NVIDIA® Virtual Reality

BENCHMARKING GUIDE

NVIDIA

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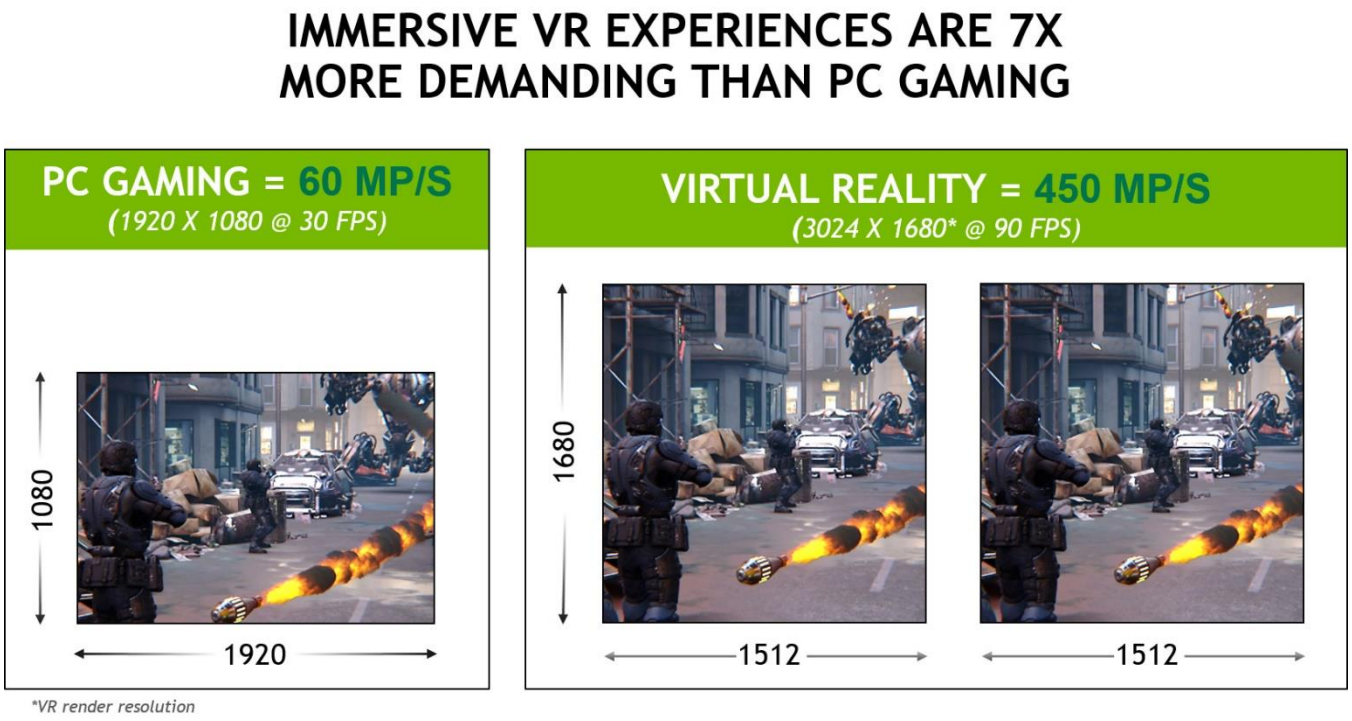
NVIDIA FCAT VR

Virtual Reality (VR) is a new computing platform poised to change the way we enjoy games and entertainment, interact with friends, and do business. VR immerses you in a virtual world—as you move, your view into the virtual world changes; and as you move your VR controllers, your avatar reaches out and interact with objects. Once you've experienced the unprecedented immersion and realism that VR delivers, you'll *get* it—and instantly want your own VR setup.

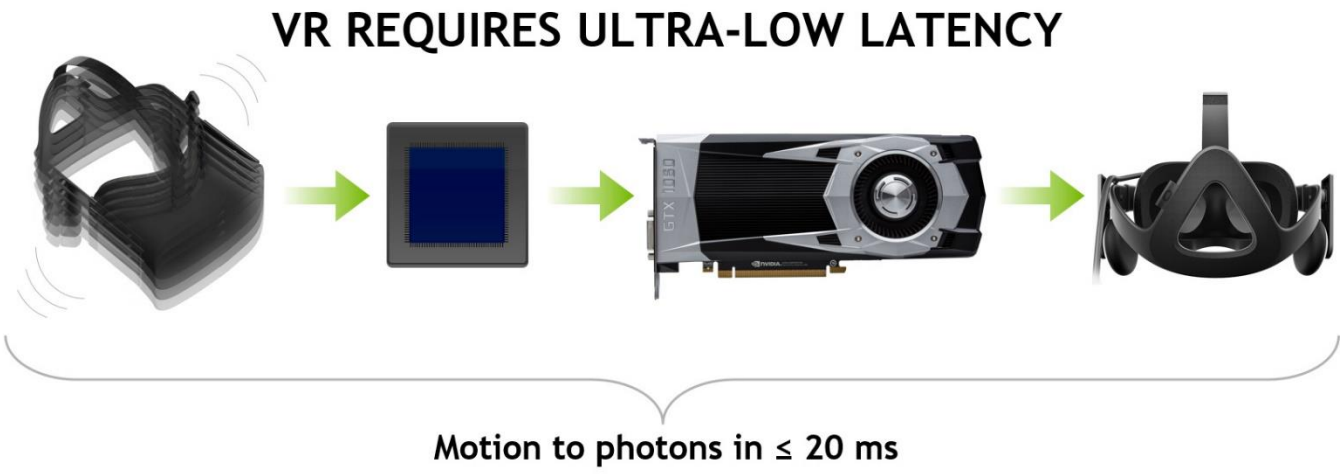
VR Challenges

For VR to deliver an immersive experience with graphically rich games and applications, a considerable amount of GPU processing power is required. As an example, the HTC Vive headset is a little over seven times as demanding on the GPU compared to a 1920 x 1080 monitor rendering at 30 Frames Per Second (FPS). In VR, if a consistent 90 FPS is not achieved, the application will stutter, potentially causing discomfort to the user.



NOTE: In VR, the GPU renders the scene at a resolution of 3024 x 1680. This image is then warped or distorted in a post-process down to the final display resolution of 2160 x 1200.

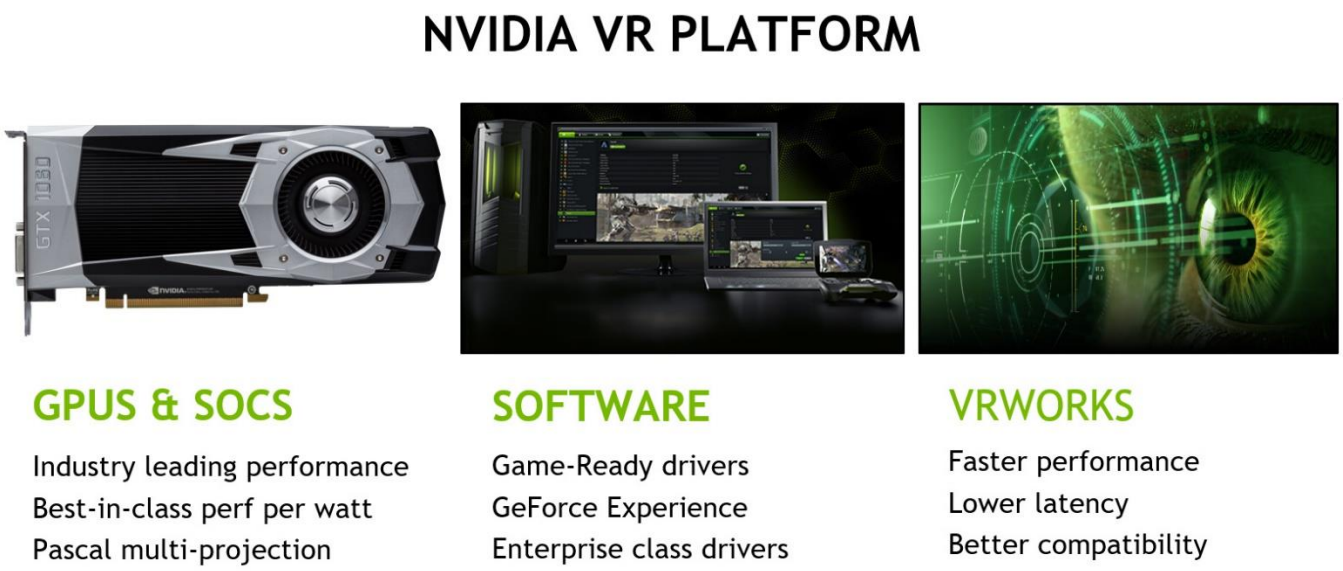
In addition to rendering at high frame rate and resolution, the GPU also needs to maintain low latency between head motion and display updates. This is important so that when you move your head, your senses stay in sync with what your eyes see on the display. If the display updates too slowly, the user may experience discomfort.



Research has shown that the motion-to-photon latency should be no more than 20 milliseconds to ensure that the experience is comfortable for users.

A consequence of rendering that quickly is that the GPU pipeline becomes even more critical. Input has to first be processed and a new frame submitted from the CPU, then the image has to be rendered by the GPU, and finally scanned out to the display. Each of these steps adds latency.

Traditional real-time rendering pipelines have not been optimized to minimize latency to the levels required by VR. New techniques were needed to further reduce latency in the VR rendering and display pipeline.



To overcome these challenges, NVIDIA has been building a VR graphics platform that increases performance, reduces latency, and provides a seamless out-of-box VR experience. The components of this graphics platform are NVIDIA® GeForce® GTX GPUs, NVIDIA® GeForce Experience™, and our NVIDIA® VRWorks™ SDK.

GeForce® GTX GPUs

NVIDIA Pascal-based GeForce GTX GPUs (such as the GTX 1060, GTX 1070, GTX 1080, and GTX 1080 Ti) are built to deliver the raw frame rates and high resolution required for demanding VR experiences. With full support for the next generation DirectX 12 graphics API, and a Pascal Simultaneous Multi-Projection (SMP) architecture that enables new rendering techniques for VR, GeForce GTX GPUs are designed for amazing VR experiences.

Recommended Configurations for VR Desktops and Notebooks:

Recommended	**GeForce GTX 1060**	GTX 1060 is the recommended baseline GPU for virtual reality due to its combination of performance and accessibility. The GTX 1060 will provide a good baseline VR experience.
Better	**GeForce GTX 1070**	With 30% faster performance over GTX 1060, the GTX 1070 allows allows for higher in-game settings for better visual quality.
Best	**GeForce GTX 1080** **GeForce GTX 1080 Ti** **GeForce GTX 1070 SLI®** **GeForce GTX 1080 SLI** **GeForce GTX 1080 Ti SLI**	The ultimate performance for maximum settings and future headroom in VR games and apps.

Game Ready Drivers

It's about more than just hardware though. The GeForce gaming platform includes the best software in the industry. In VR, even minor game compatibility issues or stutter can ruin the experience and create discomfort. NVIDIA GeForce Experience™ software delivers Game Ready Drivers to users the moment the hottest new VR titles are released. Game Ready Drivers optimize games for an incredible out-of-the-box experience.

NVIDIA VRWORKS

NVIDIA VRWorks software is a comprehensive suite of APIs, sample code, and libraries for VR developers. Whether developing a groundbreaking VR application or designing the next generation of Head Mounted Displays, NVIDIA VRWorks helps developers achieve the highest performance, lowest latency, and plug-and-play compatibility. VRWorks includes the following features:

NVIDIA VRWorks for Headset developers

With **Direct Mode**, the NVIDIA driver treats VR headsets as head mounted displays accessible only to VR applications, rather than a normal Windows monitor that your desktop shows up on, providing better plug and play support and compatibility for the VR headset.

Context Priority provides headset developers with control over GPU scheduling to support advanced virtual reality features such as asynchronous timewarp, which cuts latency and quickly adjusts images as gamers move their heads, without the need to re-render a new frame.

Front buffer rendering reduces latency by rendering directly to the front buffer.

NVIDIA VRWorks for Application Developers

Multi-Res Shading is an innovative new rendering technique for VR whereby each part of an image is rendered at a resolution that better matches the pixel density of the warped image. Multi-Res Shading uses Maxwell's multi-projection architecture to render multiple scaled viewports in a single pass, delivering substantial performance improvements.

Lens Matched Shading uses the new Simultaneous Multi-Projection architecture of NVIDIA Pascal™-based GPUs to provide substantial performance improvements in pixel shading. The feature improves upon Multi-res Shading by rendering to a surface that more closely approximates the lens corrected image that is output to the headset display. This avoids rendering many pixels that would otherwise be discarded before the image is output to the VR headset.

Traditionally, VR applications have to draw geometry twice -- once for the left eye, and once for the right eye. **Single Pass Stereo** uses the new Simultaneous Multi-Projection architecture of NVIDIA Pascal-based GPUs to draw geometry only once, then simultaneously project both right-eye and left-eye views of the geometry. This allows developers to effectively double the geometric complexity of VR applications, increasing the richness and detail of their virtual world.

VR SLI provides increased performance for virtual reality apps where multiple GPUs can be assigned a specific eye to dramatically accelerate stereo rendering. With the GPU affinity API, VR SLI allows scaling for systems with two or more GPUs. VR SLI is supported for DirectX and OpenGL.

In addition, NVIDIA VRWorks includes components that cater to professional VR environments like Cave Automatic Virtual Environments (CAVEs), immersive displays, and cluster solutions.

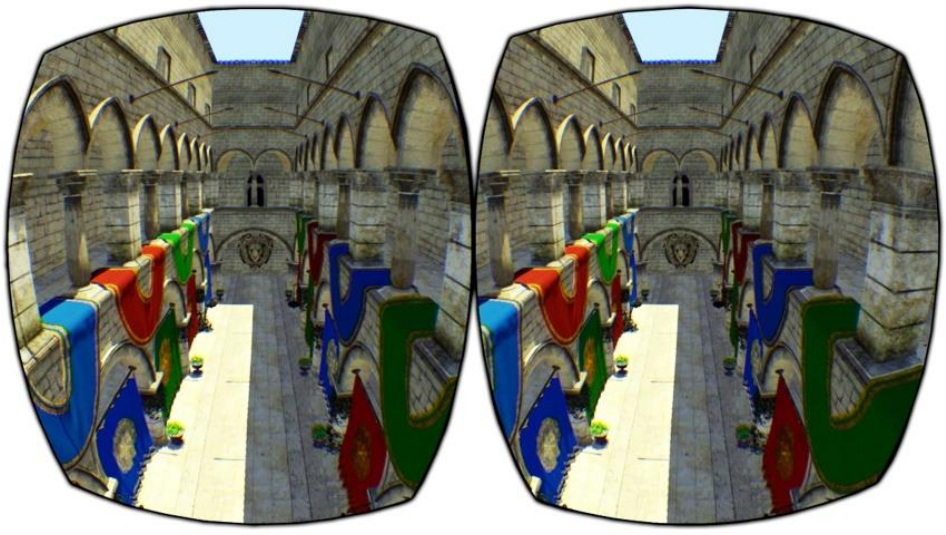
We will go into more detail about Multi-res Shading and VR SLI later. To learn more about other NVIDIA VRWorks, visit https://developer.nvidia.com/vrworks.

Multi-Res Shading (MRS)

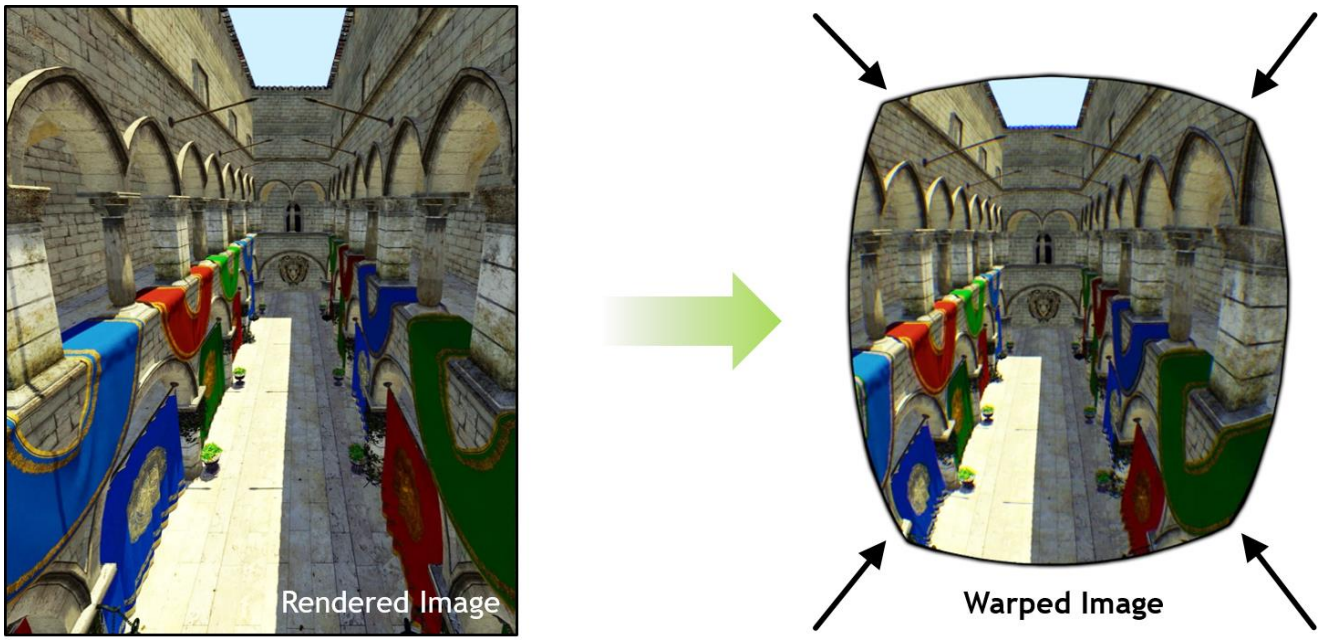
Multi-Res Shading is a rendering technique that helps reduce rendering cost without impacting perceived image quality. The screen is divided into multiple viewports, and by using the Maxwell and Pascal GPU hardware-based multi-projection feature, the entire scene geometry can be broadcasted to each viewport, and geometry that does not touch particular viewports is culled (thrown away) quickly. The outer viewport images are rendered at lower resolution, while the center viewport is rendered at full resolution. Overall performance is improved while not reducing perceived image quality.

Issues with Lens Distortion and Warped Images

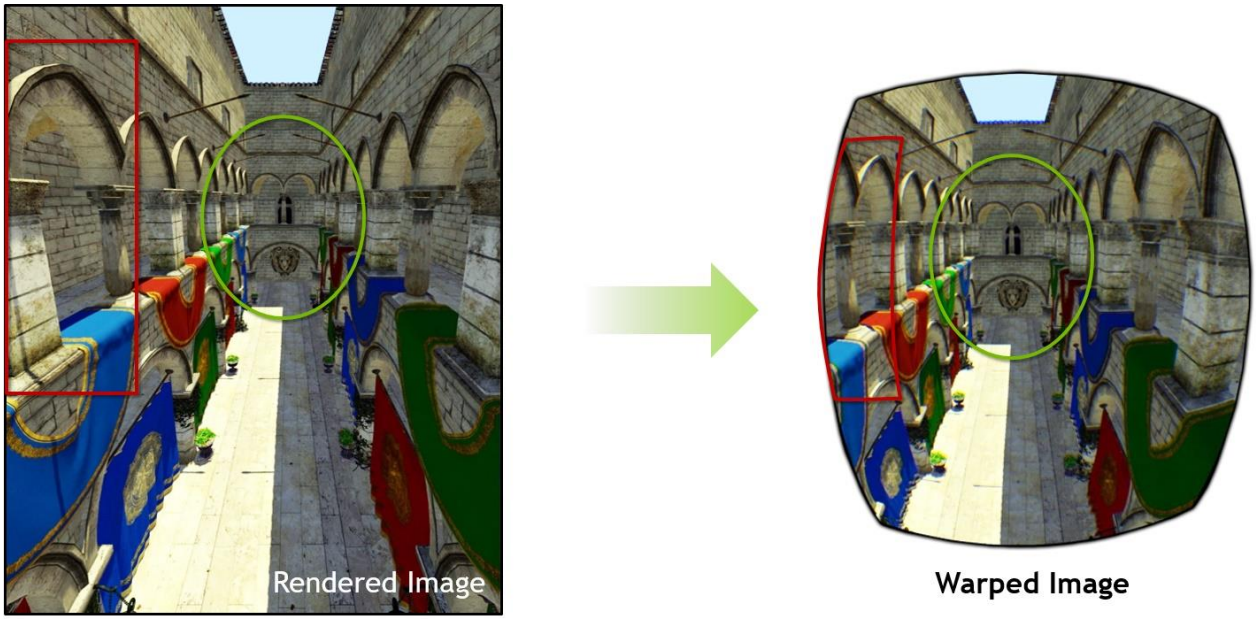
The image presented on a virtual reality headset has to be warped to counteract the optical effects of the lenses.



Instead of being square, the images look curved and distorted, but when viewed through appropriate lenses, the image appears accurate.



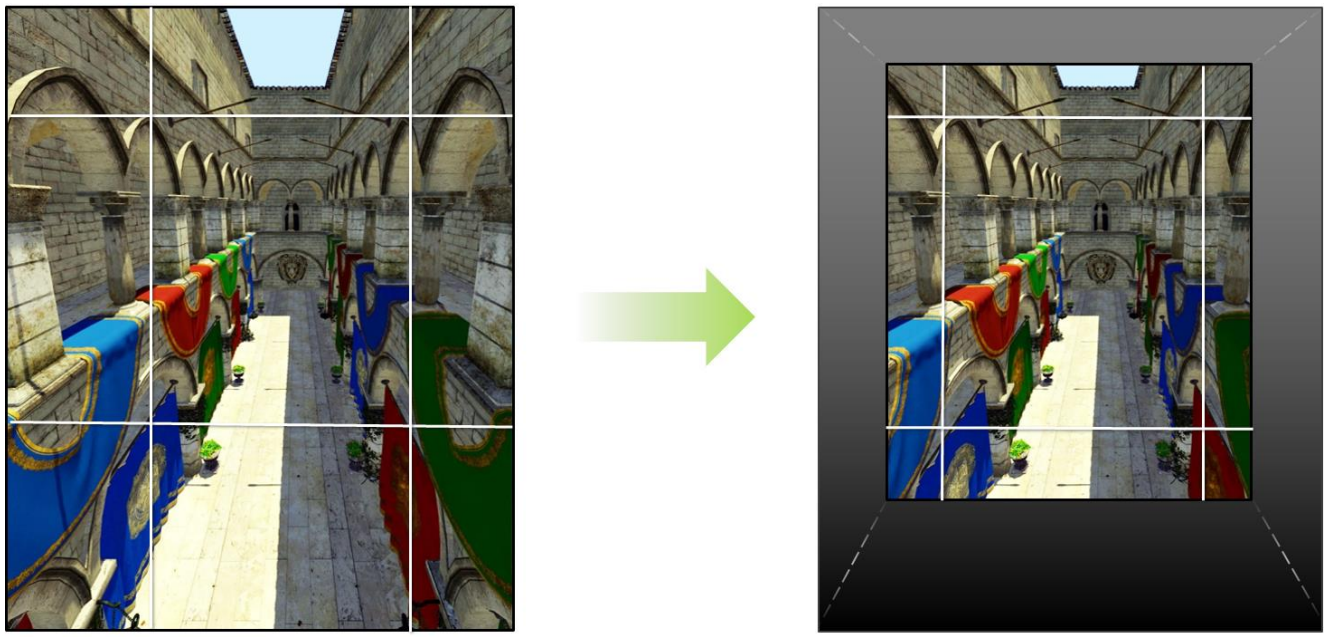
GPUs do not natively render into this sort of distorted view. Rather, current VR platforms use a two-step process that first renders a normal image (left), then second does a post-processing pass that resamples and prewarps the image to the distorted view (right). While this solution works, it is inefficient because there is oversampling at the edges.



In the image above, the center (green) is nearly unaffected, but the sides (red) are squished. The result is that many of the rendered pixels along the edges are discarded when creating the final, warped image. Generating pixels that will just get discarded later is inefficient and wasted work.

Subdividing and Scaling

NVIDIA Multi-Res Shading works by subdividing the image into separate viewports. As described above, the Maxwell and Pascal multi-projection hardware feature is able to send scene geometry to each viewport without extra processing except for culling geometry not hitting those viewport areas.



Each viewport is then warped, and the maximum sampling resolution needed within that portion of the image is closer to the final displayed pixels. The center viewport is also warped and stays nearly the same. This better approximates the warped image, but without over shading. And because fewer pixels are shaded, the rendering is faster. Depending on the settings for the Multi-Res Shading, savings can be anywhere from 25% to 50% of the pixels. This translates into a 1.3x to 2x pixel shading speedup.

Multi-res Shading is now integrated into Epic's UE4. UE4-based VR applications such as *Everest VR* by Sólfar Studios and *Thunderbird: the Legend Begins* by InnerVision Games have also integrated this technology with many more apps to come.

Multi-Res Shading integrations for Unity and Max Play engines are currently in progress. These engine integrations will make it easy for more VR developers to integrate the technologies into their apps.

Smart Supersampling

In some situations MRS Level 1 (MRS 1) will *increase* quality by supersampling the the center viewport. The *quality increase* may cause a *decrease* in performance. In the current Unreal Engine 4 branch, MRS

Level 1 is defined relative to the lens parameters that will give this visual quality increase without the large performance degradation due to typical sumpersampling methods.

Benefits of MRS

Quality settings can be increased since MRS reduces the rendering cost of VR games. For example, the graphics quality preset in Raw Data can be increased from Low to Medium with a GeForce GTX 1060 when Multi-Res Level 2 is used.

Setting	Without VRWorks	With VRWorks
Preset	**Low**	**Medium**
Resolution Multiplier	1.0x	1.1x
Post Processing	Low	Medium
Shadow Quality	Low	Medium
Texture Quality	Low	Medium
Effect Quality	Low	Medium
View Distance	Near	Medium
Multi-Res Level	Off	2

Figure 1: With VRWorks disabled, lower quality settings must be used, which does not include anti-aliasing or shadows.

Figure 2: VRWorks with MRS allows for higher-quality settings. The Medium Preset with higher quality shadows makes the control panel look more realistic and polished.

Lens Matched Shading (LMS)

The explosive growth of interest in VR applications has increased the importance of supporting displays which require rendering to non-planar projections. VR displays have a lens in between the viewer and the display, which bends and distorts the image. For the image to look correct to the user, it would have to be rendered with a special projection that inverts the distortion of the lens. Then when the image is viewed through the lens, it will look undistorted, because the two distortions cancel out.

Traditional GPUs do not support this type of projection; instead they only support a standard "planar" projection with a uniform sampling rate. Producing a correct final image with traditional GPUs requires two steps—first, the GPU must render with a standard projection, generating more pixels than needed. Second, for each pixel location in the output display surface, look up a pixel value from the rendered result from the first step to apply to the display surface.

Figure 3: *First pass image* and **Figure 4**: *Final image required for correct viewing through HMD optics* provide an example of this traditional GPU two-step process. **Figure 3:** *First pass image* illustrates standard planar rendering with a uniform sampling rate. **Figure 4** demonstrates an example of the final image as it would be shown on the VR display. The center of the image looks about the same as it

would with a standard planar projection, but on the sides the image is squeezed. In this example, **Figure 4** is 1.1 Megapixels per eye (based on Oculus Rift parameters). If the source rendering was perfectly matched to the final projection, it should also be 1.1 Megapixels per eye. However, due to the mismatch in projections, the source image is 2.1 Megapixels per eye—86% *more* pixels than necessary.

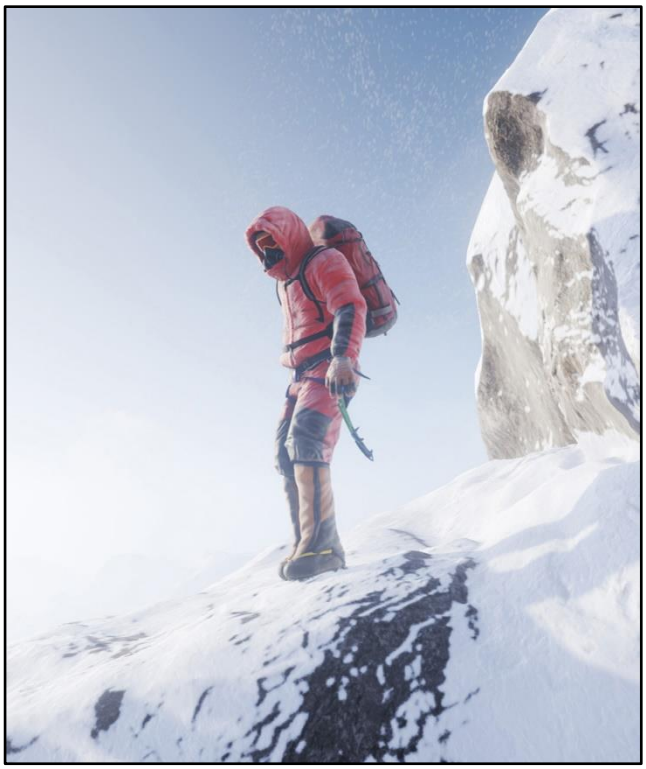


Figure 3: First pass image

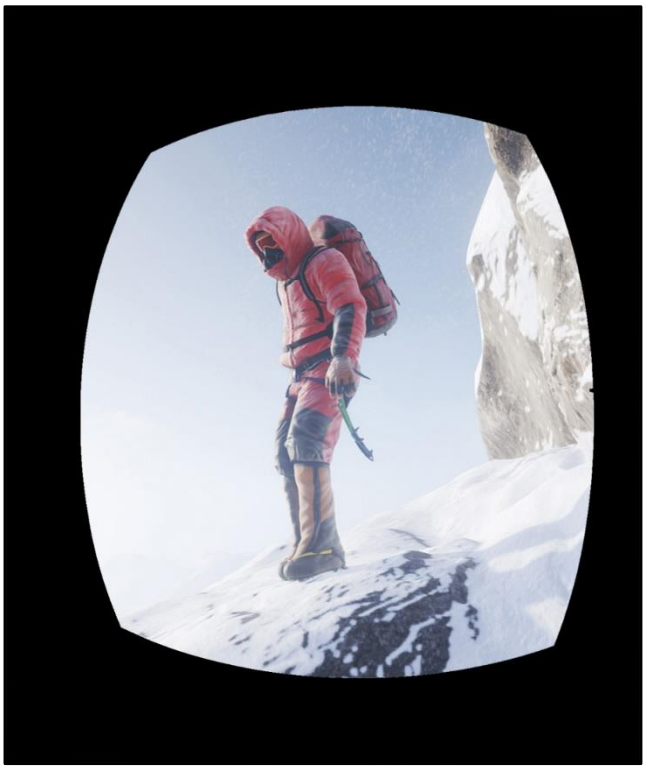


Figure 4: Final image required for correct viewing through HMD optics

Leveraging SMP's ability to use multiple projection planes for a single viewpoint, we can attempt to approximate the shape of the lens-distorted projection. This feature is known as **Lens Matched Shading**.

With Lens Matched Shading, the SMP engine subdivides the display region into four quadrants, with each quadrant applying its own projection plane. The parameters can be adjusted to approximate the shape of the lens distortion as closely as possible. **Figure 5** illustrates the rendered image with Lens Matched Shading, and **Figure 6** demonstrates the final image that the GPU delivers to the HMD. The source image on the left is now 1.4 Megapixels per eye instead of 2.1 Megapixels. This is a significant reduction in shading rate that translates to a 50% increase in throughput available for pixel shading!

Figure 5: First-pass image with Lens Matched Shading

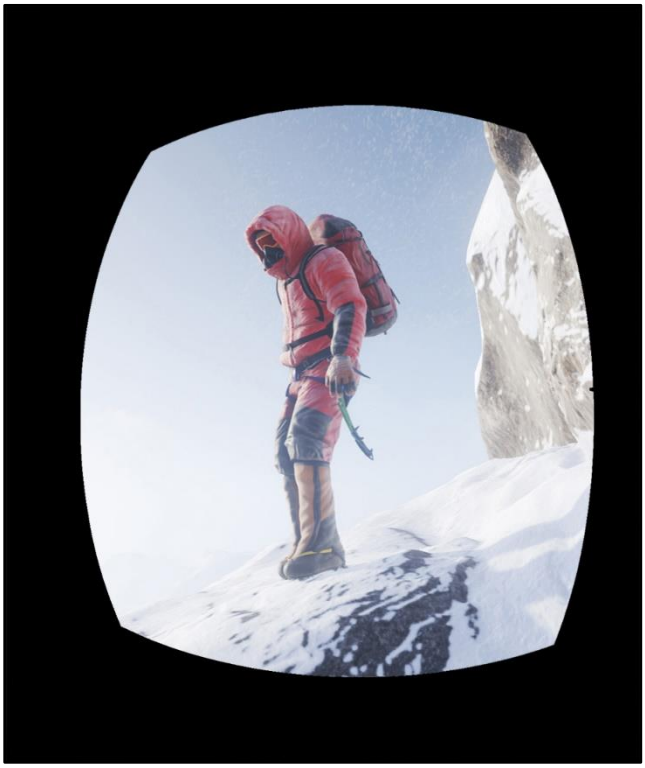


Figure 6: The final image required for correct viewing through HMD optics

One step in determining the Lens Matched Shading parameters is to check the sampling rate compared to the sampling rate required for the final image. The objective for the default, “conservative”, setting of Lens Matched Shading is to always match or exceed the sampling rate of the final image. Error! Reference source not found. demonstrates an example comparison for the preceding lens matched shading image.

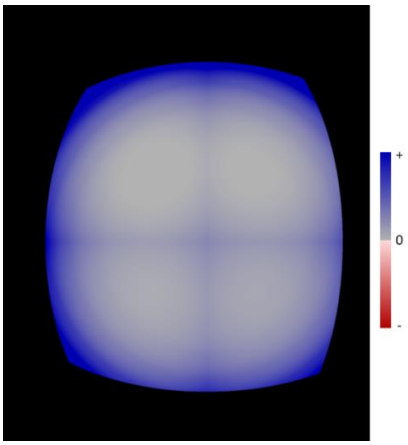


Figure 7: First Pass image sampling rate compared to the final image

Blue indicates pixels that were sampled at a higher rate than required, gray indicates a matched rate, and any red pixels would indicate initial sampling that was below the rate in the final image. The absence of red pixels confirms that the setting matches the objective.

In addition, developers have the option to use different settings; for example one could use a setting that is higher resolution in the center and undersampled in the periphery, to maximize frame rate without significant visual quality degradation.

Single Pass Stereo

Traditionally, VR applications have to draw geometry twice — once for the left eye, and once for the right eye. Single Pass Stereo uses the new Simultaneous Multi-Projection architecture of NVIDIA Pascal-based GPUs to draw geometry only once, then simultaneously project both right-eye and left-eye views of the geometry. This allows developers to effectively double the geometric complexity of VR applications, increasing the richness and detail of their virtual world.

SINGLE PASS STEREO

VR SLI

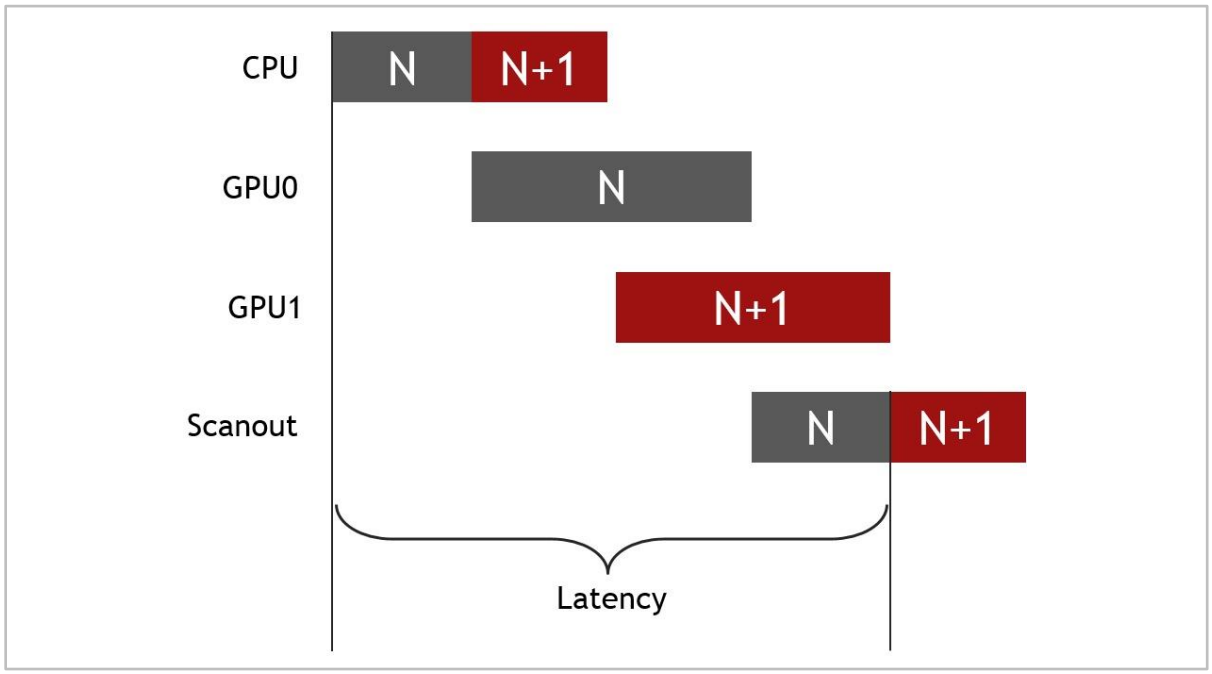
With VR SLI, multiple GPUs can be assigned a specific eye to dramatically accelerate stereo rendering. VR SLI even allows scaling for PCs with more than two GPUs.

VR SLI provides increased performance for virtual reality applications where multiple GPUs can be assigned to a specific eye (the same number of GPUs are assigned to each eye) to dramatically accelerate stereo rendering. With the GPU affinity API, VR SLI allows scaling for systems with >2 GPUs. VR SLI is supported for DirectX and OpenGL.

VR SLI

AFR SLI — Not Appropriate for VR

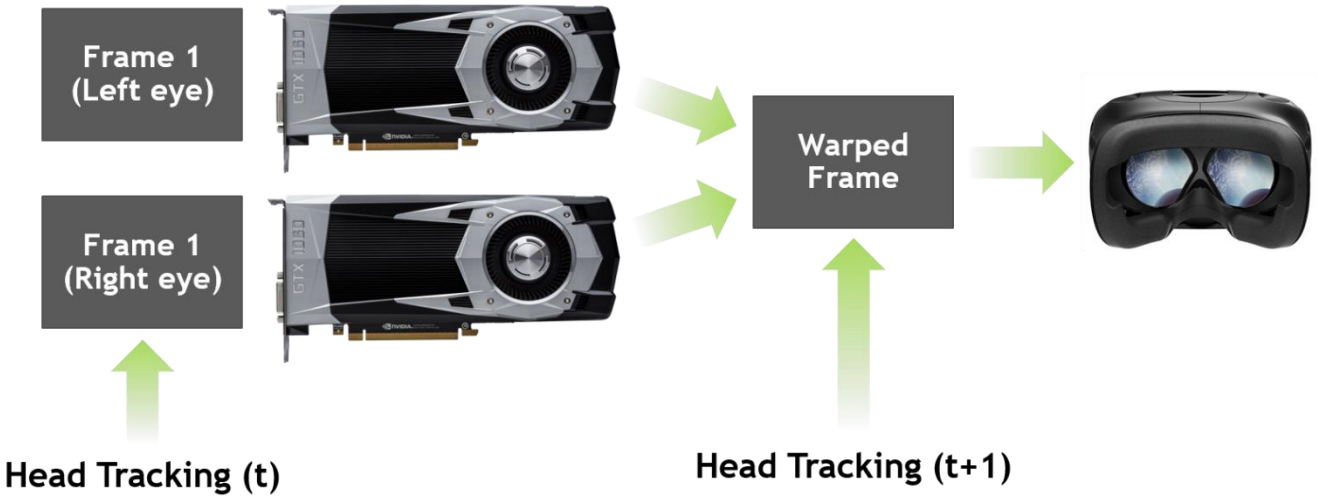
Alternate-frame rendering (AFR) is the method used for SLI on traditional monitors. GPUs using AFR SLI trade off work on entire frames. In the case of two GPUs, the first GPU renders the even frames and the second GPU renders the odd frames. The GPU start times are staggered by a half-a-frame to maintain regular frame delivery to the display.



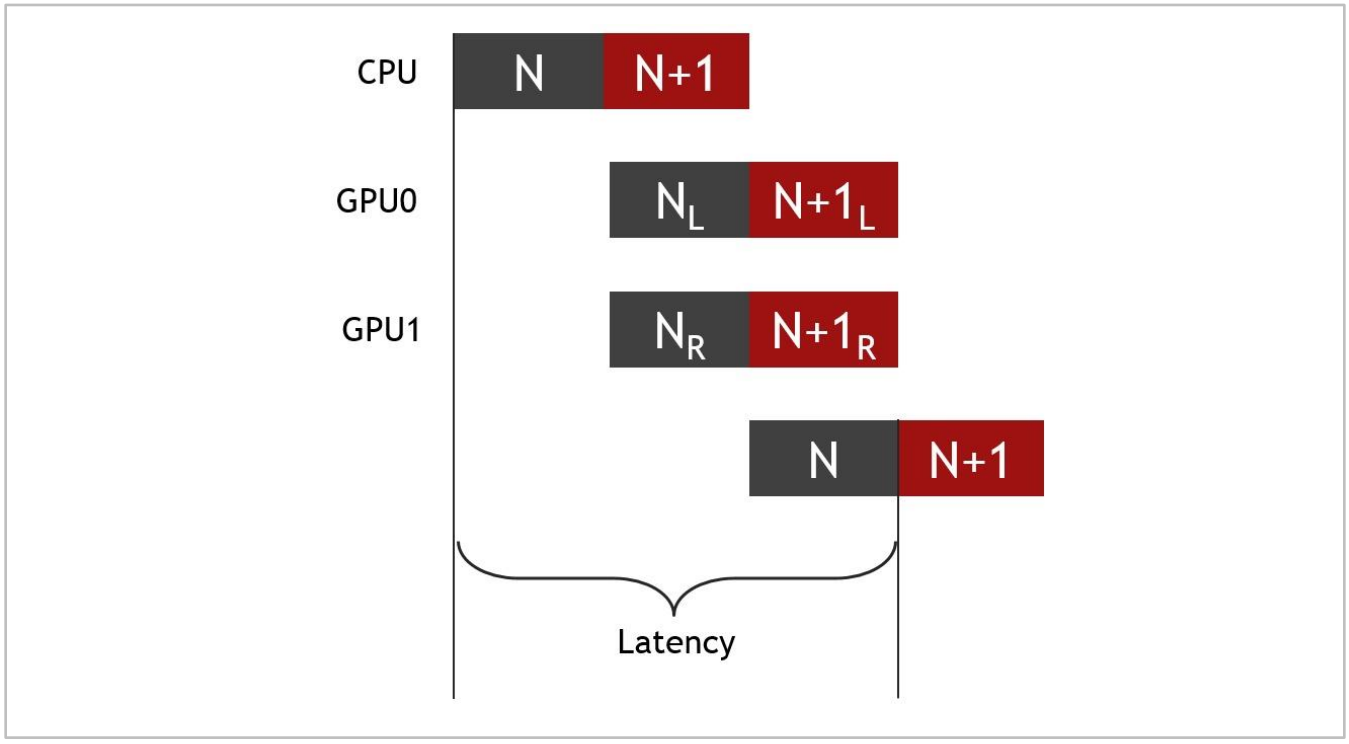
AFR SLI works reasonably well to increase frame rates relative to a single-GPU system, but it doesn't help with latency. So this method is not the best model for VR.

How VRI SLI Works

A better way to use two GPUs for VR rendering is to split the work of drawing a single frame across both GPUs. With VR SLI, this means rendering the frames for each eye on their own individual GPU.



The frame for the left eye is rendered on the first GPU, and the frame for the right eye is rendered on the second GPU at the same time.



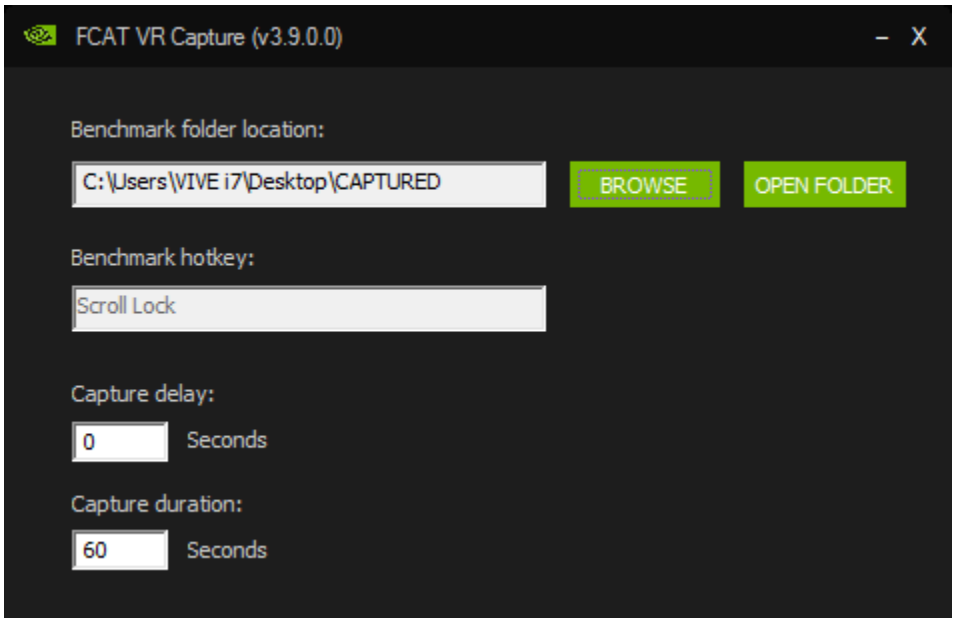
Parallelizing the rendering of the left- and right-eye frames across two GPUs yields a massive improvement in performance, allowing VR SLI to improve both frame rate and latency relative to a single-GPU system.

Note that unlike traditional AFR SLI, which uses a profile in the NVIDIA driver, VR SLI requires application side integration to enable performance scaling. VR SLI is now integrated into applications

such as Valve's *The Lab,* ILMxLAB's *Trials on Tatooine,* and Croteam's Serious Sam VR: The Last Hope, with many more in progress including UE4, Unity and Max Play engine integrations.

FCAT VR CAPTURE

FCAT VR Capture is a new frametime capture tool with a user interface similar to other frame capture tools (such as FRAPS), but it uses NVIDIA driver stats, Oculus Event Tracing for Windows (ETW) events, or SteamVR's performance API data (for HTC Vive) to generate precise VR performance data. FCAT VR Capture works for all GPUs independent of GPU vendor.



Most importantly, FCAT VR Capture works with popular VR Head-Mounted Displays (HMDs) to capture key performance events:

- Total frametime
- Application dropped frames
- Runtime warp dropped frames
- Asynchronous Space Warp (ASW) synthesized frames (Oculus Rift only)

From these events we can draw meaningful conclusions about the GPU performance and the VR experience.

How FCAT Software Capture Works

Today's leading high-end VR headsets, the Oculus Rift and HTC Vive, both refresh their screen at a fixed interval, 90 Hz, which equates to one screen refresh every ~11.1 ms. VSYNC is enabled to prevent tearing, since tearing in the HMD can cause major discomfort to the user.

VR software for delivering frames can be divided into two parts: the **VR Game** and the **VR Runtime**. When timing requirements are satisfied and the process works correctly, the following sequence is observed:

1. The **VR Game** samples the current headset position sensor and updates the camera position in a game to correctly track a user's head position.
2. The game then establishes a graphics frame, and the GPU renders the new frame to a texture (not the final display).
3. The **VR Runtime** reads the new texture, modifies it, and generates a final image that is displayed on the headset display. Two of these interesting modifications include color correction and lens correction, but the work done by the VR Runtime can be much more elaborate.

With the timestamps generated by FCAT Software Capture we can determine how long it took the system to generate each frame, if frames were dropped, and why those frames were dropped. By examining how long the system takes to render each frame, we see just how quickly the system *could have* displayed that frame if not for the fixed 90 Hz refresh cadence. As a result we have achieved a way to truly measure relative GPU performance of demanding VR content within the fixed refresh VR ecosystem.

We can further investigate the data related to dropped, or "missed," frames. From here we determine where in the pipeline the frame was missed. In the VR pipeline, we can colloquially call the system components and the application being run as the "app" and the effect for warping the frame the "warp." Either the app failed to render the next frame within the allocated time (app miss), or the runtime failed to warp the frame delivered by the GPU within the allocated time (warp miss).

NOTE: Refer to the **FCAT VR Reviewer's Guide** for more details about FCAT Software Capture and instructions for running it.

ASYNCHRONOUS SPACEWARP (ASW)

Asynchronous Spacewarp (ASW) is a technology developed by Oculus aimed at reducing system hardware requirements while maintaining content quality across a wider array of hardware. Like Asynchronous Timewarp (ATW), ASW is automatic and enabled without any additional effort from developers.

How does ASW Work?

In order to understand ASW, we must first understand Asynchronous Timewarp (ATW). ATW is a process that is separate from the main rendering thread and runs within the Oculus Runtime where the HMD position is sampled very close to the VSYNC interval, the difference from the previous position is calculated, the most recently completed frame is translated (shifted without full re-rendering) based on the position difference, and the new translated frame is displayed on the HMD.

Asynchronous Spacewarp (ASW) is a process that applies animation detection from previously rendered frames in order to synthesize a new, predicted frame. Colloquially, we can refer to this as an ASW synthesized frame.

If the application is able to consistently render at 90 Hz, the synthesized frames are never displayed in the HMD. ASW is “activated” when a frame cannot be rendered as per usual, on time. Predicting a synthesized frame based on motion detection from previously rendered frames is less demanding than rendering a new frame.

If ASW is disabled and an application fails to submit frames to the Oculus Runtime at 90 Hz, the Runtime will select the most recently completed frame and apply ATW to it.

If ASW is enabled and an application fails to submit frames to the Oculus Runtime at 90 Hz, the Runtime renders the application at 45 FPS and applies ATW to both regularly rendered frames and ASW synthesized frames. These ASW synthesized frames act as intermediary frames between the regularly rendered frames. Thus the result is that the viewer sees smoother animation, rendered at 45 FPS, but presented at 90 FPS.

NOTE: Please refer to the **FCAT VR Reviewer’s Guide** for more information on testing games with ASW.

RECOMMENDED GAMES & SETTINGS

GAME	VR HMD	GEFORCE GTX 1060	GEFORCE GTX 1080	BENCHMARK AREA
Everest VR (LMS/MRS)	HTC Vive & Oculus RIft	"Medium Settings" Weather Effect 0.4 Supersampling 140 LOD Distance 1	"High Settings" Weather Effect 0.8 Supersampling 170 LOD Distance 1	Khumbu Icefall: Start at the front of the ladder, walk across the ladder, turn to the left and climb the other ladder; stop recording when you reach the top.
NVIDIA VR Funhouse (MRS)	HTC Vive	Low Preset	High Preset	Load the Clown Painter mini-game, slecet the desired MRS level using the numpad keys, benchmark 30-60 seconds filling the balloons with goo. *Clown Painter uses a FleX particle based fluid simulation along side an ellipsoid splatting fluid surface rendering technique.
Raw Data (MRS)	HTC Vive	Low Preset	Epic Preset	Bishop character, 1st level (Hard Point), insert the key into the slot. Begin benchmarking when the robot breaks the glass. Shoot robots and stop benchmarking after the first wave is defeated.
Robo Recall	Oculus Rift	Planar Reflections: No Indirect Shadows: No Adaptive Resolution: No Antialiasing MSAA: 0 Graphics Quality: Low Pixel Density: 1.0	Planar Reflections: Yes Indirect Shadows: Yes Adaptive Resolution: No AntiAliasing MSAA: 4 VFX Quality: High Pixel Density: 1.5	Play through the intro, you will be placed back into the office area. From the office, select Zone 1 (City Center) Mission 1-1 (Batch Recall). Set Time of Day to "DAY". Play through the first 3 waves of enemies (3 warps), until 60 seconds has expired.
Serious Sam VR: The Last Hope	HTC Vive	CPU Speed: Medium GPU Speed: Medium GPU Memory: Medium Level Caching: Medium	CPU Speed: Ultra GPU Speed: Ultra GPU Memory: Ultra Level Caching: Ultra	Play through the first wave of enemies on the Earth level at the easiest difficulty.
Sports Bar VR (MRS)	Oculus Rift	GFX Quality: Medium Pixel Density: 1.7 Screen Sharpening: 1.5	GFX Quality: Ultra Pixel Density: 1.7 Screen Sharpening: 1.5	8-ball Free play for ~60 seconds. Use Ctrl+0,1,2,3 to change MRS levels.

GAME	VR HMD	GEFORCE GTX 1060	GEFORCE GTX 1080	BENCHMARK AREA
SUPERHOT	Oculus Rift	Default Setting	Default Settings	Start the game and get to the balcony within 30 seconds.
The Unspoken	Oculus Rift	Medium Preset	Ultra Preset	Practice, Elmhurst Ave, Targets. Throw 3 fireballs at targets. Use 2 special attacks (Push and Fireworks). Continue throwing fireballs for about 45 seconds.
Trials on Tatooine	HTC Vive	Medium Preset	High Preset	Begin recording when you pick up the lightsaber, end recording when the imperial ship takes off.

MULTI-RES SHADING (MRS) GAMES

Everest VR | MRS

Everest VR | MRS Hardware Requirements

To access MRS settings in *Everest VR,* press the menu button on a Vive controller and select Graphic Settings. The Graphic Settings menu will appear and the first settings option will be Multires. Press the - or + button to toggle between the different MRS settings.

NOTE: The settings below were given names to more easily differentiate them by GPU.

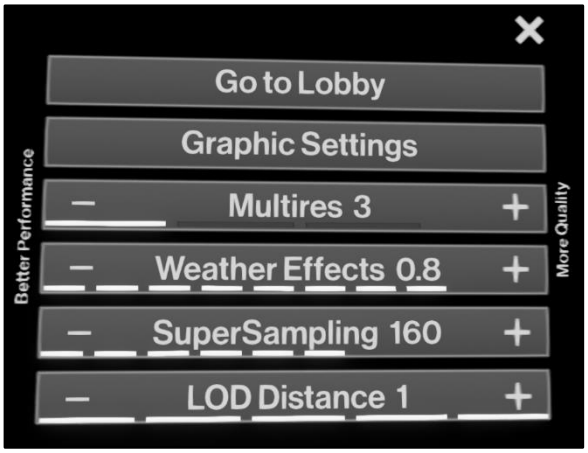
EVEREST VR MRS Settings	"Medium Settings"	"High Settings"
Recommended GPU	**GTX 1060**	**GTX 1080**
Weather Effects	0.8	0.8
Supersampling	160	170
LOD Distance	1	1

Everest VR is recommended with the following NVIDIA GeForce™ GTX Graphics cards:

"Medium Settings": GeForce 1060

"High Settings": GeForce GTX 1080 or greater

Supported VR Headsets: HTC Vive



The Settings Explained

Lens Matched Shading (LMS): NVIDIA specific optimization that provides performance improvements in pixel shading by avoiding the rendering of pixels that end up being discarded in the final view sent to the HMD after the distortion process. MRS is supported by Maxwell and Pascal architecture GPUs.

Weather Effects: This controls the amount of particle effects used throughout the experience to simulate weather. The default value is 0.4, while 0.0 turns them off. Higher values will result in more dramatic effects.

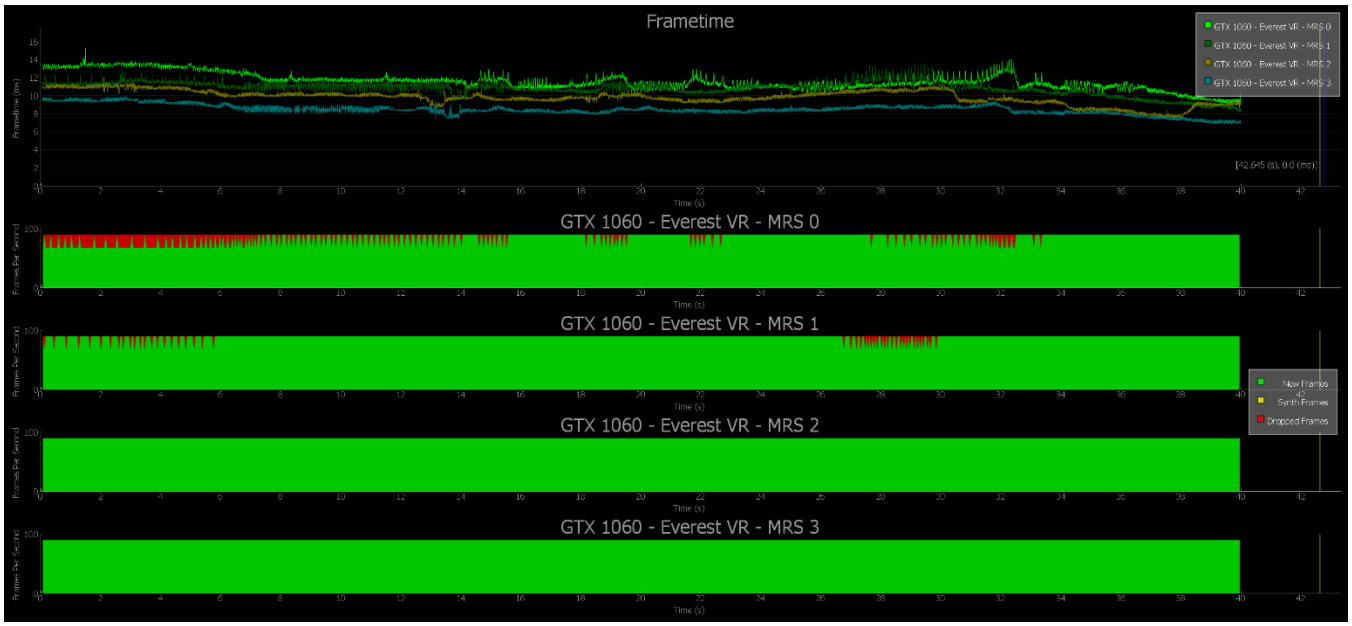
SuperSampling: By default, Unreal renders into a screen buffer that is 40% higher than the Vive display and scales the result down to the native resolution. This results in crisper textures. This default setting is displayed as 140. Increasing the screen percentage will result in increasingly crisper images, but at the cost of performance. High-end GPUs should have room to increase this significantly.

LOD Distance: Geometry has a series of increasingly higher levels of detail based on the distance from the viewer. This multiplier affects at what distance higher density geometry is activated. Lower is better.

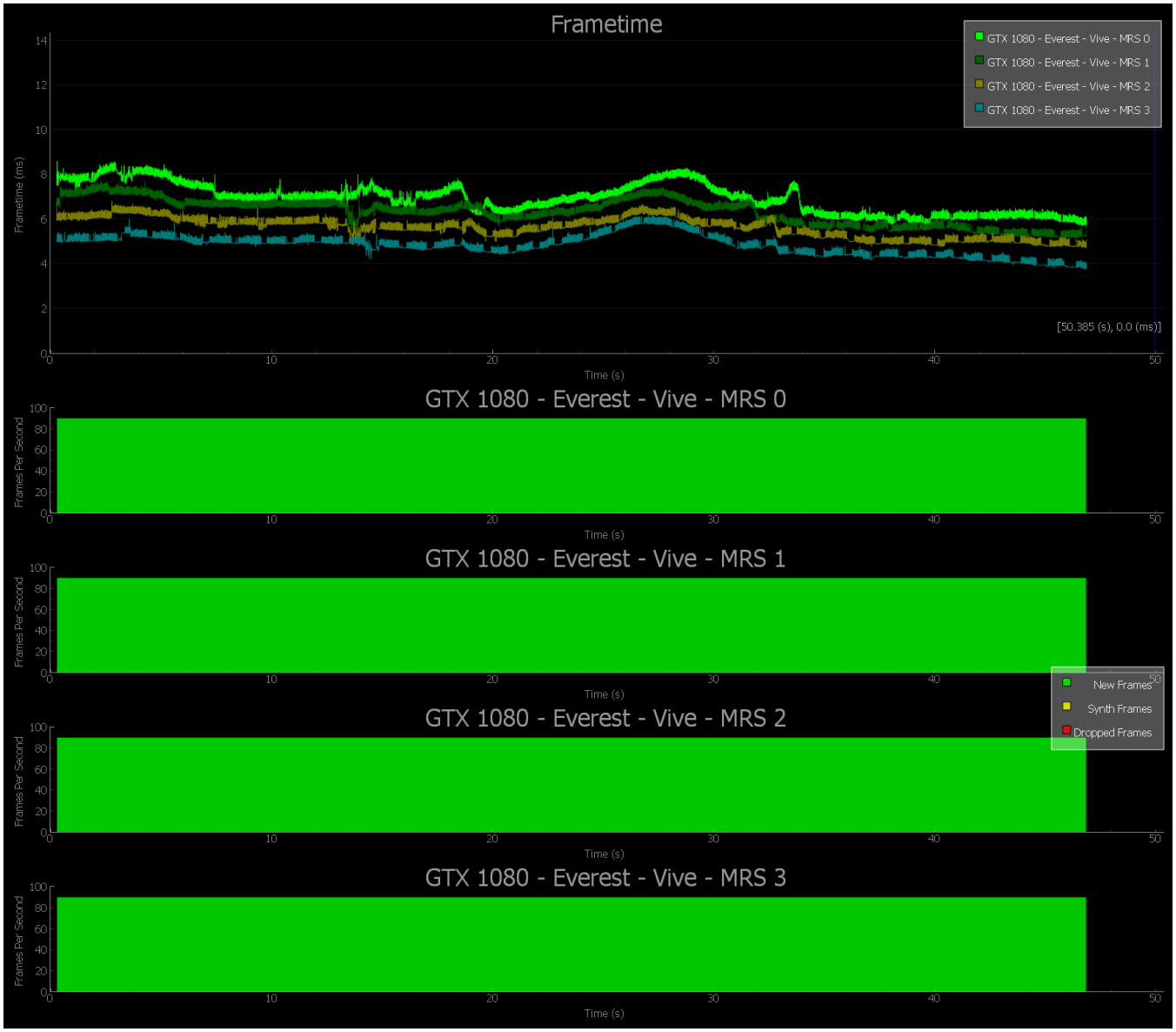
Everest | FCAT VR MRS Charts

The following charts show a comparison of MRS settings across the GTX 1060, GTX 1080, and GTX 1080 Ti GPUs. This data was captured using the FCAT VR Software Capture Tool, which captures and analyzes dropped frames and warp misses in VR gameplay. The FCAT VR Data Analyzer was used to generate the charts.

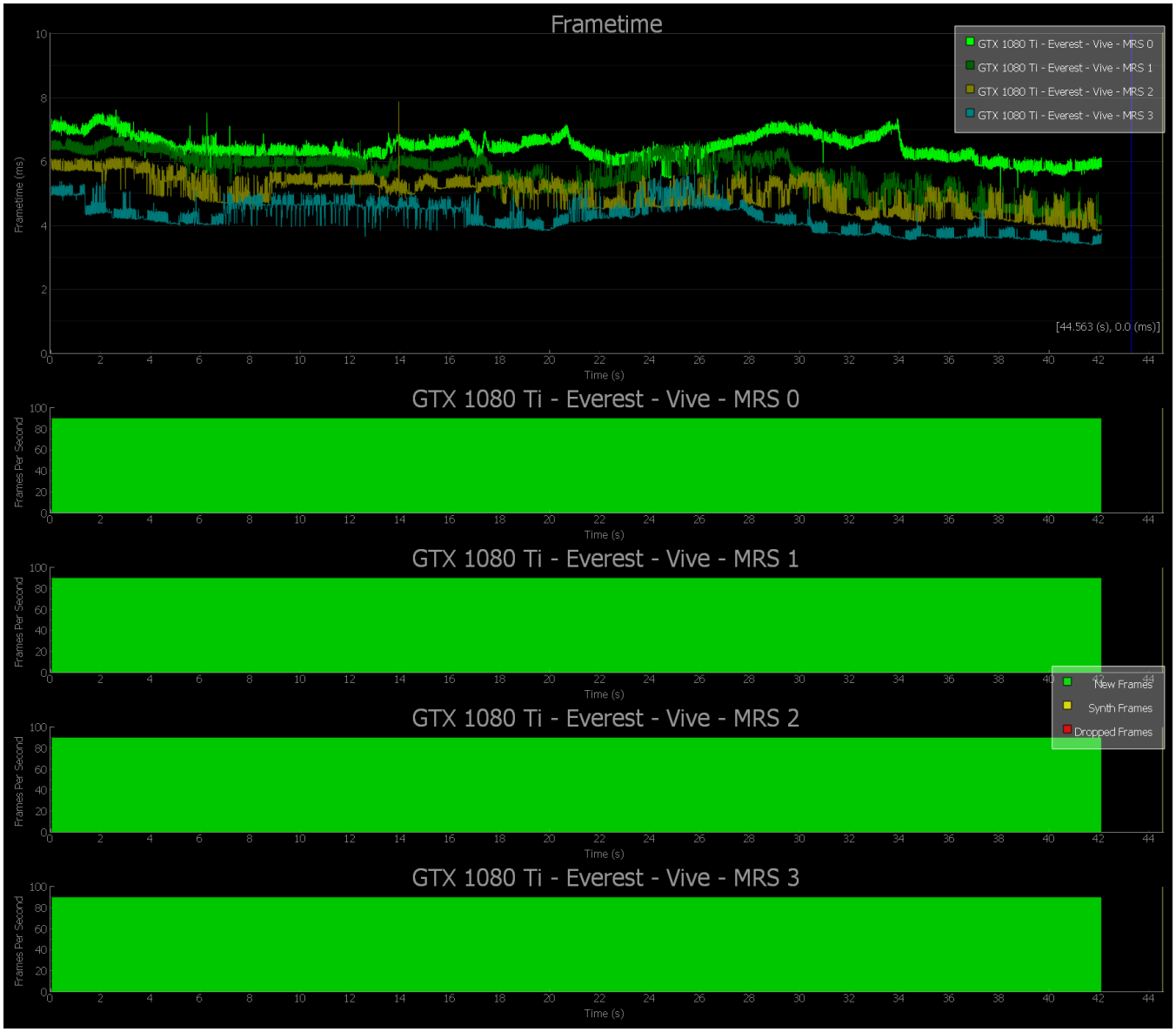
Everest MRS with GTX 1060 | "Medium Settings"



Everest MRS with GTX 1080 | "High Settings"



Everest MRS with GTX 1080 Ti | "High Settings"



NVIDIA VR Funhouse | MRS

VR Funhouse features the hottest simulation and rendering technologies, all supporting an incredibly engaging VR game.

VR Funhouse is built using the Unreal Engine and features the following technologies used in AAA game development:

- **Destruction:** Destroy rigid bodies
- **HairWorks:** The best hair and fur in the business
- **Flow:** Volumetric fire and smoke
- **FleX:** Particle based physics liquids and solids
- **VRWorks:** Advanced VR rendering techniques for faster performance

VR Funhouse | MRS Hardware Requirements

Settings Used:

NOTE: These settings were chosen to best show MRS scaling.

VR Funhouse MRS Presets	LOW	HIGH
Recommended GPU	GTX 1060	GTX 1080

Obtain the correct build of NVIDIA VR Funhouse

In order to modify MRS settings in VR Funhouse, you must obtain a particular build of VR Funhouse. Follow this procedure

1. Subscribe to NVIDIA VR Funhouse on Steam.
2. In Steam, right click on **NVIDIA VR Funhouse** and select **Properties.**
3. Select the **Betas** tab
4. Select the **beta** list drop down arrow.
5. Select '**1.3.3-1157350-vrworks-mrs'** branch.
6. Steam will automatically download the different beta branch that includes numpad keys to change MRS levels.

Changing the MRS Settings in VR Funhouse

Once you successfully obtained the 1.3.3-1157350-vrworks-mrs build of VR Funhouse, then you can use the following numpad keys to change the MRS level while in game. Type the following for each of the MRS Levels:

MRS 0: Num0
MRS 1: Num1
MRS 2: Num2
MRS 3: Num3

CRITICAL NOTE: Settings get reset every time a new level is started. Make sure to set your MRS level again before testing.

Benchmark VR Funhouse

The MRS settings automatically change every time a scene (mini game) is changed. So ensure that you select the appropriate MRS level at the beginning of every scene.

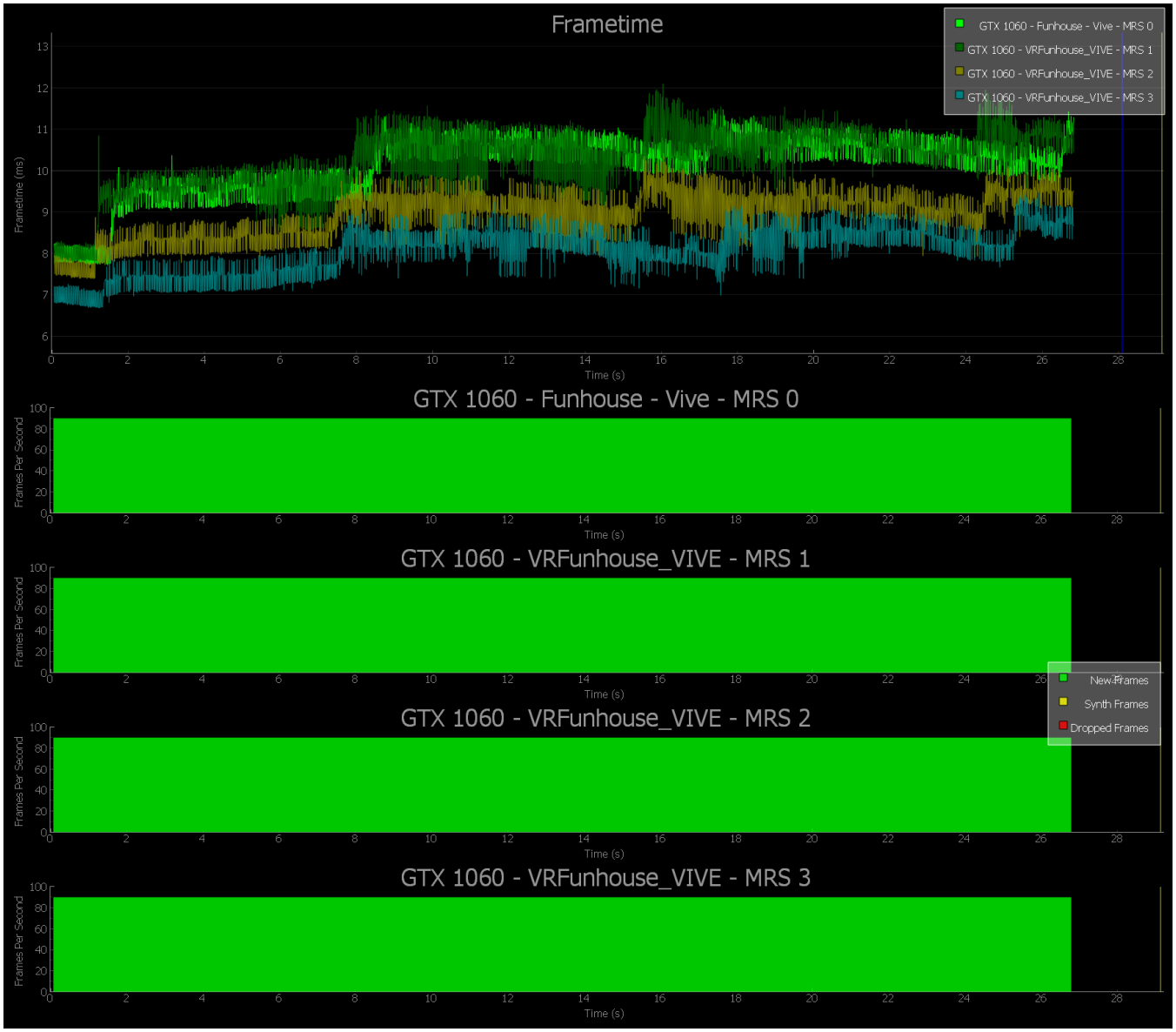
Run-to-run variance can pose a significant problem when running benchmarks in VR, especially for scenarios which involve chance. For this reason, we recommend that the Clown Painter scene for benchmarking VR Funhouse. Follow this procedure:

1. Launch **NVIDIA VR Funhouse** from Steam.
2. From the opening scene, select the **Settings** button on the right.
3. Choose the appropriate settings level.
4. Push the number **1** button on your keyboard to load the Clown Painter scene.
5. Select the appropriate MRS level by pushing the corresponding number on the numpad.
6. Begin recording your benchmark with **FCAT VR Software Capture**.
7. Use one hand to shoot a goo gun into a clown mouth until the balloon breaks or the gun runs out of goo.
8. Stop shooting from that hand to let the goo gun recharge.
9. Use the other hand to continue shooting goo into a clown mouth.
10. Repeat this alternating pattern for 30 – 60 seconds. The idea is to always have goo shooting and interacting with the geometry in the scene.
11. Stop the benchmark.

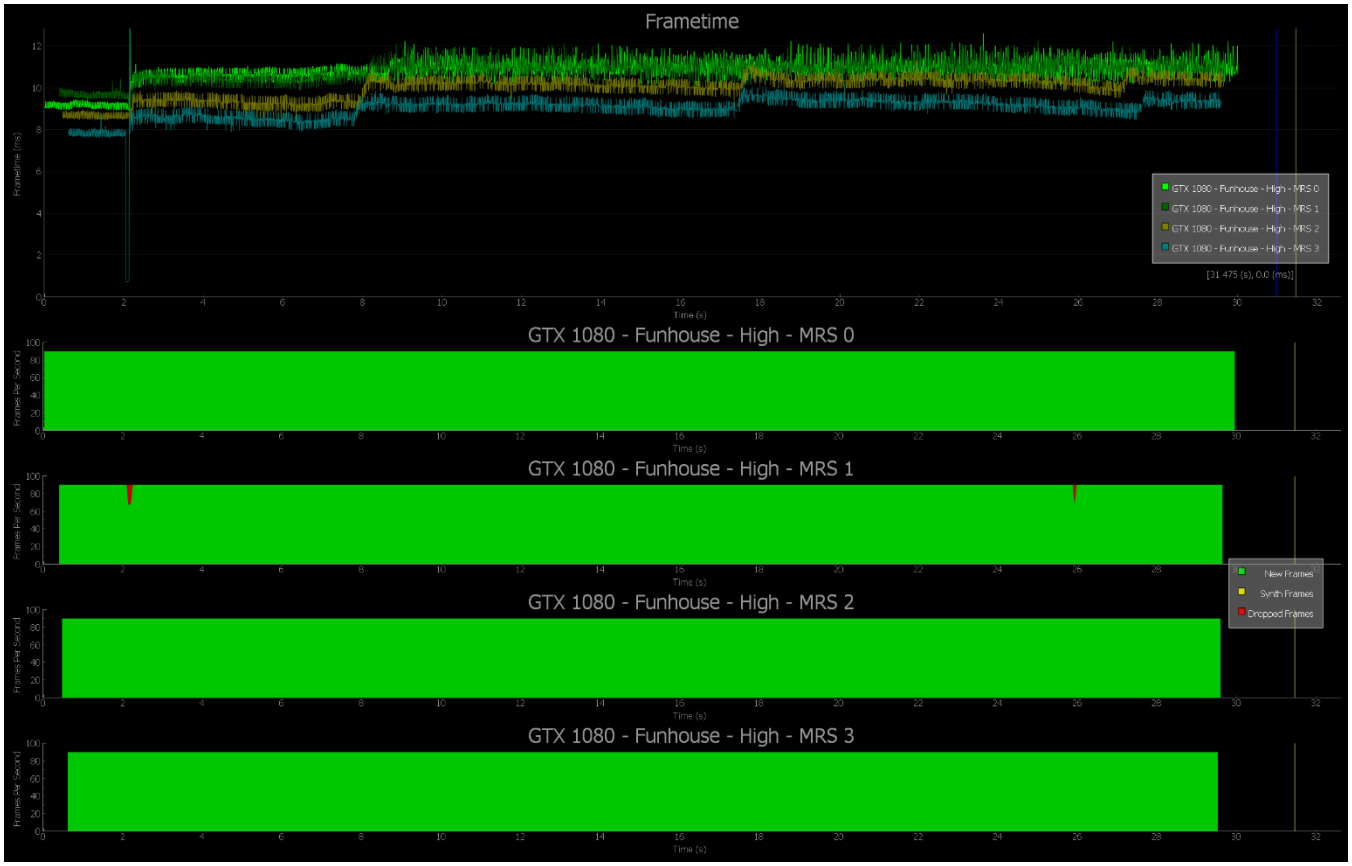
VR Funhouse | FCAT VR MRS Charts

The following charts show a comparison of MRS settings across the GTX 1060, GTX 1080, and GTX 1080 Ti GPUs. This data was captured using the FCAT VR Software Capture tool, which captures and analyzes dropped frames and warp misses in VR gameplay. The FCAT VR Analyzer was used to generate the charts.

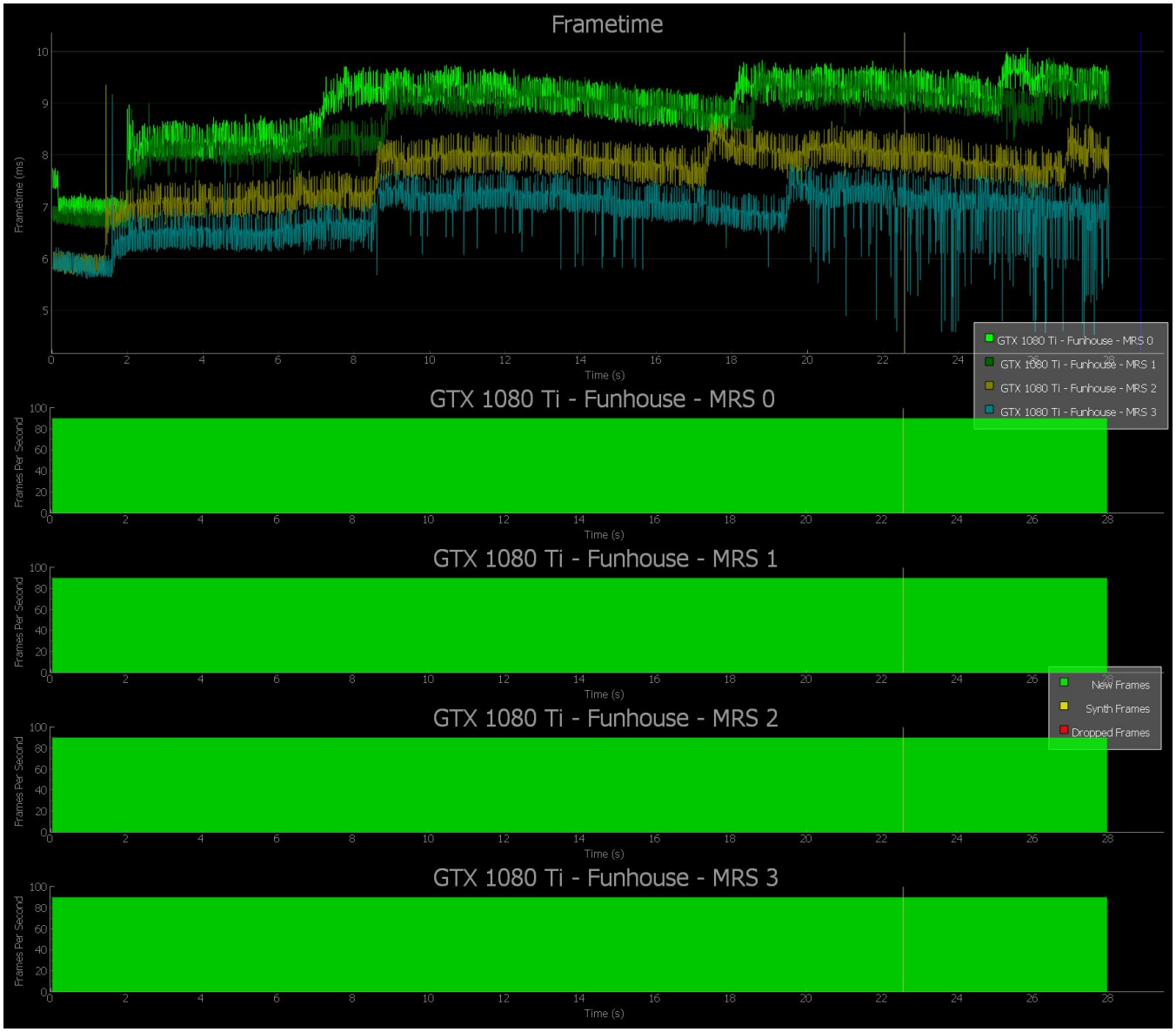
VR Funhouse MRS with GTX 1060 | Low Settings



VR Funhouse MRS with GTX 1080 | High Settings



VR Funhouse MRS with GTX 1080 Ti | High Settings



Sports Bar VR | MRS

Sports Bar VR VR demonstrates more than just how pool physics will be experienced in the VR space. Players will be able to interact with all sorts of objects, create trick shots with any plates, bottles and other items in the pool hall, play virtual darts, and take part in the time-honored pastime of throwing empty beer bottles against the wall.

With the most advanced proprietary physics engine honed for billiards realism, Sports Bar VR VR aims to deliver the most interactive VR pool experience in the most chilled VR hangout.

Sports Bar VR | MRS Hardware Requirements

Settings Used:

Consider the following Super Sampling and Sharpening settings after selecting the presets below.

Sports Bar VR MRS Presets	MEDIUM	ULTRA
Recommended GPU	**GTX 1060**	**GTX 1080**
Graphics Setting	Medium	Ultra
Super Sampling	170	170
Sharpening	7	7

MRS settings reduce instances of dropped frames and warp misses on the GTX 1080. With MRS2 settings, dropped frames and warp misses are eliminated entirely.

Adjusting the MRS level in Sports Bar VR

MRS levels in Sports Bar VR can be adjusted by pressing CTRL + 0, 1, 2, 3. MRS level 0 is considered "disabled." MRS level has an inverse relationship with GPU rendering time and dropped frames: As MRS level *increases*, GPU rendering time and number of dropped frames *decreases*, providing a better user experience with little or no observable difference in image quality.

MRS 0: CTRL + 0 (MRS off)
MRS 1: CTRL + 1 (MRS Level 1)
MRS 2: CTRL + 2 (MRS Level 2)
MRS 3: CTRL + 3 (MRS Level 3)

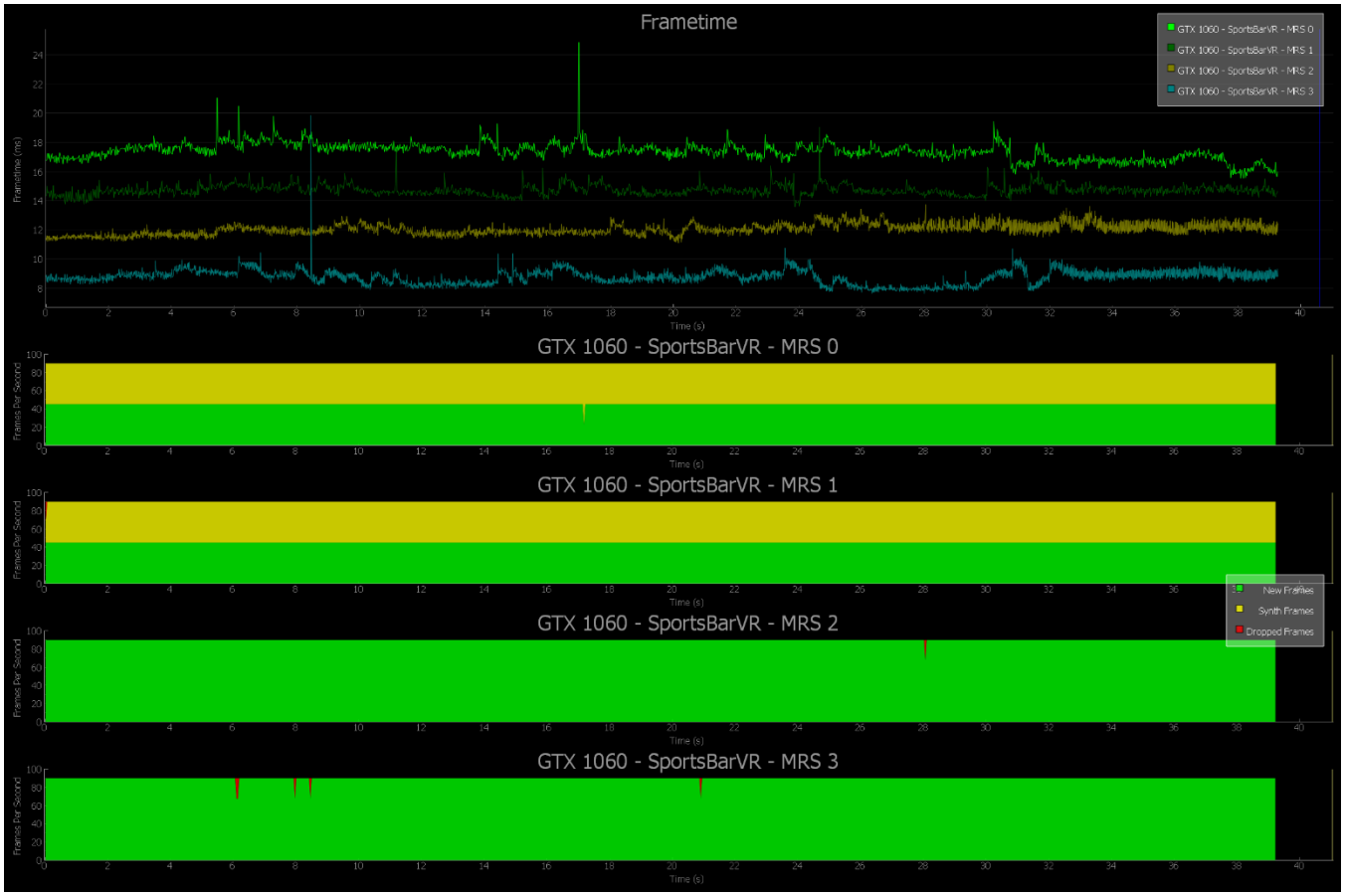
Caution: Do **NOT** use the numpad keys when changing MRS levels. Numpad keys may cause Oculus Rift to change ASW modes which will invalidate your test results.

NOTE: SportsBarVR may launch with MRS enabled by default. If you plan to test the effects of MRS, explicitly choose the MRS level for each test.

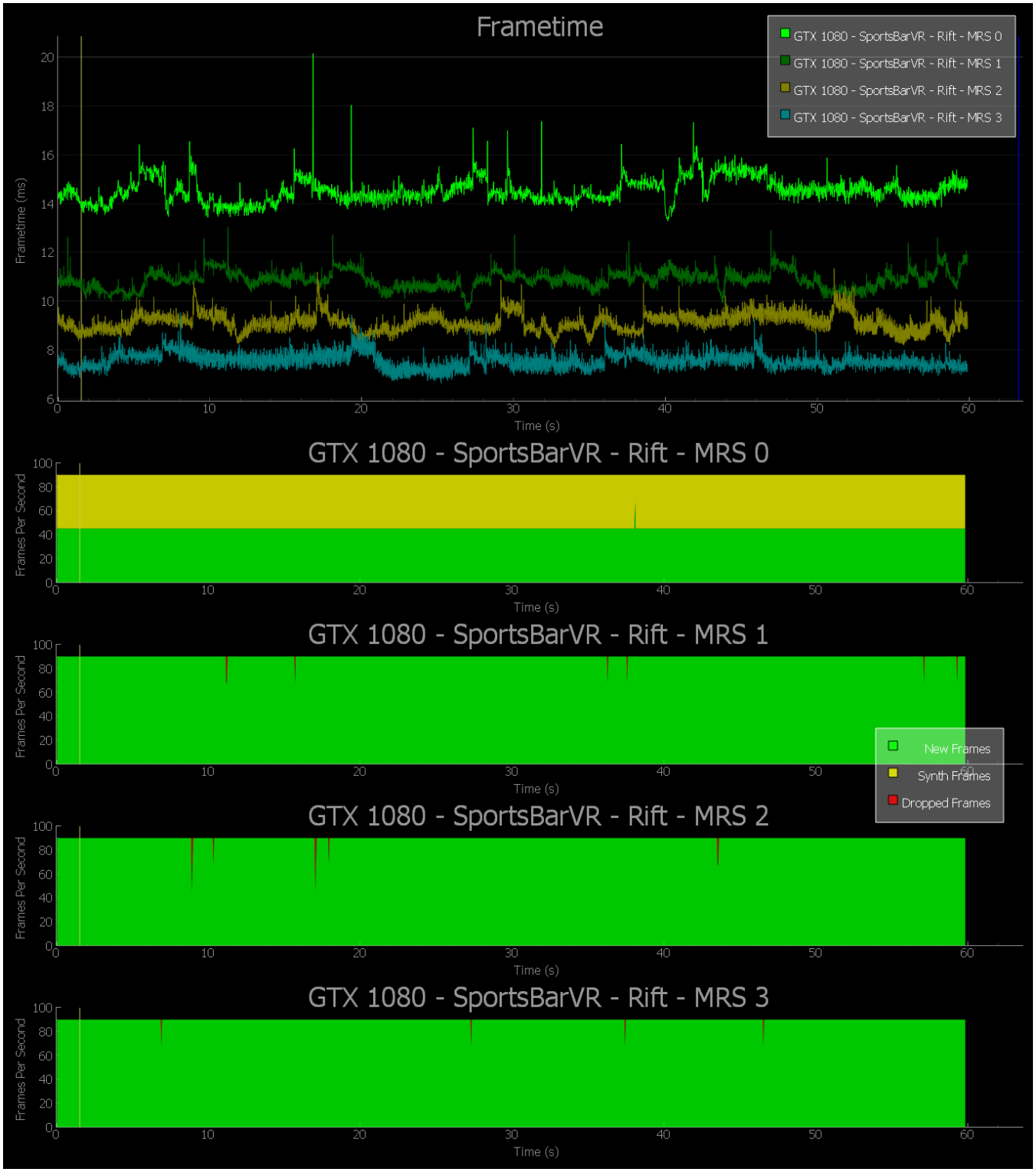
Sports Bar VR | FCAT VR MRS Charts

The following charts show a comparison of MRS settings across the GTX 1060, GTX 1070, and GTX 1080 GPUs. This data was captured using the FCAT VR Software Capture Tool, which captures and analyzes dropped frames and warp misses in VR gameplay. The FCAT VR Data Analyzer was used to generate the charts.

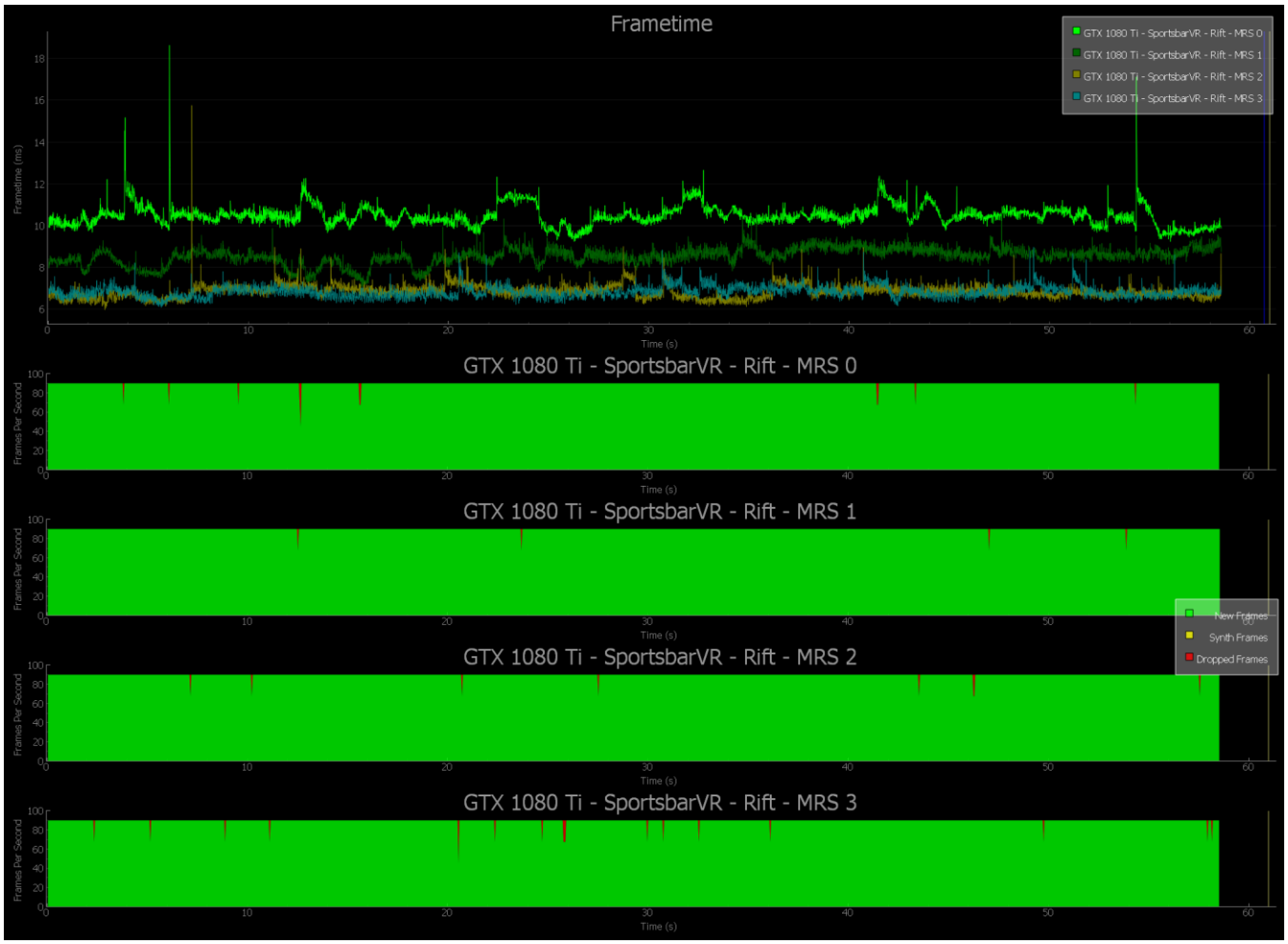
Sports Bar VR MRS with GTX 1060 | Medium Settings



Sports Bar VR MRS with GTX 1080 | Ultra Settings



Sports Bar VR MRS with GTX 1080 Ti | Ultra Settings



Raw Data | MRS

Neo-Shinjuku—2271. The massive and seemingly benevolent Eden Corporation owns the world. The elite hacker resistance movement SyndiK8 has unearthed the sinister reality behind Eden Corp's newest line of robotic products. As one of SyndiK8's top operatives, your mission is simple: infiltrate Eden Tower, steal one geopbyte of data, and get out alive—bringing Eden Corp down in your wake.

Built from the ground up for virtual reality, Raw Data's action combat gameplay, intuitive controls, challenging enemies, and sci-fi atmosphere will completely immerse you within the game world. Go solo—or team up with a friend—and become the adrenaline-charged heroes of your own futuristic technothriller. You will put your wits, boldness, and endurance to the test.

Active VR gameplay turns you into a controller, with instant reflex access to an arsenal of advanced weapons and cutting-edge nanotech powers. Shared spaces with avatars and motion tracking encourage players to physically communicate through body language and environment interaction.

Raw Data | MRS Hardware Requirements

Go to *Raw Data's* main menu, select Options, then Graphics. The last entry under the graphics settings will be Multi-Res Level. You can select from these MRS settings: Off, 1, 2, and 3.

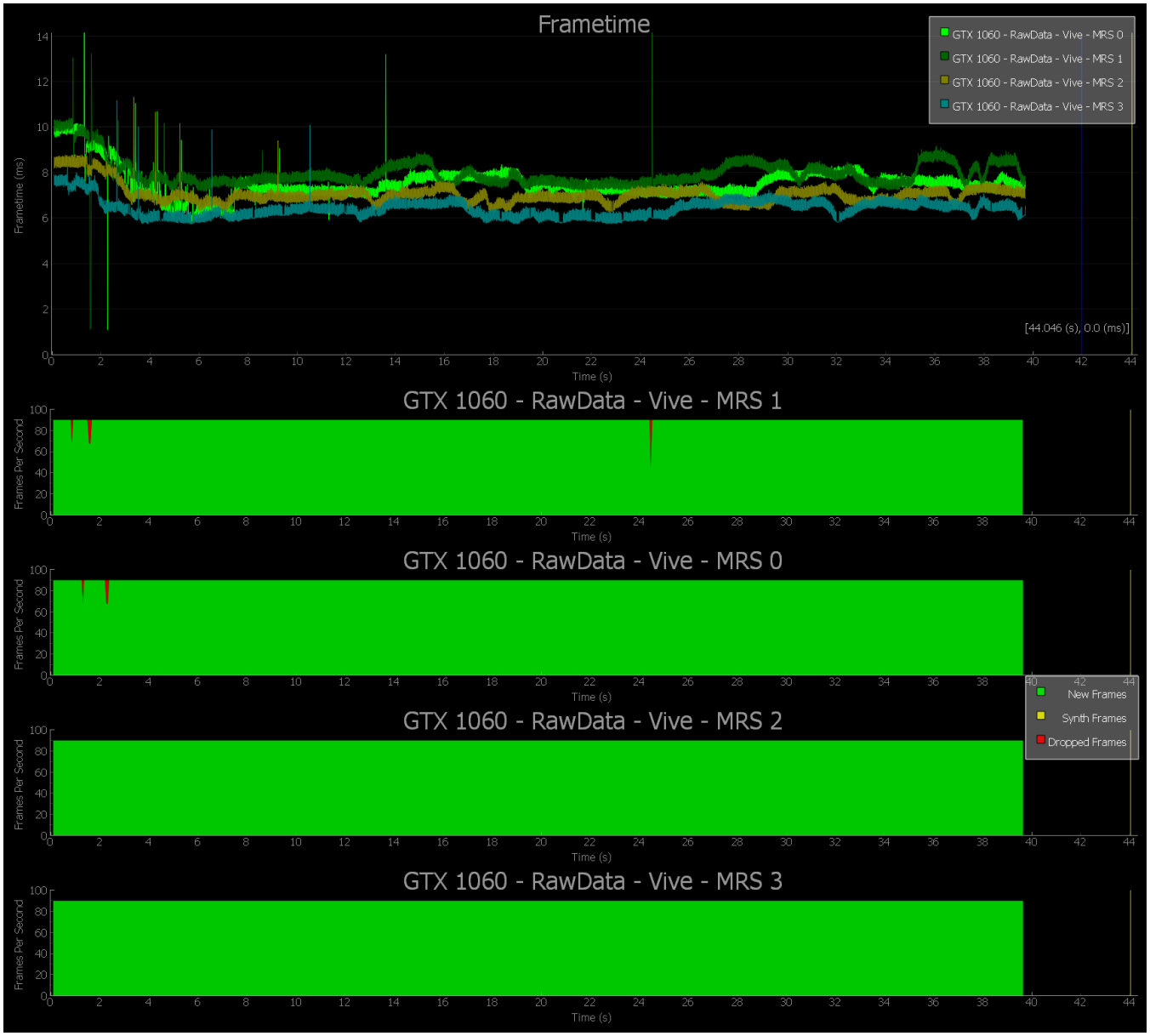
Settings Used:

Raw Data MRS Presets	LOW	EPIC
GPU	GTX 1060	GTX 1080

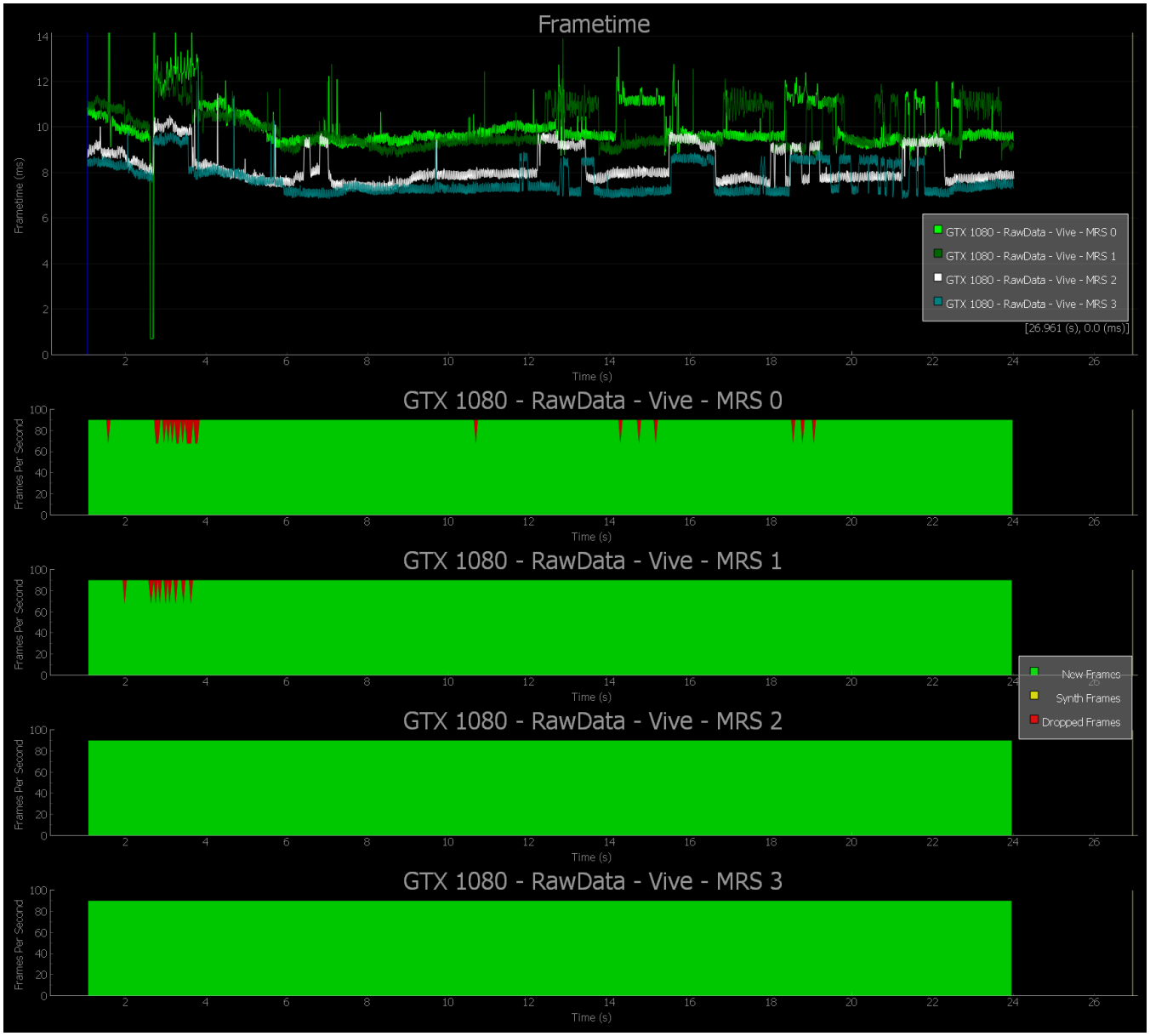
Raw Data | FCAT VR MRS Charts

The following charts show a comparison of MRS settings across the GTX 1060, GTX 1080, and GTX 1080 Ti GPUs. This data was captured using the **FCAT VR Software Capture** tool, which captures and analyzes dropped frames and warp misses in VR gameplay. The FCAT VR Data Analyzer was used to generate the charts.

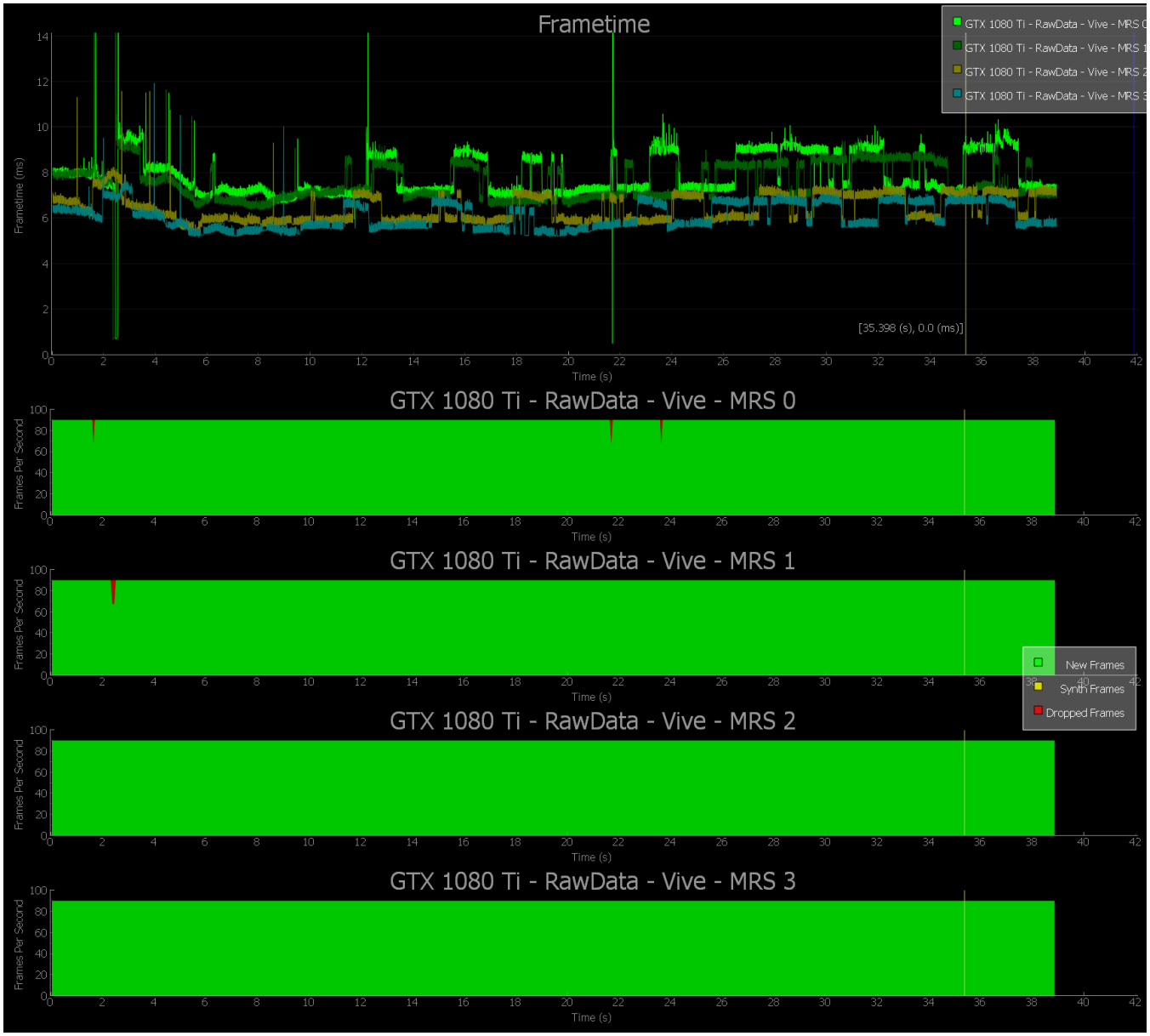
Raw Data with GTX 1060 | Low Settings



Raw Data with GTX 1080 | Epic Settings



Raw Data with GTX 1080 Ti| Epic Settings



LENS-MATCHED SHADING (LMS) GAMES

Everest VR | LMS

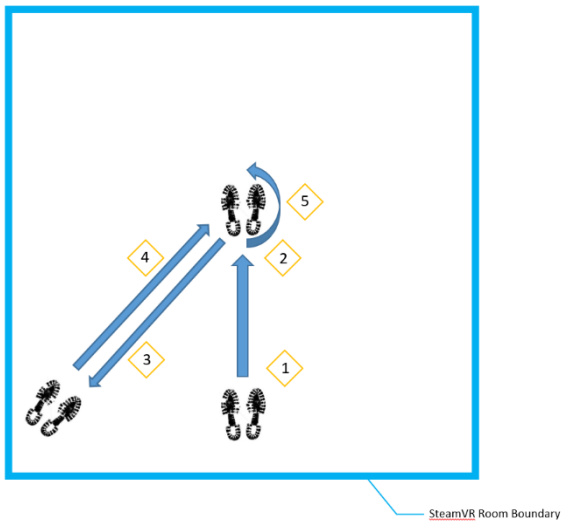
Everest VR allows you to experience what it feels like to climb Mount Everest in a series of first person challenges as you strive to reach Everest summit. Incomparable visual fidelity combine with player agency in a VR journey that feels both real and emotionally stunning. Developed by VR studio Sólfar in partnership with RVX—the Nordics' leading visual effects and animation house—*Everest VR* is designed from the ground up for virtual reality.

NVIDIA Turbulence

NVIDIA Turbulence enables high definition smoke and fog interaction, dust devils, sand and snow storms as well as supernatural effects in games to provide a much more dynamic and interactive game experience. It can be used to augment any existing particle techniques with realistic response to moving solid objects and turbulent fluid motion. The simulation quality can be easily scaled up or down based on target platform performance. The authoring tool allows the artist to change parameters such as fluid viscosity, turbulence and particle mass to create inspiring particle effects based on fluid dynamics.

Climbing Guide

1. Starting Position, walk forward
2. Camp 4 Base Sight
    a. Teleport to Blue Tent
    b. Get Oxygen Mask; unzip Tent
    c. Get Head Lamp
3. Walk to corner position
4. Carabiner cliff walk



Everest VR | LMS Hardware Requirements

To access LMS settings in *Everest VR,* press the menu button on a Vive controller and select Graphic Settings. The Graphic Settings menu will appear and the first settings option will be Multires. Press the - or + button to toggle between the different LMS settings.

NOTE: The settings below were given names to more easily differentiate them by GPU.

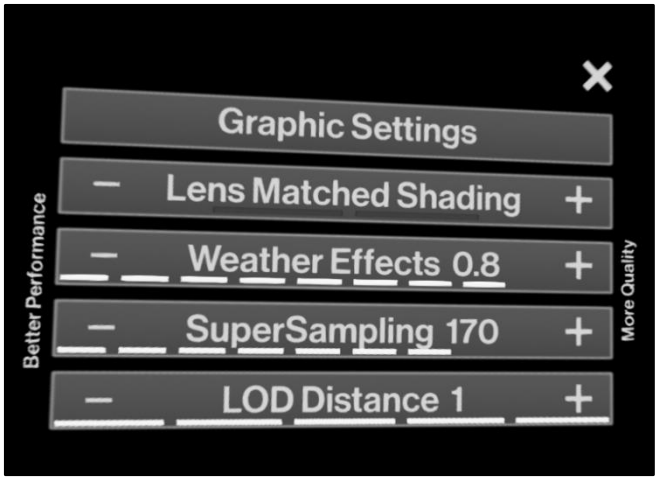
EVEREST VR MRS Settings	"Medium Settings"	"High Settings"
Recommended GPU	**GTX 1060**	**GTX 1080**
Weather Effects	0.4	0.8
Supersampling	140	170
LOD Distance	1	1

Everest VR is recommended with the following NVIDIA GeForce™ GTX Graphics cards:

"Medium Settings": GeForce GTX 1060

"High Settings": GeForce GTX 1080 or greater

Supported VR Headsets: HTC Vive



The Settings Explained

Lens Matched Shading (LMS): NVIDIA specific optimization that provides performance improvements in pixel shading by avoiding the rendering of pixels that end up being discarded in the final view sent to the HMD after the distortion process. LMS is supported by Pascal architecture GPUs.

Weather Effects: This controls the amount of particle effects used throughout the experience to simulate weather. The default value is 0.4, while 0.0 turns them off. Higher values will result in more dramatic effects.

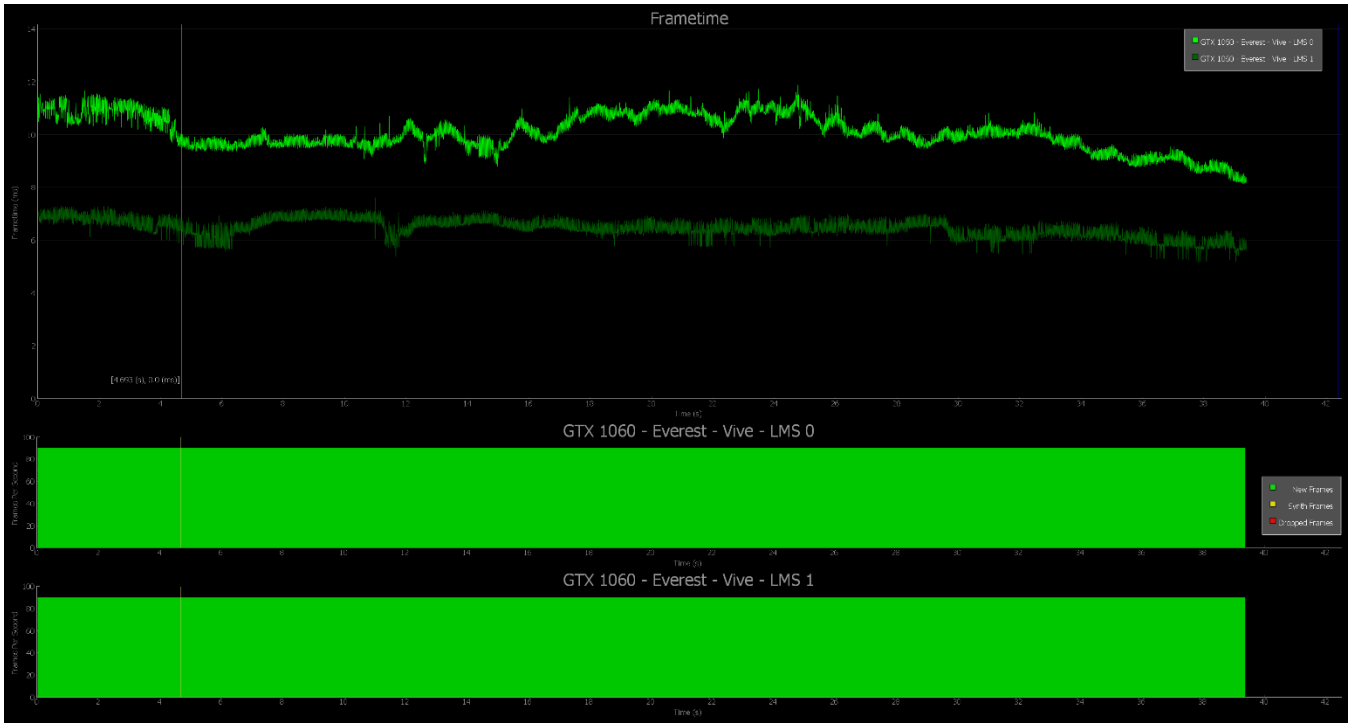
SuperSampling: By default, Unreal renders into a screen buffer that is 40% higher than the Vive display and scales the result down to the native resolution. This results in crisper textures. This default setting is displayed as 140. Increasing the screen percentage will result in increasingly crisper images, but at the cost of performance. High-end GPUs should have room to increase this significantly.

LOD Distance: Geometry has a series of increasingly higher levels of detail based on the distance from the viewer. This multiplier affects at what distance higher density geometry is activated. Lower is better.

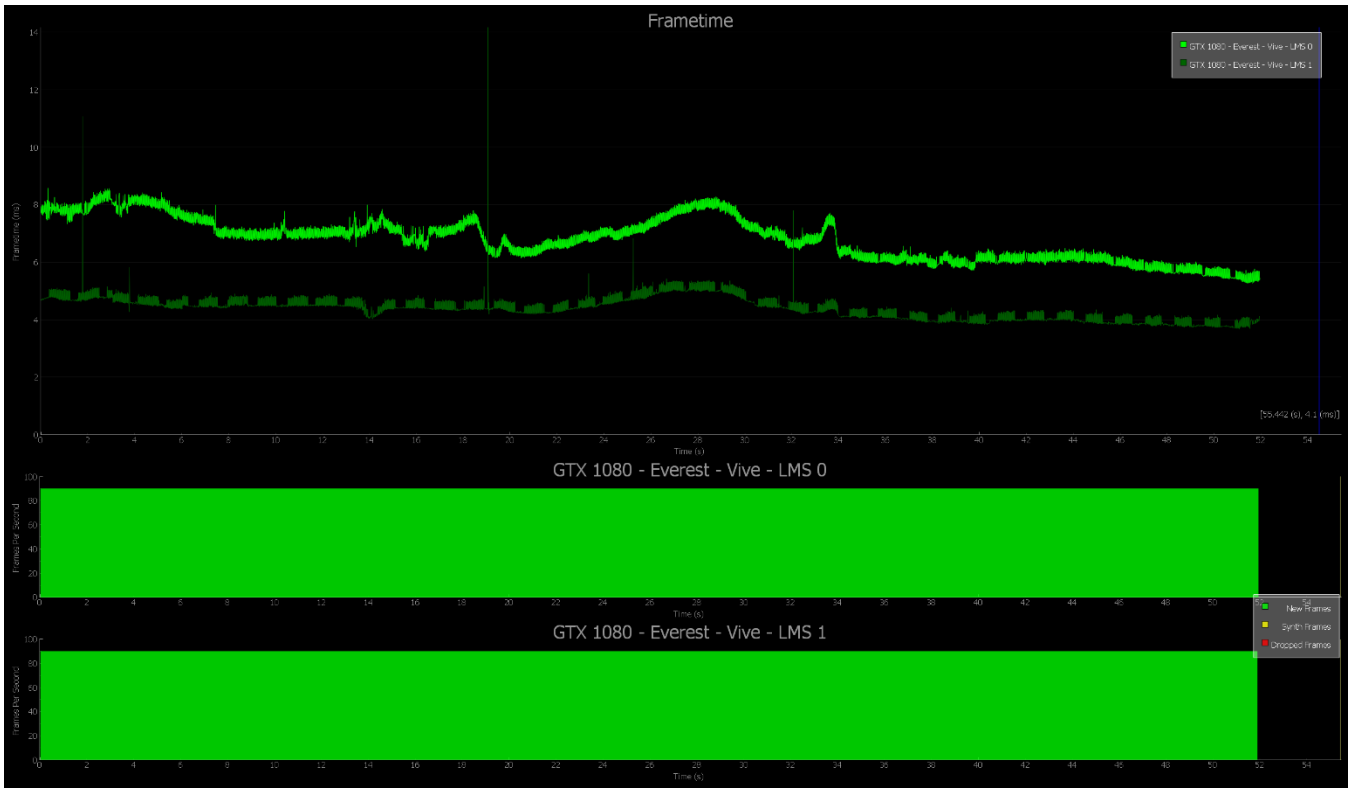
Everest | FCAT VR LMS Charts

The following charts show a comparison of LMS settings across the GTX 1060, GTX 1080, and GTX 1080 Ti GPUs. This data was captured using the **FCAT VR Software Capture** tool, which captures and analyzes dropped frames and warp misses in VR gameplay. The FCAT VR Data Analyzer was used to generate the charts.

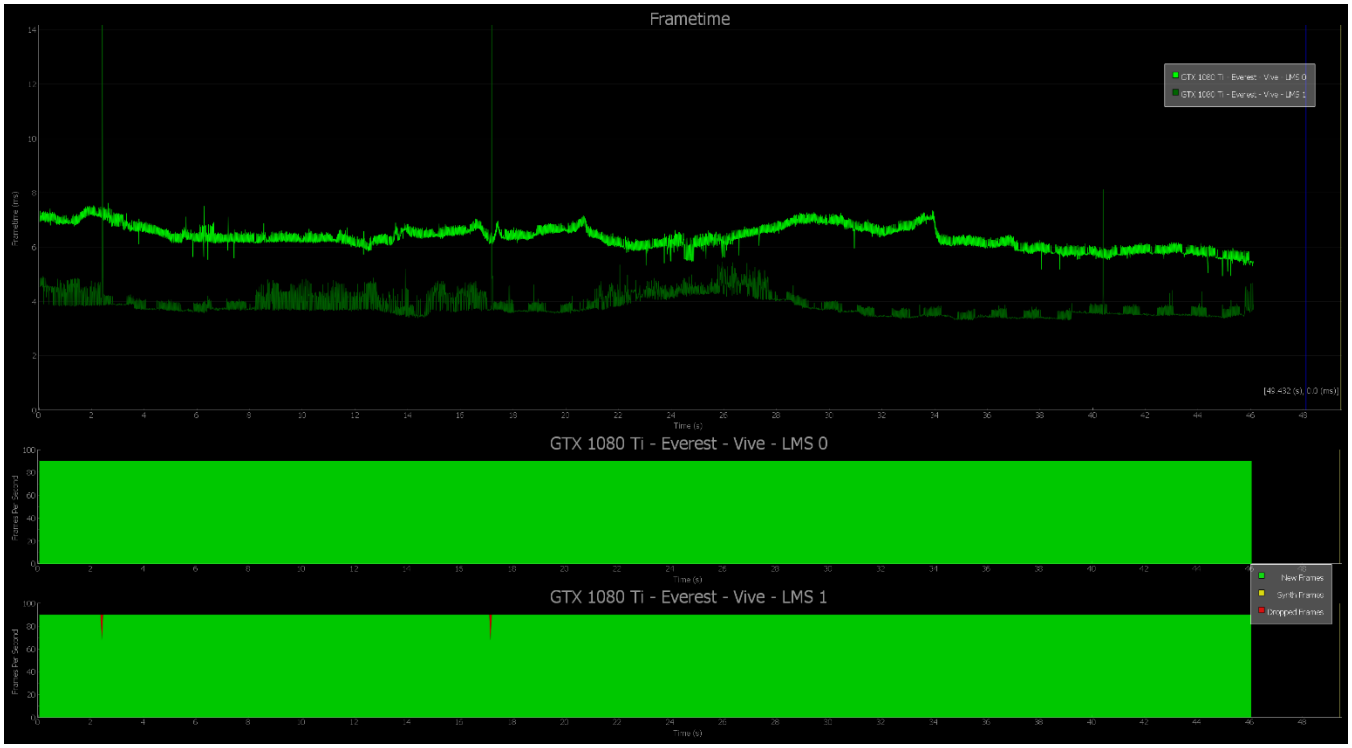
Everest LMS with GTX 1060 | "Medium Settings"



Everest LMS with GTX 1080 | "High Settings"



Everest LMS with GTX 1080 Ti | "High Settings"



VR-SLI GAMES

VR SLI provides increased performance for virtual reality apps where multiple GPUs can be assigned a specific eye to dramatically accelerate stereo rendering. With the GPU affinity API, VR SLI allows scaling for systems with more than two GPUs.

Serious Sam VR: The Last Hope | VR-SLI

Simulating physics takes incredible processing power, and we found it by applying NVIDIA VRWorks technologies, including Multi-Res Shading and VR SLI, to increase rendering performance.

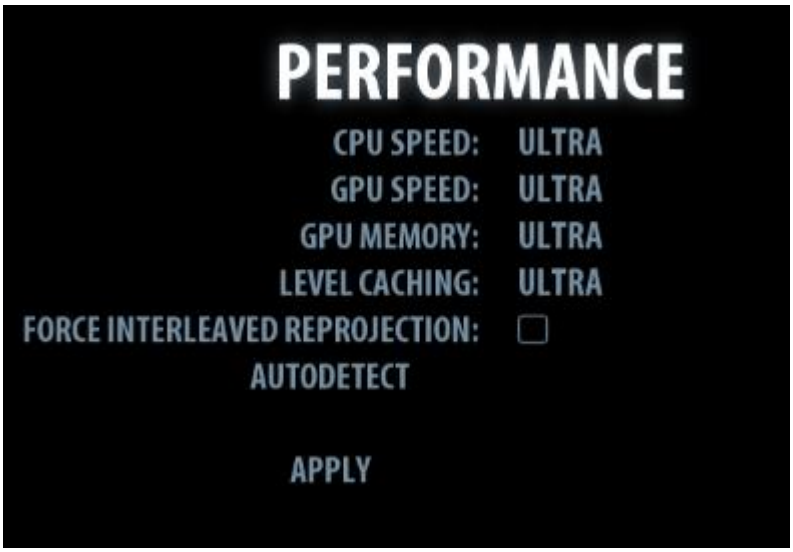
Serious Sam VR: The Last Hope | VR-SLI Hardware Requirements

From the Serious Sam VR: The Last Hope main menu, slect **Options**, then **Performance**.

Settings Used:

NOTE: These settings were chosen to best show VR-SLI scaling.

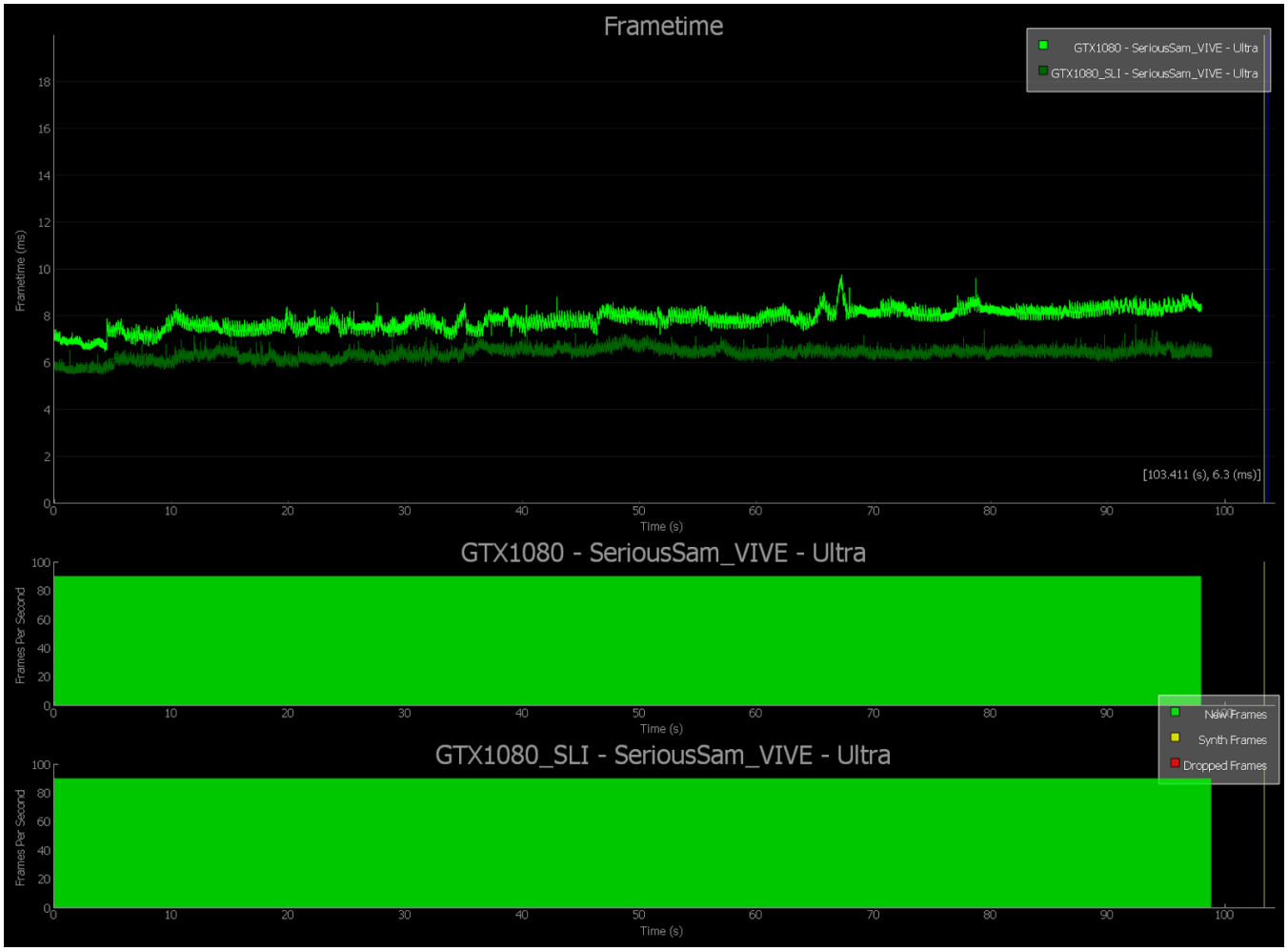
Serious Sam VR-SLI Presets	Ultra Settings
Single GPU	GTX 1080
VR-SLI	2 x GTX 1080



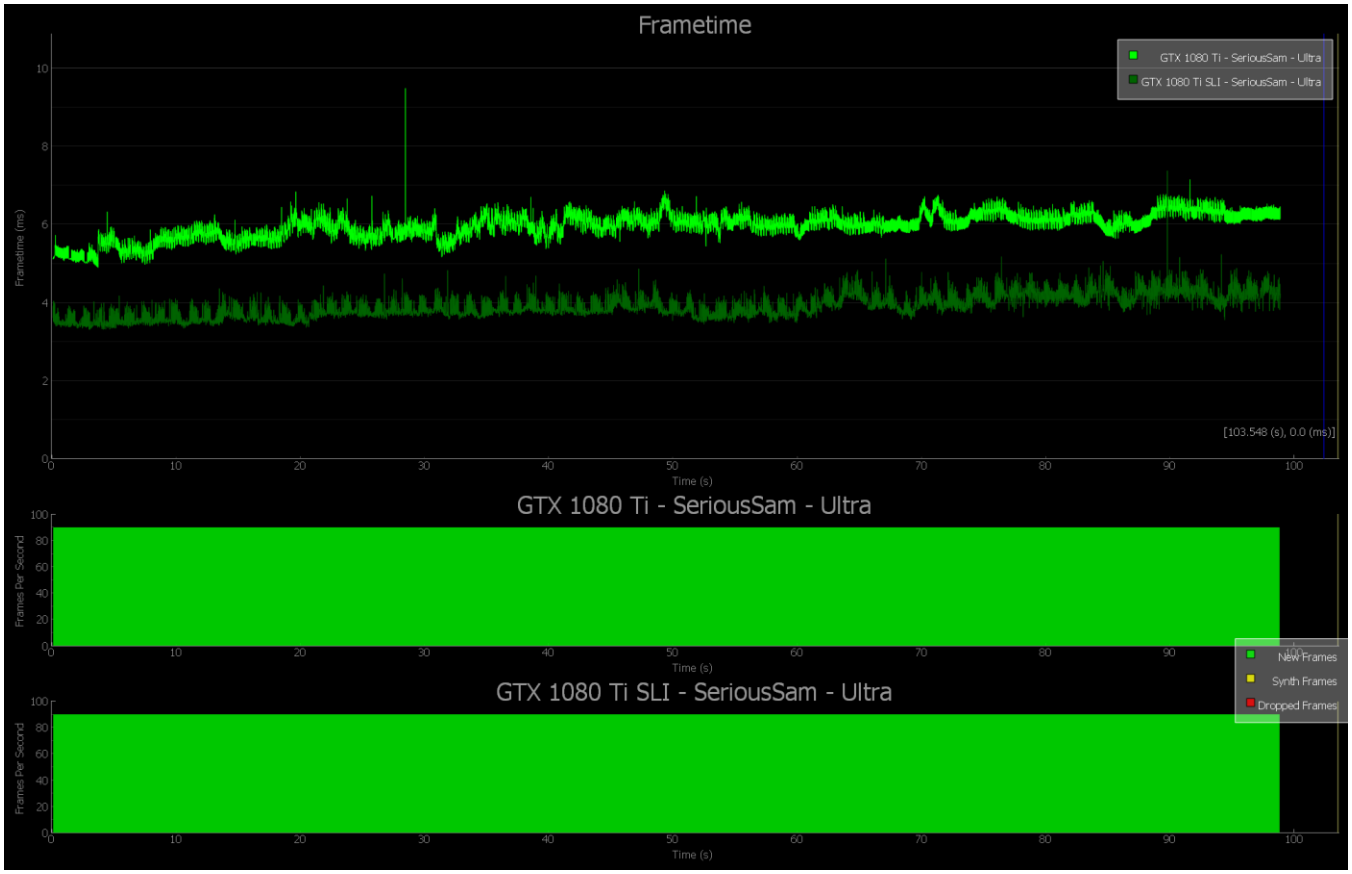
Serious Sam VR: The Last Hope | FCAT VR-SLI Charts

The following charts show a comparison of MRS settings across the GTX 1080 and GTX 1080 Ti GPUs. This data was captured using the **FCAT VR Software Capture** tool, which captures and analyzes dropped frames and warp misses in VR gameplay. The FCAT VR Data Analyzer was used to generate the charts.

Serious Sam VR Single vs. SLI GTX 1080 | Ultra Settings



Serious Sam VR Single vs. SLI GTX 1080 Ti | Ultra Settings



Trials on Tatooine | VR-SLI

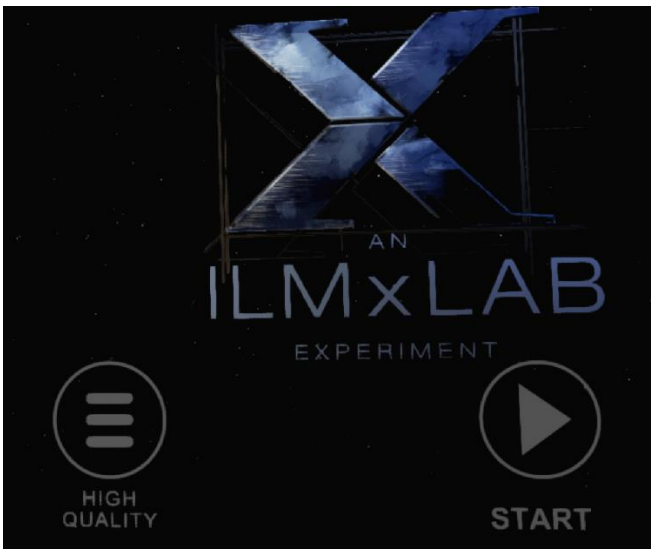
Simulating physics takes incredible processing power, and we found it by applying NVIDIA VRWorks technologies, including Multi-Res Shading and VR SLI to increase rendering performance.

Trials on Tatooine | VR-SLI Hardware Requirements

From the main menu, choose the desired preset before selecting start.

NOTE: These settings were chosen to best show VR-SLI scaling.

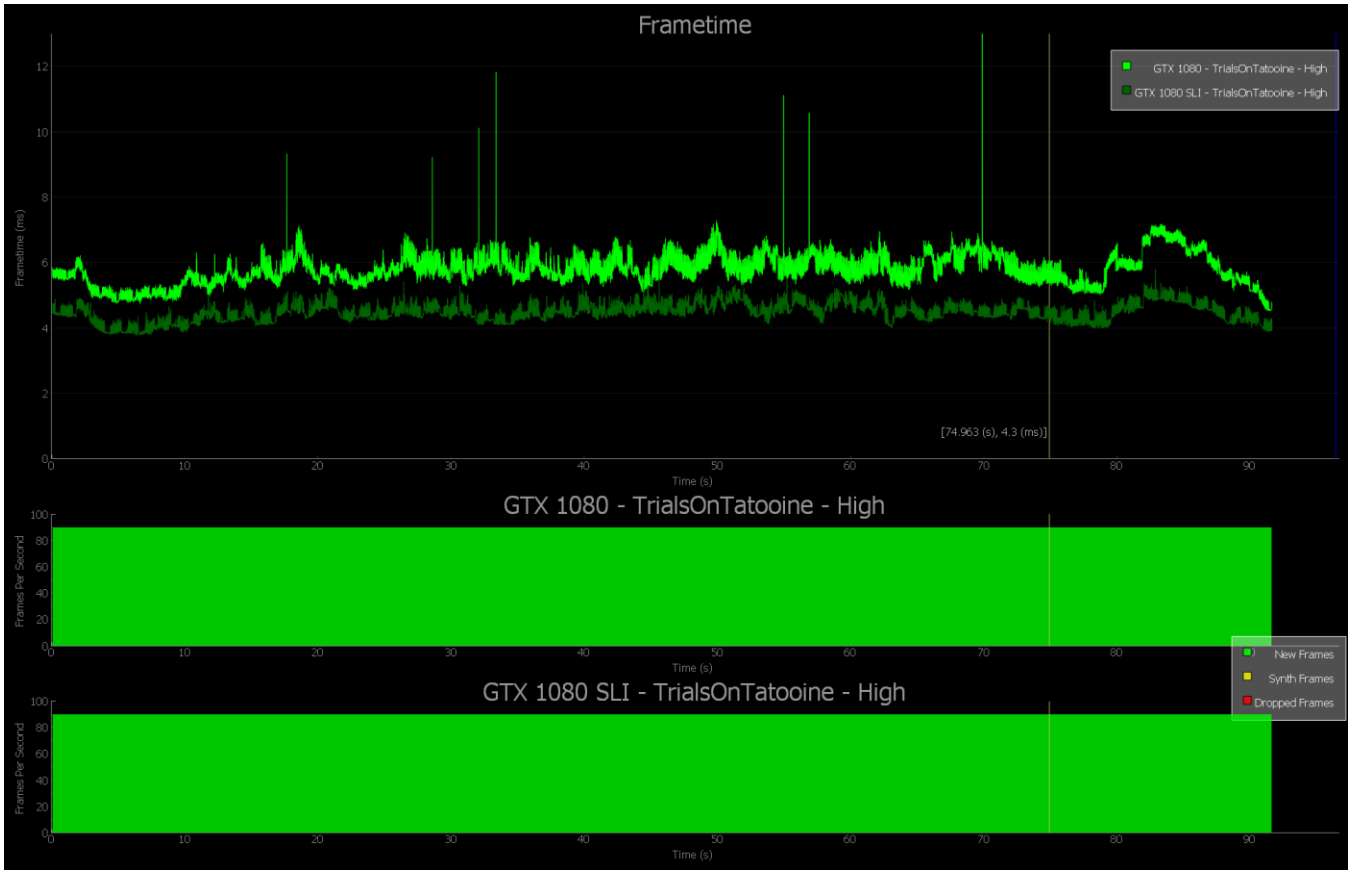
Trials on Tatooine	High
Single GPU	GTX 1080
VR-SLI	2 x GTX 1080



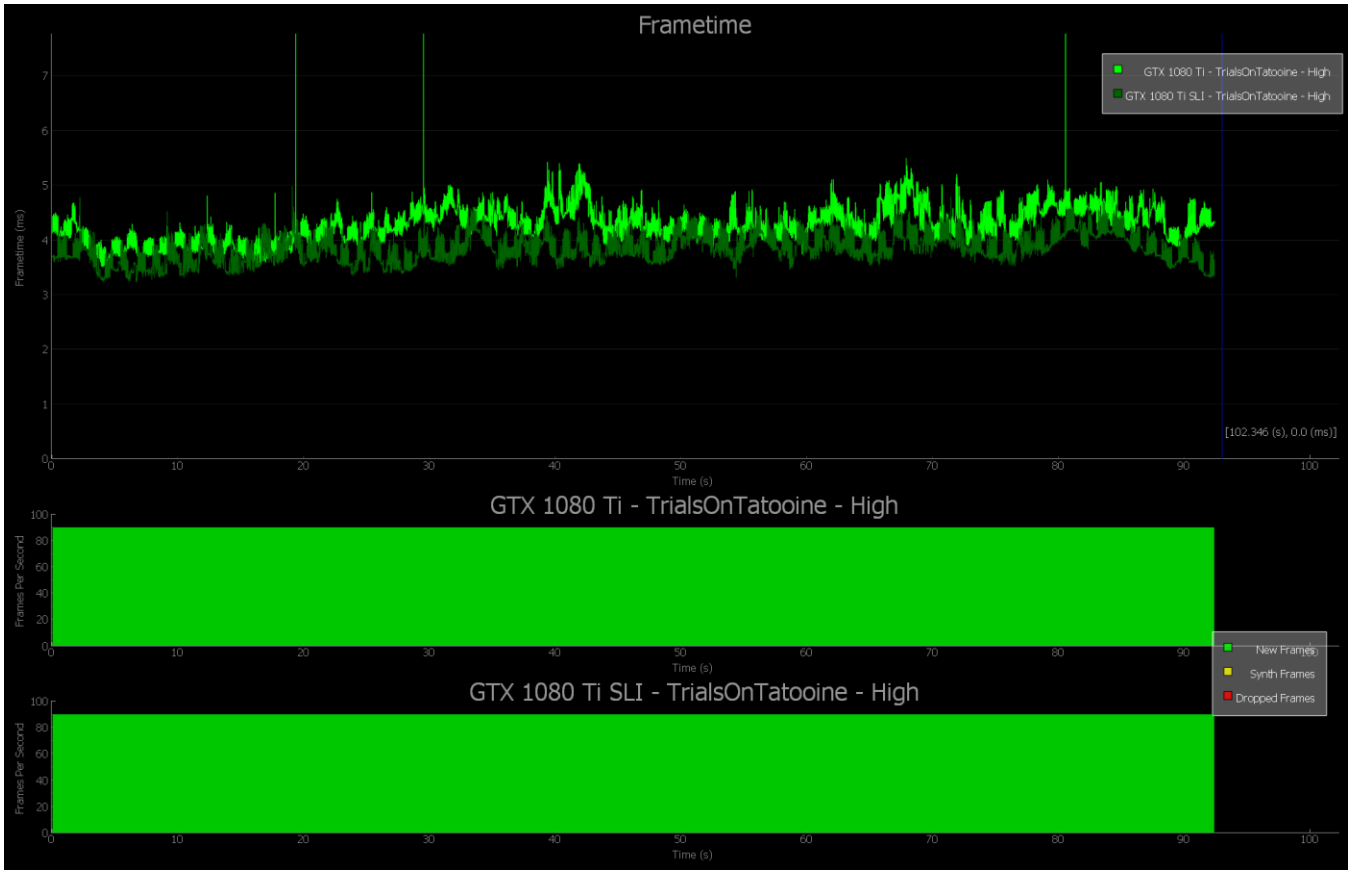
Trials on Tatooine | FCAT VR-SLI Charts

The following charts show a comparison of single vs. (dual) SLI GPUs. This data was captured using the **FCAT VR Software Capture** tool, which captures and analyzes dropped frames and warp misses in VR gameplay. The FCAT VR Data Analyzer was used to generate the charts.

Trials on Tatooine with Single vs. SLI GTX 1080 | Ultra Settings



Trials on Tatooine Single vs. SLI GTX 1080 Ti | Ultra Settings



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