. Once all these options have been configured, select **Create Array** to finalize array creation.

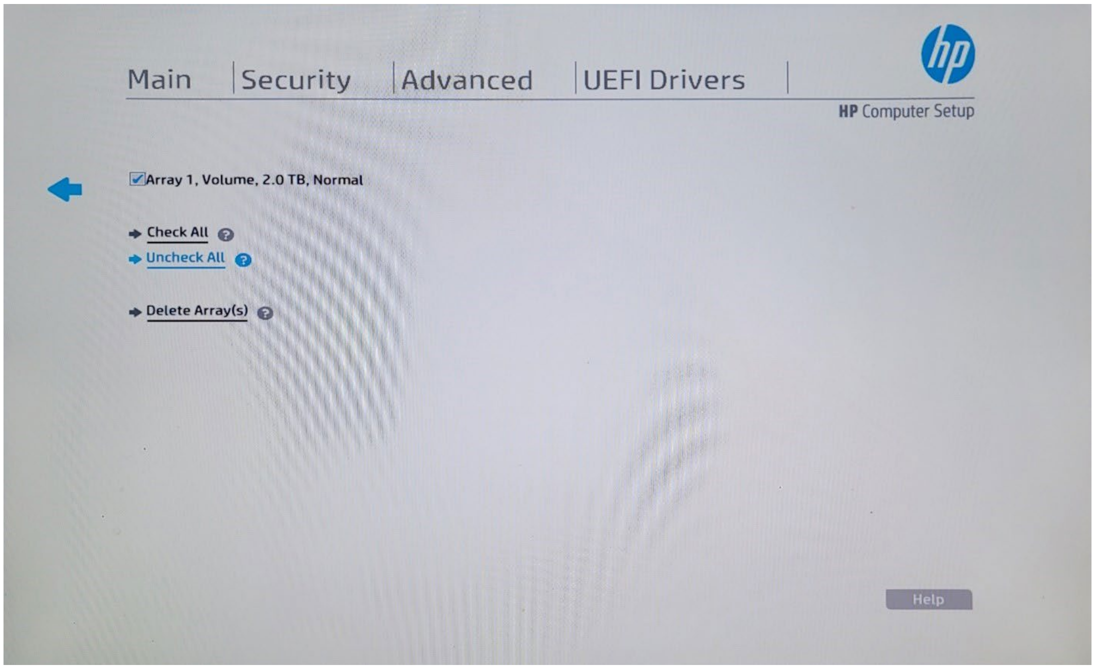


Deleting an Array

From the Array Management menu, select Delete Array. You will be presented with a list of arrays present on the system. Check the box next to arrays to be delete, then select Delete Array(s).

Technical Whitepaper

Contents & Navigation



Installing Windows to a RAID Boot Volume

The Intel® User Guide covers the basics of manually installing a Windows OS to an Intel® VROC RAID volume that has been pre-created in the Human Interface Infrastructure(HII). The AMD™ RAIDXpert2 User Guide covers the same details for the AMD™ RAIDXpert2 solution. This section provides a few notes on the process.

The important fact is that the right storage driver needs to be available during the OS installation. It becomes the boot storage driver in the finished image. The VROC or AMD™ RAIDXpert2 drivers are absolutely required for deployment to either an SATA or NVMe RAID volume. The Windows in-box SATA driver seems able to deal with the primary SATA controller in RAID mode, but you may choose to use the VROC primary SATA driver anyway. (See a note below concerning installation of this driver.)

In the Intel® User Guide, the tables early in the chapter "Supported Platforms and Capabilities" identifies which driver is needed for each platform and drive type. The HP web package containing VROC bits (SoftPaq) includes a folder (VROC_xxxxxx_F6-Drivers) containing the VROC device drivers, that you can copy to a USB drive for use during the installation.

Similarly, Chapter 4.4 in the AMD™ RAIDXpert2 highlights the drivers needed for OS installation on the AMD™ platform. The HP web package containing AMD™ RAIDXpert2 bits (SoftPaq) includes a folder (AMD_RAID_Drivers) contains the AMD™ RAIDXpert2 device drivers that you can copyt to a USB drive for use during installation.

The reminder in the Intel® User Guide to try Refresh on the "Where do you want to install Windows?" page if you do not see your target drives, after loading the right driver, is important to remember.

Alternatives

There is an alternative method to get to a boot RAID: One can install to a single drive (already under a controller in the correct mode) and then install the VROC application software and create the volume and migrate to it in the GUI. This process isn't as fast since the migration can take quite a while. Drive capacity and type are important factors of course; large SATA HDDs take much longer to migrate than small NVMe drives.

If you are doing an "enterprise" deployment of a Windows image, it is recommended that you use driver injection to add the needed VROC drivers. Learn about the Microsoft Deployment Toolkit (MDT) to understand how.

Technical Whitepaper

Contents & Navigation

Special Note Regarding Installation of Windows 11

As of this writing, there is a timeout that can be encountered when introducing the VROC primary SATA driver (iaStorE.sys) during a manual OS installation. The problem occurs as the VROC driver is substituted for the in-box primary SATA driver. It can cause the Windows installer to fail with an error.

If you are pre-injecting the driver into a Windows installer image, you will not encounter the timeout, because you've already replaced the in-box driver.

Workarounds:

These tricks basically defer the timeout problem until the OS is installed and booted. See the next chapter.

- If you are not installing the OS to a SATA RAID under the primary controller, just leave the iaStorE.sys driver out of the set you are loading during the installation process.
- If you are installing to a primary SATA RAID, you can still leave the VROC driver out of load list, however with some risk. The in-box driver seems to work, even with a SATA RAID 5, however this is not a supported method. As soon as you are booted up into the installed OS, you need to install the VROC SATA driver.
- If you really don't need the primary SATA driver anyway, you can disable the SATA controller in the BIOS (see the Advanced->System Options page in F10 Setup). If the controller is not visible, the driver need not apply.

Installing RAID Software in Windows

Intel® VROC Software in Windows

Installing the Intel® VROC GUI and Monitor Task

The Intel® User Guide includes screenshots from the installer program (SetupVROC.exe) in the chapter entitled "Installing Intel® VROC GUI".

Please consider the need for the prerequisite packages listed in the subsection "Installing Required Microsoft Components for VROC GUI". The installation of the GUI is simpler if you install those small packages first. They are easy to find on Microsoft's site. As noted, if you have a network connection, the installer will attempt to download and install them for you. If you don't have them present when you first try to start the GUI, you'll get prompts then.

The GUI installer also sets up a task that runs whenever a user is logged in, to monitor RAID health and provide notifications of status changes, if those are set up via the GUI. You can see this task running as the "tray icon". You can right click that icon to start the GUI via "Open Application".

If you want to automate the application installation, you can run the installer with -? to see the options.

An important thing to know about the installer: It only adds the drivers for controllers it can see. If you are on a system with no sSATA controller, it will never put that driver into the Windows image. More importantly, if you don't have a VMD controller enabled, it will not install that driver either. You'll have to come back and rerun it later if you change the controller landscape. (or you can use Device Manager, see below.)

Special Note regarding Windows 11

As of this writing, the same timeout mentioned above for a manual installation of Windows, can also occur when running the GUI installer program. The problem occurs as the VROC driver is substituted for the in-box primary SATA driver. If a prior version of the VROC SATA driver is already on the system, the timeout does not occur.

The timeout manifests this way: The installer seems to be almost done, however continues to animate its activity bar for a very long time. This timeout does not occur in every execution of the installer; sometimes it finishes gracefully. When it does occur, you could wait a very long time before the installer will eventually say it failed, however the SATA driver is already in place by now, so rather than waiting for the failure message, you can force a graceful shutdown of Windows. You may have to tell the system to "restart" if the SetupVROC installer is lingering. When your system boots next, it may restart the installer, however it will complete very quickly.

Technical Whitepaper

Contents & Navigation

Updating Drivers in Device Manager

The HP web package containing VROC software (SoftPaq) includes a folder (VROC_xxxxxx_F6-Drivers) of the VROC device drivers. If you choose to update a driver using the Windows Device Manager method (Storage controllers->Properties->Driver interface), you can search this folder on a USB key or on your system storage to find a driver to load.

The timeout described above can also be seen if you use Device Manager to update from the Windows in-box driver to the VROC iaStorE.sys driver. When the timeout occurs, you'll see an error message, however the VROC driver is already in place by that point. (This issue might be fixed in a future Windows update or release.)

Adding the Intel® VROC Command Line Interface

As mentioned before, the GUI installer does not add the CLI to the system. The HP SoftPaq includes the CLI software, and you can copy it to a useful location on your system. There is a version dependency between the CLI program and the VROC UEFI support in the system BIOS, so the 8.x version will not operate correctly on older platforms.

See below for some basic examples of CLI commands. The "specification" document for the CLI options is part of the SoftPaq.

AMD™ RAIDXpert2 Software in Windows

The AMD™ RAIDXpert2 software package on the HP website (SoftPaq) contains a folder (windows_app_(version number) that contains the executable for installing the AMD™ RAIDXpert2 GUI Management suite. Simply run the setup application and the GUI will be installed to your system. Once installation is complete, a AMD™ RAIDXpert2 shortcut and the AMD™ RAIDXpert2 User Guide will be added to the desktop.

Configuring RAID using the Windows Graphical User Interface (GUI)

Configuring RAID using the Intel® VROC interface

The same chapter in the Intel® User Guide that describes the installer, goes on to cover the design of the GUI in some detail. The style and navigation are different than that used for older releases up through 7.x, however there are some new capabilities, especially in managing drive information.

The subsequent chapter gives several examples of how to create and delete RAID volumes in the GUI. You might notice you can name the array in the GUI. The BIOS Human Interface Infrastructure (HII) does not support that.

Chapter 9 covers the Windows GUI support for an NVMe RAID "Trial Period", where no VROC upgrade key is needed on the system board. Arrays and volumes created this way are not visible at all in the BIOS UEFI Driver interface. Be careful here: in the BIOS the drives are shown as non-members so you might be tempted to use them to create volumes, however they are already so employed.

The trial period expires after 90 days. The volume(s) become inaccessible until an upgrade module is added to the system.

Configuring RAID using the AMD™ RAIDXpert2 Interface

Chapter 6 of the AMD™ RAIDXpert2 User Guide describes how to use the AMD™ RAIDXpert2 GUI interfeace for the management of RAID Arrays.

- Section 6.2 provides a general overview of the software
- Section 6.3 describes how AMD™ RAIDXpert2 can be used for disk management, including scanning disks, initializing disks, and more.
- Section 6.4 describes how AMD™ RAIDXpert2 can be used for array management, including creating, transforming, and deleting arrays.

Technical Whitepaper

Contents & Navigation

Configuring Intel® VROC using the Windows Command Line Interface (CLI)

The VROC Command Line Interface (CLI) provides for RAID creation and management from a Windows Administrator Command Prompt or Administrative PowerShell window.

As mentioned earlier, the CLI is not installed by the Windows GUI installer program, however it is available from the HP web SoftPaq. The executable name is IntelVROCCLI.exe.

Failure to run command line tools with administrative privileges may result in data not being returned, or an error message.

You can capture the built-in descriptions of the CLI options by running the command with the `--help` option. Output can be redirected to a text file for future reference. A similar description of the command options is available in the **RSTe_VROC_CLI_ Specifications_2.0.pdf** file that is also part of the HP SoftPaq content.

Array and Volume Creation with the VROC CLI

There are three steps in creating arrays using the CLI:

1. Collect IDs of devices to be configured as members.
2. Design the command that will create the RAID.
3. Execute the command (in the command prompt shell or PowerShell, with administrator privileges).

Gathering information about the drives

The -I (or `--information`) option queries the system. The following command will show drives, controllers, software and firmware versions, and other relevant data.

```
Intel®VROCCLI --information
```

Here's an example output from a system with SATA and NVMe devices attached:

```
--CONTROLLER INFORMATION--

Name:                 Intel® C600+/C220+ series chipset SATA RAID Controller
Type:                 AHCI
Supported RAID:       0,1,5,10
Max Disks/Array:      8
HW Information:
Vendor ID:            0x8086
Device ID:            0x2826
HW Revision:          17
Read Patrol:          Disabled
Rebuild On Hot Insert: Disabled

--END DEVICE INFORMATION--
```

```
ID:                     0-0-0-0
Type:                   Disk
Disk Type:              SATA
State:                  Normal
Size:                   931.51 GB
System Disk:            False
Usage:                  Pass through
Serial Number:          WD-WCC6M7AH55SP
Model:                  HGST HUS722T1TALA604
Logical sector size:    512 B

ID:                     0-1-0-0
Type:                   Disk
Disk Type:              SATA
State:                  Normal
Size:                   931.51 GB
System Disk:            False
Usage:                  Pass through
Serial Number:          WD-WCC6M0THUUH0
Model:                  HGST HUS722T1TALA604
Logical sector size:    512 B
ID:                     0-4-0-0
Type:                   ATAPI
Model:                  DVDRW  GUD1N
Logical sector size:    Unknown

--CONTROLLER INFORMATION--

Name:                   ntel(R) VROC (Premium)
Type:                   VMD
Supported RAID:         0,1,5,10
Max Disks/Array:        96
HW Information:
Vendor ID:              0x8086
Device ID:              0x28c0
HW Revision:            32
Read Patrol:            Disabled
Rebuild On Hot Insert:  Disabled
Upgrade key version:    Premium

--ARRAY INFORMATION--
```

Technical Whitepaper

Contents & Navigation


```
Name:                NVMe*_Array_0003
Size:                953.88 GB
Free:                47.70 GB
Num Disks:           2
Num Vols:            1
Write Cache:         On

--ARRAY INFORMATION--

Name:                NVMe*_Array_0000
Size:                1907.74 GB
Free:                95.40 GB
Num Disks:           2
Num Vols:            1
Write Cache:         On

--VOLUME INFORMATION--

Name:                Volume1
Raid Level:          0
Size:                906.18 GB
StripeSize:          128 KB
Num Disks:           2
State:               Normal
System:              False
Bootable:            True
Initialized:         True
Cache Policy:        Off

--VOLUME INFORMATION--

Name:                Volume0
Raid Level:          1
Size:                906.17 GB
StripeSize:          N/A
Num Disks:           2
State:               Normal
System:              False
Bootable:            True
Initialized:         False
```

Technical Whitepaper

Contents & Navigation


```
Cache Policy:           Off

--END DEVICE INFORMATION--

ID:                     1-0-0-0
Type:                   Disk
Disk Type:              NVMe*
State:                  Normal
Size:                   953.87 GB
System Disk:            False
PCH Connected:          False
Usage:                  Array member
Serial Number:          62UZZ029F9F6
Model:                  KXG8AZNV1T02 KIOXIA
Logical sector size:    512 B
Socket Number:          0
Vmd Controller Number:  1
Root Port Offset:       2
Slot Number:            4
ID:                     1-0-1-0
Type:                   Disk
Disk Type:              NVMe*
State:                  Normal
Size:                   953.87 GB
System Disk:            False
PCH Connected:          False
Usage:                  Array member
Serial Number:          S641NF0T406453
Model:                  SAMSUNG MZVL21T0HCLR-00BH1
Logical sector size:    512 B
Socket Number:          0
Vmd Controller Number:  1
Root Port Offset:       3
Slot Number:            4

ID:                     2-0-0-0
Type:                   Disk
Disk Type:              NVMe*
State:                  Normal
Size:                   476.94 GB
System Disk:            False
```

Contents & Navigation


```
PCH Connected:          False
Usage:                  Array member
Serial Number:          62UZZ00VF8V6
Model:                  KXG8AZNV512G KIOXIA
Logical sector size:    512 B
Socket Number:          0
Vmd Controller Number:  2
Root Port Offset:       0
Slot Number:            5

ID:                     2-0-1-0
Type:                   Disk
Disk Type:              NVMe*
State:                  Normal
Size:                   476.94 GB
System Disk:            False
PCH Connected:          False
Usage:                  Array member
Serial Number:          62UZZ00PF8V6
Model:                  KXG8AZNV512G KIOXIA
Logical sector size:    512 B
Socket Number:          0
Vmd Controller Number:  2
Root Port Offset:       1
Slot Number:            5
```

Adding `-d (or --disk)` to the query will restrict the output to just the drives.

For a storage device, the **ID** value you can see in the query output is normally used to identify a device in a CLI command, although the serial number can be used instead.

In practical usage, here's how to interpret the parts:

- The first number in the ID represents a controller ordinal. The GUI and CLI both enumerate SATA controllers first. Enabled VMD controllers are shown with higher numbers. On systems with two CPUs, the socket 0 controllers will enumerate first. These controller numbers do not necessarily match the VMD controller numbers you'll see in the BIOS and GUI interfaces.
- For SATA devices:
  - The second number is the port number on the controller.
  - The third and fourth numbers are usually zero.
- For NVMe devices:
  - The second number is always zero.
  - The third number is the ordinal of the group of four lanes dedicated to that device (out of the full lane width of the location) may range from 0 to 3.
  - The fourth number is always 0.

The output format is not restricted to just the disks, you might notice the information about a volume does not tell you which array it belongs to nor does disk details. The GUI provides more information about the hierarchy.

Important: Before creating a RAID where you want to preserve data from an existing disk,

Contents & Navigation

verify that the serial number of the disk containing the important data corresponds to the disk ID that you use with the "-E" option when you create the RAID. If you a migrating an installed OS image, make sure the disk ID used in the "-E" option corresponds to the drive showing "System Disk: True" in the Disk Information output.

Also important: When creating a RAID from existing data, 5MB of unallocated space must be available on each member drive including the source drive. You might need to shrink the last partition.

Designing the command to create a volume

The Intel® specification document some example command lines for volume creation.

The -C (`--create`) option is critical, along with a specification of the RAID mode or "level" (`-l or--level`) and a list of the drives involved.

Here's a typical command to create a RAID 0 volume named "my_R0" on three drives under VMD 2:

```
Intel® VROCCLI --create --level 0 --name my_R0 2-0-0-0 2-0-1-0 2-0-2-0
```

The -E (`--create-from-existing`) option is needed if one of the drives has content to preserve and migrate to the volume. The ID of that source drive is not repeated in the list of other drives to bring into the array, as in this example:

```
Intel® VROCCLI --create --level 1 -E 2-0-1-0 --name migrated_R1 2-0-0-0
```

To add a second volume to an existing array (the uncommonly-used "matrix" usage), use the -C option again and name the same drives. As described in the chapter earlier about BIOS usage, there needs to be space on the drives for the second volume. The -z option lets you control the size of the first volume created.

There is also a -s option to create spanned volumes.

Note that you do not have control over the array name during the creation process, only the volume name.

Managing and Deleting Volumes with the CLI

The -M (`--manage`) option is used to start various operations such as initialize, verify, or rebuild, if such actions do not start on their own. It can be used to reset a volume to Normal status.

It is also used to delete a volume, as in this example:

```
Intel® VROCCLI --manage --delete my_RAID0
```

Please see the Intel® specification document for all the details.

Using Intel® VROC Capabilities in Linux

The basic software RAID system in Linux is managed with the **mdraid** software infrastructure. This software set has existed for many years and is well established. The main operative command for volume management is **mdadm(8).**

It's important to distinguish mdraid from an old and obsolete system called dmraid. The latter is not supported in modern Linux distributions, however you still may see naming patterns that use "dm" in some of the Linux OS versions.

VROC Compatibility

The "native" mode for mdraid uses a standardized metadata format. Standard mdraid volumes are created across a set of appropriate partitions on the member drives, not on the "raw devices".

However, mdraid is also capable of using the Intel Matrix Storage Manager (imsm) format.

Imsm is a common format between iRST and VROC. And it is the format used on RAID volumes created in the BIOS Human Interface Infrastructure(HII). That opens the door to creating a RAID in BIOS and installing the Linux OS to it. Another key development that contributes to Linux boot RAID working is the GRUB2 boot loader can support the boot.

In the past, Intel® provided "out-of-box" packages for some release versions of enterprise

Technical Whitepaper

Contents & Navigation

Linux distributions such as Red Hat Enterprise Linux (RHEL) and SUSE Linux Enterprise (SLE). This was a way to make the latest features available to users of new releases of the OS. (There has often been a lag between a capability being available in the “upstream” open source and when it would be included and qualified in an enterprise distribution.)

The good news is that the upstream code is much more stable now, and RHEL 8 and SLE 15 are using that code. The Linux release versions supported on the platforms covered by VROC 8.x are compatible, so no special installations are needed.

Intel® does not provide VROC application software such as a GUI or CLI for Linux.

Overview of using mdadm with VROC

Note: It is necessary to administer storage configurations in Linux using root privileges, so you’ll see “sudo” at the front of all the example commands we show.

There’s a lot of good documentation in the Linux community regarding mdraid (see some links below).

You’ll see some similarities between the command line options for mdadm and the ones for the VROC Windows CLI.

A bit of terminology:

- The mdadm documention uses the word “container” to represent a set of drives, what has been called an “array” in this guide.
- And mdadm uses the word “array” to represent what has been called a “volume”.

Installing mdadm

Some Linux distributions do a lightweight installation and expect you to download from online repositories. For example, Ubuntu assumes you’ll connect to the internet and can then do:

```
sudo apt update

sudo apt install mdadm
```

Enterprise distributions offer extra repositories on the install image. You can choose elements to include in the initial OS layout, or you can reach the same repositories after activating your subscription. Many distributions consider mdadm a basic tool and always include it.

Managing and using RAID volumes in a running system

To view your platform capabilities and attached storage devices, the following command is helpful:

```
sudo mdadm --detail-platform
```

Here’s example output from a system that has both SATA and VMD devices available:

```
Platform :          Intel® Virtual RAID on CPU
Version :           8.0.0.4006
RAID Levels :       raid0 raid1 raid10 raid5
Chunk Sizes :       4k 8k 16k 32k 64k 128k
2TB volumes :       supported
2TB disks :         supported
Max Disks :         8
Max Volumes :       2 per array, 8 per controller
 I/O Controller :   /sys/devices/pci0000:00/0000:00:17.0 (SATA)
 Port1 :            /dev/sdb (WD-WCC6M0THUUH0)
 Port4 :            - non-disk device (hp HLDS DVDRW  GUD1N) -
```

Contents & Navigation


```
Port0 :          /dev/sda (WD-WCC6M7AH55SP)
Port2 :          - no device attached -
Port3 :          - no device attached -
Port5 :          - no device attached -
Port6 :          - no device attached -
Port7 :          - no device attached -

Platform :       Intel® Virtual RAID on CPU
Version :        8.0.0.4006
RAID Levels :    raid0
Chunk Sizes :    4k 8k 16k 32k 64k 128k
2TB volumes :    supported
2TB disks :      supported
Max Disks :      96
Max Volumes :    2 per array, 24 per controller
3rd party NVMe : not supported
I/O Controller : /sys/devices/pci0000:5d/0000:5d:00.5 (VMD)
NVMe under VMD : /dev/nvme0n1 (62UZZ029F9F6)
NVMe under VMD : /dev/nvme1n1 (S641NF0T406453)
```

In this output from a Z6 G5, the tool sees that the SATA controller has eight ports, however on this hardware platform they are not all wired to physical ports

There are other mdadm command line options to get more detail on drives, as well as other Linux commands and utilities.

Assuming you have identified the drives you want to include in an array, you must first create a container (basically, an array) from a set of disks, using imsm metadata. Let's say you want to create a RAID 1 using two NVMe drives /dev/nvme0n1 and /dev/nvme1n1.

```
sudo mdadm -C /dev/md/imsm0 /dev/nvme0n1 /dev/nvme1n1 -n 2 -e imsm
```

The -n option tells the command how many devices to include, and -e imsm specifies the metadata format. /dev/md/imsm0 is the name given to the container device file.

Creating the actual RAID volume is a second step where you name the container:

```
sudo mdadm -C /dev/md/md0 /dev/md/imsm0 -n 2 -l 1
```

A name of /dev/md/md0 is set to the volume device file and identify the container file as well as specifying the RAID level with the -l option.

Just as with other Linux storage management, after a volume is created, it can be

Technical Whitepaper

Contents & Navigation

given a partition table, partitioned, file systems can be created, and the storage can be mounted for use. There are various command line and graphical interface tools to accomplish these steps.

If the RAID volume needs to complete initialization, for example to bring two mirrored drives into sync, you can monitor the progress by periodically running this command:

```
sudo cat /proc/mdstat
```

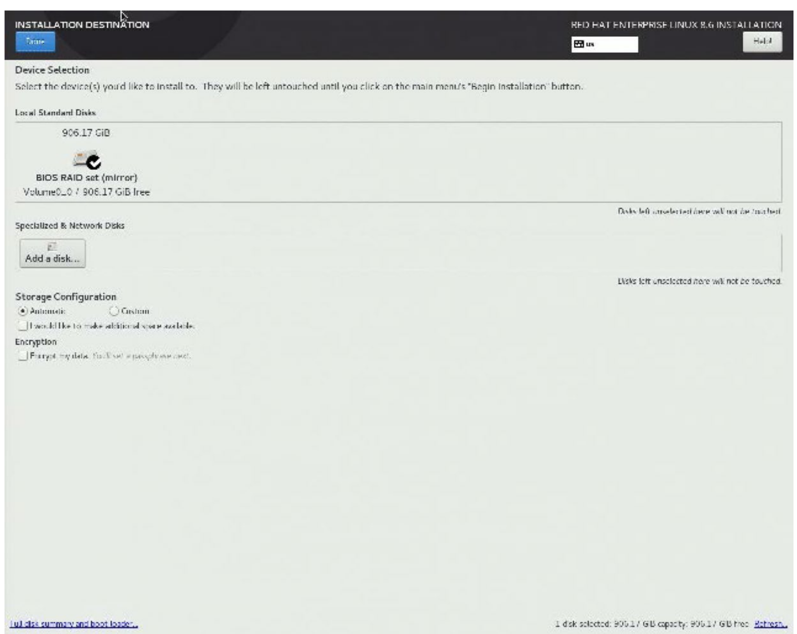
RAID on SATA really follows the same command patterns as NVMe, only the device files are different.

Installing Linux to a boot RAID

Whether or not you can successfully install a Linux OS to a software RAID volume (of any kind, let alone one created in the BIOS Human Interface Infrastructure(HII) depends greatly on the capabilities of the installer program:

- A highly capable installer can see an existing RAID volume as a target. If it can, you may be able to simply choose that target (called, for example, “md126” or “Volume 0”) and the installer will apply its normal partition scheme. RHEL 8.6 (and later) and SLE 15 SP4 (and later) have installers with this capability. See the first two images below that show the installer identifying a “BIOS RAID” target.
- Sometimes installers for the server variants of key distributions are capable, even when the “desktop” variants are not. Ubuntu 22.04 LTS falls into this group. An example image is shown below where the volume is identified as “imsm RAID”.
- Some installers only have a method for creating a non-VROC software RAID as part of the installation process. It’s unlikely you can control them to create such a RAID with imsm metadata.

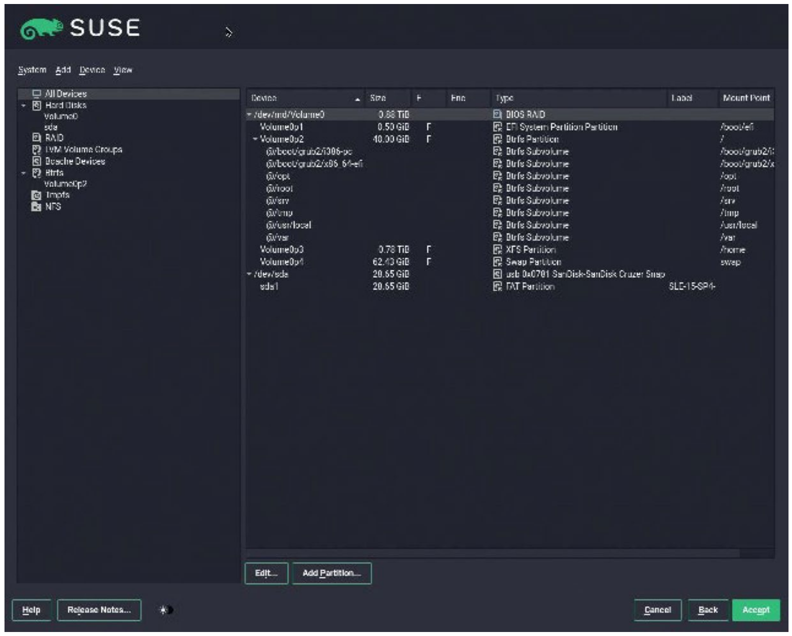
Red Hat Enterprise Linux (RHEL) 8.6 Workstation



SUSE Linux Enterprise Desktop (SLED) 15 SP4

Technical Whitepaper

Contents & Navigation



Ubuntu 22.04 LTS Server

Important Note: The GRUB boot loader finds the initial memory image (initrd or similar) and the kernel image in the /boot folder. Installations do not normally support any RAID type except RAID 1 for that folder. This is because the folder is duplicated on both mirrors, so it can be relied upon to be accessible early in the process.

References to some Linux Distribution and Community Literature

MDRAID package documentation

Here is one of many online places you can find the mdadm(8) manual page, maybe not the latest:

https://linux.die.net/man/8/mdadm

The man page is part of the mdadm package and the installed version may be more specific to the distribution. There may be additional documentation in one of these locations:

/usr/share/doc/packages/mdadm/

/usr/share/doc/mdadm

Kernel documentation

The Linux Kernel Archive has a Wiki maintained by the open-source community, however it's not that helpful for VROC usage:

https://raid.wiki.kernel.org/

Technical Whitepaper

Contents & Navigation

Note: You may see references to an older document entitled "The Software-RAID HOWTO". This document has not been updated since 2010 and is not helpful. The "Linux-RAID FAQ" is even older.

Intel® User Guide for Linux VROC

Intel® has an online user guide for VROC NVMe RAID usage in Linux. It hasn't been updated in a few years however it's still quite valuable. (Note: It is not official as support documentation for the 8.x VROC version covered in this guide.)

There is a section of this manual that covers the HII interface in a non-HP system BIOS. Please refer instead to the chapter earlier in this guide entitled "Configuring VROC in BIOS".

There is also a section covering the installation of an out-of-box package. This is not relevant to modern distributions that incorporate compatible upstream code.

Specifically for NVME, there is advice regarding increasing sync rates for volume initialization and rebuilding.

https://www.intel.com/content/dam/support/us/en/documents/memory-and-storage/ssd-software/Linux_VROC_6-0_User_Guide.pdf

Linux distribution documentation

Red Hat and SUSE both cover mdraid in their system documentation. An advantage of these document sets is that they are written for enterprise IT administrators and other parts of the sets may also be helpful. For example, they have extensive coverage of OS installation tools and automation.

https://documentation.suse.com/sled/15-SP4/pdf/book-deployment_en.pdf

https://access.redhat.com/documentation/en-us/red_hat_enterprise_linux/8/pdf/performing_a_standard_rhel_8_installation/red_hat_enterprise_linux-8-performing_a_standard_rhel_8_installation-en-us.pdf

These links are directly to the mdraid discussions:

https://access.redhat.com/documentation/en-us/red_hat_enterprise_linux/8/html/managing_storage_devices/managing-raid_managing-storage-devices

https://documentation.suse.com/sles/15-SP1/html/SLES-all/part-software-raid.html

https://help.ubuntu.com/community/Installation/SoftwareRAID

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