



Technical Guide

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HOW TO USE VRMARK

VRMark is a benchmarking application for measuring VR performance. It is built around performance levels, which we call Rooms. A Room is a piece of VR content carefully designed to require a specific level of VR performance.

There are three Rooms in the latest version of VRMark. The Orange Room is based on the recommended hardware requirements for the HTC Vive and Oculus Rift. The Cyan Room is heavier test that also uses DirectX 12. The Blue Room is a very demanding test that sets a high bar for future hardware generations.

Each Room can be run as a Benchmark, which tests performance objectively, or as a free-roaming Experience, which lets you judge the quality of the rendering with your own eyes.

In addition, each Benchmark and Experience can be run on your monitor in Desktop mode, no headset required, or on a connected headset in HMD mode.

With three Rooms, two run modes, two platform modes, and custom settings, VRMark provides a wide range of options for testing and evaluating the VR performance of the latest PC hardware.

	DESKTOP MODE	HMD MODE
BENCHMARK	"Is my PC ready for VR?" – Test your system before you buy a headset.	See how a system performs with actual VR hardware and software.
EXPERIENCE	Enjoy exploring each scene in your own time on your monitor.	Judge the subjective quality of the VR experience with your own eyes.

CHOOSE A PERFORMANCE LEVEL

VRMark measures your PC's ability to meet the performance requirements for different types of virtual reality content. The latest release includes three levels based on VR gaming content.

Orange Room

The Orange Room benchmark shows the impressive level of detail that can be achieved on a PC that meets the recommended hardware requirements for the HTC Vive and Oculus Rift. A PC that passes this test is ready for the two most popular VR systems available today.

Cyan Room

Cyan Room is a DirectX 12 benchmark. Sitting between the Orange and Blue Rooms, it features a large, complex scene and many eye-catching effects. Cyan Room shows how using an API with less overhead can help developers deliver impressive VR experiences even on modest PC systems.

Blue Room

The Blue Room is a much more demanding test. It's ideal for benchmarking the latest graphics cards. With its massive 5K rendering resolution and spectacular volumetric lighting effects, the Blue Room sets the bar for future hardware generations.

CHOOSE AN EVALUATION MODE


VRMark offers two modes that let you test and assess VR performance both objectively and subjectively.

Benchmark mode

The purpose of the benchmark is to measure a PC's ability to meet the performance requirements for a specific level of virtual reality content. The benchmark workload runs on a fixed path, which makes it easy to repeat the test on other systems.

In desktop mode, the benchmark runs on your monitor. A headset is not required. At the end of the test, you'll see whether your PC is VR-ready for that level of content, and if not, how far it falls short. See the [Results](#) section later in this guide for more details.

In HMD mode, you can run the benchmark on a connected headset to test performance with actual VR hardware and runtime libraries. Note that VR software limits the frame rate to the refresh rate of the headset, which is 90 Hz for both HTC Vive and Oculus Rift. This means that the frame rate will be capped at 90 FPS even when the system is capable of rendering at a higher frame rate.

 For your own comfort, you should not wear the headset while running the benchmark in HMD mode.

Experience mode

In Experience mode, you can freely explore each test scene in your own time.

With a connected HMD, Experience mode is a great way to see the quality of the VR experience on the system with your own eyes. VR headsets use clever techniques to compensate for missed frames and low frame rates. Even when the benchmark shows that the average frame rate is below the target, you may be surprised by the quality of the experience in Experience mode.

In desktop mode, Experience mode runs on your monitor. Take your time and enjoy getting up close to the scenes.

Experience mode does not produce a score or other results.

CHOOSE A PLATFORM

You can choose to run VRMark on your desktop monitor or on a connected VR HMD. The test content is identical whichever platform you choose.

Desktop mode

Desktop mode runs on your monitor, no headset required. It's the ideal way to answer the question, "Is my PC ready for VR?" before buying a headset.

Desktop mode is the default in VRMark. The workload is exactly the same as when an HMD is connected. It has the same resolution and a view is rendered for each eye.

HMD mode

When a supported HMD¹ is attached to the system, choosing HMD mode will render the workload on the headset. Note that the frame rate will be capped at 90 FPS when running on an HTC Vive or Oculus Rift as these HMDs are limited by vertical sync at 90 Hz.

To use HMD mode, go to the OPTIONS screen and set "Allow content to run on an HMD" to Yes.

¹ VRMark currently supports HTC Vive and Oculus Rift.

TARGET FRAME RATE

A system is said to have passed the benchmark when the average frame rate during the run meets or exceeds the target frame rate for the test.

	TARGET FRAME RATE
HMD MODE	88.9 FPS
DESKTOP MODE	109 FPS

The benchmark workload is the same whether it is run on an HMD or on the desktop. The target frame rate for desktop mode, however, is higher than the target frame rate for HMD mode. The difference is explained by VR SDK overhead and HMD refresh rate.

VR SDK overhead

To achieve 90 FPS, the system must create and present each frame within 11 ms. When running on an HMD, however, there is additional CPU overhead. The VR SDK reserves 1–3 ms of time for each frame, depending on the HMD and the state. This time is used for reading the sensors, motion prediction, techniques like asynchronous time warp and frame reprojection, and for image manipulation to allow for lens distortion.

When running on the desktop, there is no SDK overhead, which enables the system to achieve a higher frame rate.

HMD refresh rate

When running on an HMD, the system is always locked to the refresh rate of the headset, which is 90 Hz for both the HTC Vive and Oculus Rift. This means that the frame rate is capped to a maximum of 90 FPS. The concept is similar to vertical sync on a desktop monitor, though the implementation in the VR SDK is more complex. The result is that even when the system is capable of rendering an individual frame faster, it must wait for the VR SDK before moving on to the next frame.

There is no such restriction when running in desktop mode. As soon as the system is finished with one frame, it can move on to the next. These savings are then reflected in a higher average frame rate for the complete run.

JUDGE WITH YOUR OWN EYES

One of the hurdles for VR becoming mainstream is that the performance requirements are far higher than for a typical game.

When a system's average frame rate is below the target frame rate for the test, it means the system is not strictly VR-ready for that level of VR content. However, VR headsets will use clever techniques to compensate for the missed frames. In many cases, these techniques are very effective at providing a good-quality VR experience for the user by covering up missed frames.

When a system falls short of the benchmark's target frame rate, we highly recommend trying Experience mode with an HMD for yourself. You may find that, even though the rendering frame rate is below the target, the actual experience with a headset is still comfortable and enjoyable.

This is especially the case for systems with the recently announced, lower minimum hardware requirements for the Oculus Rift. These systems cannot render the Orange Room benchmark at 90 FPS on an HMD. Instead, they rely on a technique called [Asynchronous SpaceWarp](#) (ASW) in the Oculus Runtime.

"The Rift operates at 90 Hz. When an application fails to submit frames at 90 Hz, the Rift runtime drops the application down to 45 Hz with ASW providing each intermediate frame. ASW applies animation detection, camera translation, and head translation to previous frames in order to predict the next frame. As a result, motion is smoothed and applications can run on lower performance hardware."

SETUP AND SETTINGS

EDITIONS

VRMark is available in a range of editions to meet the needs of different users.

	BASIC EDITION	ADVANCED EDITION	PROFESSIONAL EDITION
LICENSED FOR COMMERCIAL USE	×	×	●
ORANGE ROOM BENCHMARK	●	●	●
ORANGE ROOM EXPERIENCE	●	●	●
CYAN ROOM BENCHMARK	×	●	●
CYAN ROOM EXPERIENCE	×	●	●
BLUE ROOM BENCHMARK	×	●	●
BLUE ROOM EXPERIENCE	×	●	●
DESKTOP MODE	●	●	●
HMD MODE	●	●	●
DETAILED RESULTS	×	●	●
HARDWARE MONITORING	×	●	●
CUSTOM SETTINGS	×	●	●
SAVE RESULTS OFFLINE	×	●	●
PRIVATE, OFFLINE RESULTS OPTION	×	×	●

	BASIC EDITION	ADVANCED EDITION	PROFESSIONAL EDITION
COMMAND LINE AUTOMATION	X	X	•
SUPPORT	Online	Online	Email & phone
PRICE	Free	\$19.99	From \$995 p.a.

SYSTEM REQUIREMENTS FOR VR HMDS

HTC Vive

	RECOMMENDED
OS	Windows 7 with SP1 64-bit
PROCESSOR	Intel Core i5-4590 or AMD FX 8350
RAM	4 GB
GPU	NVIDIA GeForce GTX 1060 or AMD Radeon RX 480
VIDEO OUTPUT	HDMI 1.4 or DisplayPort 1.2
USB PORTS	1×USB 2.0

Oculus Rift


	RECOMMENDED	MINIMUM ²
OS	Windows 7 with SP1, 64-bit	Windows 8, 64-bit
PROCESSOR	Intel Core i5-4590	Intel Core i3-6100 or AMD FX 4350
RAM	8 GB	8 GB
GPU	NVIDIA GeForce GTX 970 or AMD R9 290	NVIDIA GeForce GTX 960
VIDEO OUTPUT	HDMI 1.3	HDMI 1.3

² Announced at Oculus Connect on October 6, 2016. The minimum spec relies on Asynchronous SpaceWarp.

	RECOMMENDED	MINIMUM ²
USB PORTS	3×USB 3.0 1×USB 2.0	1×USB 3.0 2×USB 2.0

HOW TO BENCHMARK PERFORMANCE

To get accurate, consistent benchmark results you should test clean systems without third party software installed. If this is not possible, you should close as many background tasks as possible, especially automatic updates or tasks that feature pop-up alerts such as email and messaging programs.

 When running in desktop mode, ensure that HMD processes, such as the SteamVR empty world scene and the Oculus Rift home scene, are closed as they can negatively affect your results.

Vertical sync, FreeSync, and G-SYNC can also negatively affect your results. They should be disabled before running the benchmark.

Recommended process

1. Install all critical updates to ensure your operating system is up to date.
2. Install the latest drivers for your hardware.
3. Close other programs.
4. Run the benchmark.

Expert process

1. Install all critical updates to ensure your operating system is up to date.
2. Install the latest drivers for your hardware.
3. Restart the computer or device.
4. Wait 2 minutes for startup to complete.
5. Close other programs, including those running in the background.
6. Wait for 15 minutes.
7. Run the benchmark.
8. Repeat from step 3 at least three times to verify your results.

OPTIONS

License

If you have a VRMark Advanced Edition or Professional Edition upgrade key, copy it into the box and press the Register button. To unregister your key, to move your license to a different PC for example, press the Unregister button.

Version details

Here you see the current version number of the VRMark application and the different Rooms. If a newer version is available, you will be able to update from this screen.

Language

Use this drop down to change the display language. Your choices are:

- English
- German
- Simplified Chinese
- Russian

Experience mode audio

Use this setting to turn the sound effects in Experience mode on or off. The option is provided as a preference. It has no effect on performance.

Validate result online

This option is only available in VRMark Professional Edition where it is disabled by default. In VRMark Basic and Advanced Editions, all results are validated online automatically.

Automatically hide results online

Check this box if you would prefer to keep your VRMark scores private. Hidden results are not visible to other users and do not appear in search results.

- VRMark Basic Edition, disabled by default and cannot be selected.
- VRMark Advanced Edition, disabled by default.
- VRMark Professional Edition, selected by default.

Scan SystemInfo

SystemInfo is a component used in UL benchmarks to identify the hardware in your system or device. It does not collect any personally identifiable


information. This option is selected by default and is required in order to get a valid benchmark test score.

SystemInfo hardware monitoring

This option controls whether SystemInfo monitors your GPU frequency, load, and temperature, and other hardware information during the benchmark run. This option is selected by default.

Allow content to run on an HMD

Selecting this option lets you use your VR headset as the output device instead of your desktop monitor. When you run a Benchmark or Experience on a VR headset, the frame rate will be capped at 90 frames per second. You will not get full result details.

 The benchmarks use an animated camera. For your own comfort, you should not wear the headset while the test is running. Some headsets, such as the Oculus Rift, detect whether the headset is being worn. You will need to cover the proximity sensor with your finger or tape. Or you can place the headset on your forehead rather than over your eyes.



VRMARK ORANGE ROOM

ORANGE ROOM BENCHMARK

The VRMark Orange Room benchmark shows the impressive level of detail that can be achieved on a PC that meets the recommended hardware requirements for the HTC Vive and Oculus Rift. If your PC passes this test, it's ready for the two most popular VR systems available today.

Target frame rate

The Orange Room benchmark has been carefully tuned so that a system with the recommended hardware for HTC Vive and Oculus Rift will achieve a consistent average frame rate of 90 FPS when running on an HMD. The target frame rate is slightly lower, 88.9 FPS, to allow for occasional missed frames.

On the desktop, the same workload running on the same hardware achieves a consistent average frame rate of 109 FPS. The difference is explained by VR SDK overhead and the HMD refresh rate, as [explained earlier in this guide](#).

Implementation

The Orange Room benchmark focuses on geometry processing, illumination and GPU simulated particles. The test uses a deferred, tile-based lighting method with seven shadow-casting spotlight. It features bloom effects and uses FXAA as an anti-aliasing solution.

The benchmark features CPU simulated physics using the Bullet Open Source Physics C++ Library. CPU simulated cloths are created using RigidBody, SoftBody and DynamicsWorld.


The rendering resolution is 2264×1348 , which is 1132×1348 per eye. When a headset is connected, the rendered image is distorted to make it look natural when seen through the headset's lens and then scaled to the native display resolution, 1080×1200 per eye, used by both the HTC Vive and the Oculus Rift.

Benchmarking on your desktop

By default, the benchmark runs on your monitor to show you whether your PC is VR-ready before you purchase a VR headset. To pass the test, your PC has to maintain a consistent frame rate of 109 FPS or above without dropping frames.

Benchmarking with an HMD connected

You can choose to run the test on a connected HMD from the OPTIONS screen. Some VR headsets, such as the Oculus Rift, detect whether the headset is being worn. You will need to cover the proximity sensor with your finger or tape. Or you can place the headset on your forehead rather than over your eyes. The target frame rate is 88.9 FPS when an HMD is connected.

 VRMark benchmark tests use an animated camera. For your comfort, please take off your headset while the test is running.

ORANGE ROOM EXPERIENCE

In Experience mode, you can freely explore the test scene in your own time.

With a connected HMD, Experience mode is a great way to see the quality of the VR experience on the system with your own eyes. VR headsets use clever techniques to compensate for missed frames and low frame rates. Even when the benchmark shows that the average frame rate is below the target, you may be surprised by the quality of the experience in Experience mode.

On the Custom Run screen, you can change the rendering resolution and other settings to make the scene more or less demanding. This is a great way to see how performance affects your personal VR experience.

In desktop mode, Experience mode runs on your monitor. Take your time and enjoy exploring the scene. Try pressing the Space bar to toggle the flashlight on and off.

CONTROLS FOR EXPERIENCE MODE

HTC Vive

ACTION	VIVE CONTROLLER
--------	-----------------

Flashlight on/off	Touchpad button
-------------------	-----------------

Oculus Rift

ACTION	KEYBOARD OPTION 1	KEYBOARD OPTION 2	GAMEPAD
--------	----------------------	----------------------	---------

Move	WASD + QE	Arrows + PageUp/Dn	Left stick
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Flashlight on/off	Space	Return	A button
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Reset camera	R	R	X button
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Monitor

ACTION	KEYBOARD OPTION 1	KEYBOARD OPTION 2	GAMEPAD
--------	----------------------	----------------------	---------

Look	Mouse	Mouse	Right stick
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Move	WASD + QE	Arrows + PageUp/Dn	Left stick
------	-----------	-----------------------	------------

Flashlight on/off	Space	Return	A button
-------------------	-------	--------	----------

Press the Esc key to end the Experience and return to the application.

CUSTOM RUNS

You can change the rendering resolution and other settings on the Custom run screen. The settings you choose apply to Benchmark and Experience modes.

Making the scene more or less demanding with custom settings, then running Experience mode on an HMD is a great way to see how system performance affects your personal VR experience.

Options

	DEFAULT
WINDOW MODE	Yes
LOOPING	No
WIREFRAME	No
PHYSICS SYSTEMS DISABLED	No
PARTICLE SYSTEMS DISABLED	No
FORWARD RENDERING	No
IMMEDIATE CONTEXT	No
FORCE ALWAYS-ON REPROJECTION (HTC VIVE ONLY)	Yes
FORCE OPENVR API (OCULUS RIFT ONLY)	No

Rendering quality

	DEFAULT
RESOLUTION	2264 × 1348
MAX TESSELLATION FACTOR	32
MAX SHADOW MAP TESSELLATION FACTOR	4

	DEFAULT
TEXTURE FILTERING MODE	Trilinear
MAX AF ANISOTROPY	16
ANTIALIASING MODE	FXAA
MSAA SAMPLE COUNT	2
TESSELLATION FACTOR SCALE	1

SYSTEM REQUIREMENTS

OS	Windows 7, 64-bit with SP1
PROCESSOR	Dual core CPU with SSE 4.1 support
RAM	2 GB
GPU	DirectX 11
GPU MEMORY	1.5 GB

DEFAULT SETTINGS

BENCHMARK MODE

RENDERING RESOLUTION	2264 × 1348
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FRAME PRESENTATION	Windowed split-screen
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TARGET DESKTOP FRAME RATE	109 FPS
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TARGET HMD FRAME RATE	88.9 FPS
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VRMARK CYAN ROOM

CYAN ROOM BENCHMARK

Cyan Room is a DirectX 12 benchmark. Sitting between the Orange and Blue Rooms, it features a large, complex scene and many eye-catching effects. Cyan Room shows how using an API with less overhead can help developers deliver impressive VR experiences even on modest PC systems.

Target frame rate

The target frame rate for the Cyan Room benchmark when running in HMD mode is 88.9 FPS, slightly lower than the 90 Hz refresh rate of HTC Vive and Oculus Rift to allow for occasional missed frames.

On the desktop, the same workload running on the same hardware achieves a consistent average frame rate of 109 FPS. The difference is explained by VR SDK overhead and HMD refresh rate, as [explained earlier in this guide](#).

Implementation

The Cyan Room benchmark uses a deferred renderer and focuses on geometry processing, illumination, and GPU-simulated particles. The test uses a deferred tile-based lighting method with several shadow casting spot lights. The test utilizes high-quality SSAO, bloom effects, and CMAA anti-aliasing.

The rendering resolution is 2264×1348 , which is 1132×1348 per eye. When a headset is connected, the rendered image is distorted to make it look natural when seen through the headset's lens and then scaled to the native display resolution, 1080×1200 per eye, used by both the HTC Vive and the Oculus Rift.


Benchmarking on your desktop

By default, the benchmark runs on your monitor. To pass the test, your PC must maintain a frame rate of 109 FPS or above without dropping frames.

Benchmarking with an HMD connected

You can choose to run the test on a connected HMD from the OPTIONS screen. Some VR headsets, such as the Oculus Rift, detect whether the headset is being worn. You will need to cover the proximity sensor with your finger or tape. Or you can place the headset on your forehead rather than

over your eyes. The target frame rate is 88.9 FPS when an HMD is connected.

 VRMark benchmark tests use an animated camera. For your comfort, please take off your headset while the test is running.

CYAN ROOM EXPERIENCE

In Experience mode, you can freely explore the test scene in your own time.

With a connected HMD, Experience mode is a great way to see the quality of the VR experience on the system with your own eyes. VR headsets use clever techniques to compensate for missed frames and low frame rates. Even when the benchmark shows that the average frame rate is below the target, you may be surprised by the quality of the experience in Experience mode.

You can press the Space bar or gamepad button to toggle a flashlight on and off. The flashlight effect cannot be compensated for by asynchronous time warp or other techniques, making it a good tool for judging performance.

On the Custom Run screen, you can change the rendering resolution and other settings to make the scene more or less demanding. This is a great way to see how performance affects your personal VR experience.

In desktop mode, Experience mode runs on your monitor. Take your time and enjoy exploring the scene.

CONTROLS FOR EXPERIENCE MODE

HTC Vive

ACTION	VIVE CONTROLLER
--------	-----------------

Flashlight on/off	Touchpad button
-------------------	-----------------

Teleport	Right controller buttons
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Oculus Rift

ACTION	KEYBOARD	TOUCH CONTROLLER	GAMEPAD
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Move	WASD + QE		Left stick
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Flashlight on/off	Space	Touchpad buttons	X or Y button
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Teleport	F	Right controller buttons	A or B button
----------	---	--------------------------	---------------

Reset camera	R		
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Monitor

ACTION	KEYBOARD OPTION 1	KEYBOARD OPTION 2	GAMEPAD
--------	-------------------	-------------------	---------

Look	Mouse	Mouse	Right stick
------	-------	-------	-------------

Move	WASD + QE	Arrows + PageUp/Dn	Left stick
------	-----------	--------------------	------------

Flashlight on/off	Space	Return	X or Y button
-------------------	-------	--------	---------------

Teleport	F	F	A or B button
----------	---	---	---------------

Press the Esc key to end the Experience and return to the application.

CUSTOM RUNS

You can change the rendering resolution and other settings on the Custom run screen. The settings you choose apply to Benchmark and Experience modes.

Making the scene more or less demanding with custom settings, then running Experience mode on an HMD is a great way to see how system performance affects your personal VR experience.

Options

	DEFAULT
WINDOW MODE	Yes
LOOPING	No
PARTICLE SYSTEMS DISABLED	No
FORCE ALWAYS-ON REPROJECTION (HTC VIVE ONLY)	No
FORCE OPENVR API (OCULUS RIFT ONLY)	No

Rendering quality

	DEFAULT
RESOLUTION	2264 × 1348
MAX TESSELLATION FACTOR	32
ASYNC COMPUTE DISABLED	No
TEXTURE FILTERING MODE	Anisotropic
MAX AF ANISOTROPY	2
ANTIALIASING MODE	CMAA
ALPHA TEST PER SAMPLE	No

DEFAULT

MSAA SAMPLE COUNT

1

TESSELLATION FACTOR SCALE

1

SYSTEM REQUIREMENTS

OS	Windows 10, 64-bit
PROCESSOR	Dual core CPU with SSE 4.1 support
RAM	3 GB
GPU	DirectX 12 feature level 11_0
GPU MEMORY	2 GB

DEFAULT SETTINGS

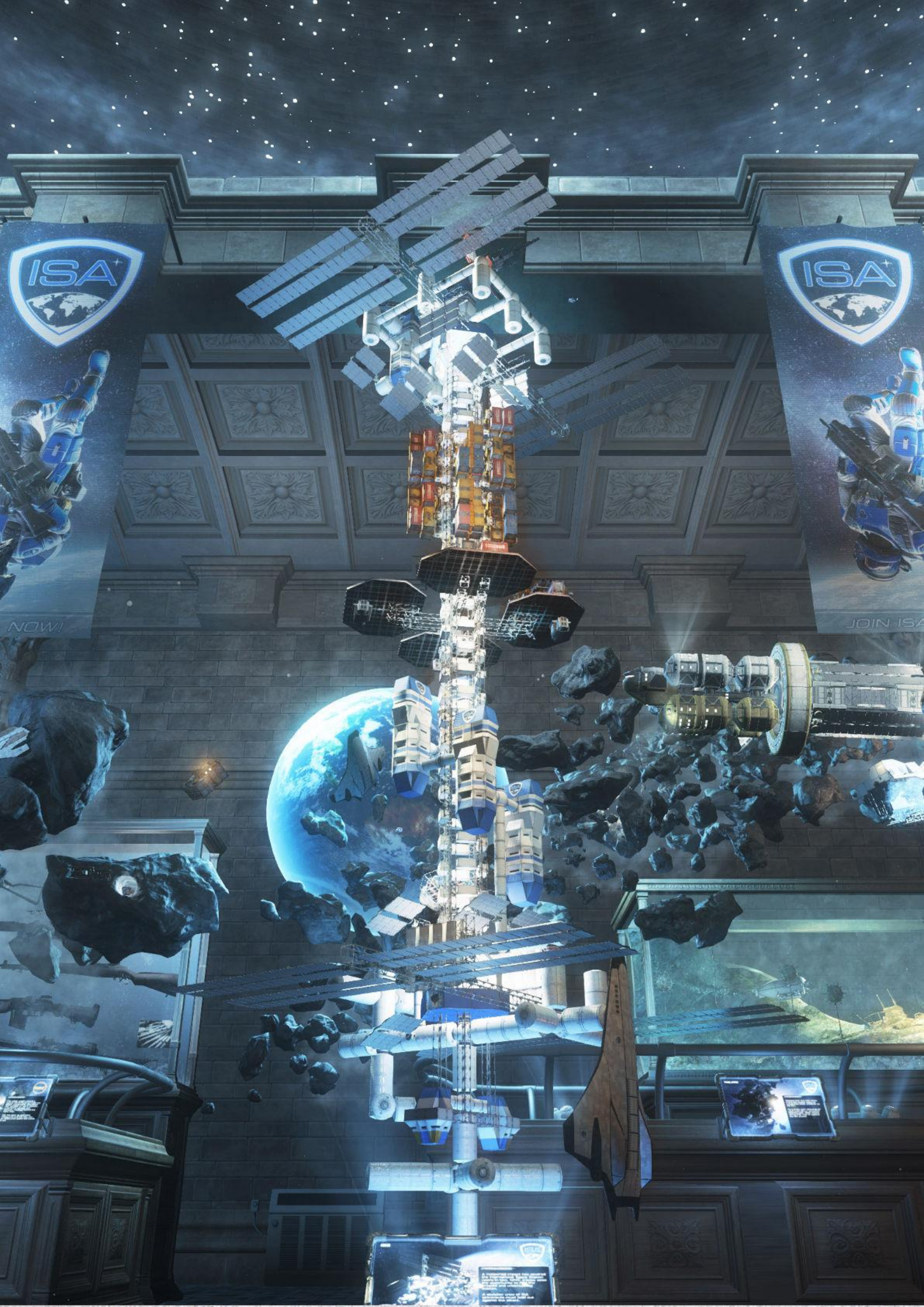
BENCHMARK MODE

RENDERING RESOLUTION	2264 × 1348
----------------------	-------------

FRAME PRESENTATION	Windowed split-screen
--------------------	-----------------------

TARGET DESKTOP FRAME RATE	109 FPS
---------------------------	---------

TARGET HMD FRAME RATE	88.9 FPS
-----------------------	----------



NOW!

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VRMARK BLUE ROOM

BLUE ROOM BENCHMARK

The Blue Room benchmark is a more demanding test with a greater level of detail that requires more powerful hardware. In fact, as of October 2016, no publicly available system running as sold is able to pass this test. This makes it the ideal benchmark for comparing high-end systems that are limited to 90 FPS when running the Orange Room benchmark in HMD mode.

The Blue Room shows the amount of detail that may be common in future VR games. A PC that passes this test will be able to run the latest VR games on the HTC Vive and Oculus Rift at the highest settings, and may even be VR-ready for the next generation of VR headsets.

Target frame rate

The target frame rate for the Blue Room benchmark when running in HMD mode is 88.9 FPS, slightly lower than the 90 Hz refresh rate of HTC Vive and Oculus Rift to allow for occasional missed frames.

On the desktop, the same workload running on the same hardware achieves a consistent average frame rate of 109 FPS. The difference is explained by VR SDK overhead and HMD refresh rate, as [explained earlier in this guide](#).

Implementation

The Blue Room test is a more intense test in terms of GPU load. It draws in a higher resolution and has more geometry. This results in a higher CPU load for preparing the scene and D3D calls. As a result, there is no CPU physics load in the Blue Room.

Rendering work focuses on surface and volumetric illumination. The test uses deferred tile-based lighting method with one volumetric shadow-casting spotlight. The test features bloom effects and 2×MSAA as the anti-aliasing solution with 16×Anisotropic filtering.


The rendering resolution is 5012 × 2880 (5K). When a headset is connected, the rendered image is then distorted so that it looks natural when seen through the headset's lens and scaled to the native 1080 × 1200 per eye display resolution used by both the HTC Vive and the Oculus Rift.

Benchmarking on your desktop

By default, the benchmark runs on your monitor. To pass the test, your PC must maintain a frame rate of 109 FPS or above without dropping frames.

Benchmarking with an HMD connected

You can choose to run the test on a connected HMD from the OPTIONS screen. Some VR headsets, such as the Oculus Rift, detect whether the headset is being worn. You will need to cover the proximity sensor with your finger or tape. Or you can place the headset on your forehead rather than over your eyes. The target frame rate is 88.9 FPS when an HMD is connected.

 VRMark benchmark tests use an animated camera. For your comfort, please take off your headset while the test is running.

BLUE ROOM EXPERIENCE

In Experience mode, you can freely explore the test scene in your own time.

With a connected HMD, Experience mode is a great way to see the quality of the VR experience on the system with your own eyes. VR headsets use clever techniques to compensate for missed frames and low frame rates. Even when the benchmark shows that the average frame rate is below the target, you may be surprised by the quality of the experience in Experience mode.

You can press the Space bar or gamepad button to toggle a flashlight on and off. The flashlight effect cannot be compensated for by asynchronous time warp or other techniques, making it a good tool for judging performance.

On the Custom Run screen, you can change the rendering resolution and other settings to make the scene more or less demanding. This is a great way to see how performance affects your personal VR experience.

In desktop mode, Experience mode runs on your monitor. Take your time and enjoy exploring the scene.

CONTROLS FOR EXPERIENCE MODE

HTC Vive

ACTION	VIVE CONTROLLER
--------	-----------------

Flashlight on/off	Touchpad button
-------------------	-----------------

Oculus Rift

ACTION	KEYBOARD OPTION 1	KEYBOARD OPTION 2	GAMEPAD
--------	----------------------	----------------------	---------

Move	WASD + QE	Arrows + PageUp/Dn	Left stick
------	-----------	-----------------------	------------

Flashlight on/off	Space	Return	A button
-------------------	-------	--------	----------

Reset camera	R	R	X button
--------------	---	---	----------

Monitor

ACTION	KEYBOARD OPTION 1	KEYBOARD OPTION 2	GAMEPAD
--------	----------------------	----------------------	---------

Look	Mouse	Mouse	Right stick
------	-------	-------	-------------

Move	WASD + QE	Arrows + PageUp/Dn	Left stick
------	-----------	-----------------------	------------

Flashlight on/off	Space	Return	A button
-------------------	-------	--------	----------

Press the Esc key to end the Experience and return to the application.

CUSTOM RUNS

You can change the rendering resolution and other settings on the Custom run screen. The settings you choose apply to Benchmark and Experience modes.

Making the scene more or less demanding with custom settings, then running Experience mode on an HMD is a great way to see how system performance affects your personal VR experience.

Options

	DEFAULT
WINDOW MODE	Yes
LOOPING	No
WIREFRAME	No
PHYSICS SYSTEMS DISABLED	No
PARTICLE SYSTEMS DISABLED	No
FORWARD RENDERING	No
IMMEDIATE CONTEXT	No
FORCE ALWAYS-ON REPROJECTION (HTC VIVE ONLY)	Yes
FORCE OPENVR API (OCULUS RIFT ONLY)	No

Rendering quality

	DEFAULT
RESOLUTION	5120 × 2880
MAX TESSELLATION FACTOR	32
MAX SHADOW MAP TESSELLATION FACTOR	4

	DEFAULT
TEXTURE FILTERING MODE	Anisotropic
MAX AF ANISOTROPY	16
ANTIALIASING MODE	MSAA
MSAA SAMPLE COUNT	2
TESSELLATION FACTOR SCALE	1

SYSTEM REQUIREMENTS

OS	Windows 7, 64-bit with SP1
PROCESSOR	Dual core CPU with SSE 4.1 support
RAM	4 GB
GPU	DirectX 11
GPU MEMORY	2 GB

DEFAULT SETTINGS

	Benchmark mode
Rendering resolution	5012 × 2880
Frame presentation	Windowed split-screen
Target desktop frame rate	109 FPS
Target HMD frame rate	88.9 FPS

VRMARK ENGINES

VRMark uses custom graphics engines developed in-house to ensure there is no bias towards a particular vendor. It also ensures that results are not skewed by the vendor-specific optimizations sometimes found in game engines.

Source code access is available to members of our Benchmark Development Program. Contact UL.BenchmarkBDP@ul.com for details.

ORANGE ROOM AND BLUE ROOM ENGINE

The Orange Room and Blue Room both use a DirectX 11 engine.

Pipeline

The engine pipeline is optimized for VR. Scene update, shadow map draw, particle simulations, physics simulation, and geometry visibility solving and culling are executed only once per frame, and the results are shared for both eye views. All other rendering passes are executed per eye view.

Multithreading

The scene update is multithreaded using all available CPU cores less one, which is left free for the display driver. On a four core CPU, for example, three cores are used for scene update, and one core is for the display driver.

Draw calls are issued through deferred device contexts in a multithreaded fashion. A small number of draw calls are made directly on the immediate context.

On the Custom run screen, there is an option to always use immediate context.

Tessellation

The engine supports Phong tessellation and displacement-map-based detail tessellation. Tessellation factors are adjusted to give a sensible edge length for the output geometry on the render target. Back-facing patches and those outside of the view frustum are culled by setting the tessellation factor to zero. When the size of an object's bounding box on the render target drops below a threshold, tessellation is turned off by disabling hull and domain shaders.

Lighting

The engine supports two lighting methods.

Deferred lighting

The compute-shader-based tiled deferred lighting method supports point lights, spotlights, and cube-map-based ambient illumination.

The geometry is first rendered to the G-buffer that contains depth, normal, and surface illumination parameters stored in three textures. The lighting is then evaluated in two compute shader passes:

1. The surface illumination pass splits the screen into tiles and culls scene lights by evaluating illumination for visible lights on each tile. The lighting is rendered to a texture.
2. The volume illumination pass uses ray marching to solve volumetric illumination for one spotlight.

Forward+ lighting

The forward+ lighting method supports up to 32 shadow-casting spotlights, a limited number of unshadowed point lights, and cube-map-based ambient illumination. It uses a pre-depth pass to solve the depth of the scene, which is then used in tiled light culling before traditional forward-style lighting. All lights are rendered in one pass to a texture.

Particles

Particles are simulated on the GPU. Particle effects are rendered on top of opaque surface illumination with additive or alpha blending. Particles are simply self-illuminated.

Post-processing

Bloom

Bloom is based on a compute shader FFT that evaluates several effects with one filter kernel. The filter combines blur, streak, lenticular halo, and anamorphic flare effects.

Fast approximate anti-aliasing (FXAA)

FXAA is implemented in the post-processing chain using the techniques described in this [whitepaper](#).

Multi-sample anti-aliasing (MSAA)

Forward+ and deferred renderers can use traditional MSAA for solving aliasing. MSAA is implemented as follows:

- Multi-sampled G-buffer is drawn.
- Edges are solved and a single sample luminance and depth is outputted.
- Illumination is multi-sampled on the edges.
- Rest of the pipeline uses single sampled resources.

In the beginning of every frame, a multi-sampled G-buffer is created with a selected sample count. Supported sample counts are 2, 4 and 8. Multi-sampled textures are drawn in geometry draw tasks.

After geometry draw tasks, geometry complex pixels are detected. Complex pixels are detected using depth, normals, reflectance, and luminance texture. This method produces significantly less complex pixels than using SV_Coverage. Detection is made in a separate edge renderer shader pass, which takes the multi-sampled G-buffer as shader resource views and finds the geometry edges. Edges are searched first by comparing samples in the normals texture, then from depth, reflectance, and luminance textures.

The illumination pass takes the G-buffer and edge texture as a resource. If the current shaded position is on the edge, illumination is calculated with contribution from each MSAA sample.

Multi-GPU

VRMark implements multi-GPU rendering by using VRSLI from [VRWorks](#) and Affinity multiGPU from [LiquidVR](#).

Audio

The engine uses the OpenAL Soft library. Spatial effects for the scene audio are based on distance and location relative to the camera. Audio occlusion and acoustics are not simulated.

CYAN ROOM ENGINE

Cyan Room runs on a DirectX 12 engine that uses a multithreaded pipeline optimized for VR rendering.

Pipeline

The engine pipeline is optimized for VR. Scene update, shadow map draw, particle simulations, physics simulation, and geometry visibility solving and culling are executed only once per frame, and the results are shared for both eye views. All other rendering passes are executed per eye view.

Multithreading

The rendering, including scene update, visibility evaluation and command list building, is done with multiple CPU threads using one thread per available logical CPU core. The aim is to reduce the CPU load by using multiple cores.

Multi-GPU support

Cyan Room implements explicit multi-GPU rendering for systems with 2×GPUs. The engine implements multi-GPU support using linked-node configuration. Heterogeneous adapters are not supported.

Visibility Solution

The Umbra occlusion library is used to accelerate and optimize object visibility evaluation for all cameras, including the main camera and light views. Culling only runs on the CPU and does not consume GPU resources.

Descriptor Heaps

One descriptor heap for each descriptor type is created when the scene is loaded and then used during the tests. Hardware Tier 1 is sufficient for containing all the required descriptors in the heaps. Root signature constants and descriptors are used when suitable.

Resource Heaps

Implicit resource heaps are used for most resources.

Asynchronous compute

Asynchronous compute is used extensively to overlap multiple rendering passes and achieve maximum utilization of the GPU.

The following rendering passes/features for the left eye are run asynchronously:

- Particle simulation
- Light culling
- Lighting
- MSAA edge detection
- Post processing

Tessellation

The engine supports Phong tessellation and displacement-map-based detail tessellation. Tessellation factors are adjusted to give a sensible edge length for the output geometry on the render target. For shadow maps, the edge length is also calculated from the main camera to reduce aliasing due to different tessellation factors between the main camera and shadow map camera. Back-facing patches and those outside of the view frustum are culled by setting the tessellation factor to zero. When the size of an object's bounding box on the render target drops below a threshold, tessellation is turned off by disabling hull and domain shaders. If an object has several geometry LODs, tessellation is used on the most detailed LOD.

Geometry rendering

Objects are rendered in two steps; first, all opaque objects are drawn into G-buffer. In the second step, transparent objects are rendered using an order-independent transparency algorithm to another target, which is then resolved on top of surface illumination later on.

Geometry rendering uses LOD system to reduce the number of vertices and triangles for far away objects. This also results in bigger on-screen triangle size.

The material system uses physically-based materials. The system supports textures for albedo, metallicity, normal, roughness, displacement, luminance, blend, opacity, detail normal, and cavity. A material need not use all textures.

Opaque objects

Opaque objects are directly rendered to the G-buffer.

The G-buffer is composed of following textures. All target textures are not enabled with all materials. For example, luminance texture is only written into when drawing geometries with luminous materials.

Transparent objects

Transparent objects are rendered using a technique called Weighted Order-independent Transparency.³ The technique only requires two render targets and the special blending settings to achieve good approximation of real transparency in the scene.

There are also additively blended objects, which do not require special treatment.

Lighting

Lighting of opaque surfaces is evaluated using a tiled method in multiple separate passes.

Before main illumination passes, compute shaders are used to cull lights and mark the tiles that are to be illuminated for shadowed and unshadowed lights.

Every lighting pass has its own result texture. All illumination passes are executed on 8x8 tiles.

Prebaked global diffuse illumination and prebaked environment reflections are evaluated for all tiles.

Unshadowed lights contribution is evaluated by using light culling data per tile.

Shadowed lights are evaluated similarly, but with their own light culling data and shadow maps.

Shadowed and unshadowed passes are executed indirectly only on tiles that contain appropriate light data.

The combined result is fed to the post-processing stages.

Shadows are sampled in surface illumination shaders. For shadow casting lights, following textures can be rendered.

Particles

Particles are simulated on the GPU using the asynchronous compute queue. Simulation work is submitted to the asynchronous queue. G-buffer and shadow map rendering commands are submitted to the main command queue.

³ McGuire and Bavoild <http://jcgt.org/published/0002/02/09/>

Particle illumination

Particles can be illuminated with scene lights or they can be self-illuminated. The output buffers of the GPU light culling pass are used as inputs for illuminated particles. The illuminated particles are drawn without tessellation and they are illuminated in pixel shader. Particles are blended together with the same order-independent technique as transparent geometries.

Post-processing

Bloom

Bloom is based on a compute shader FFT that evaluates several effects with one filter kernel. The filter combines blur, streak, lenticular halo, and anamorphic flare effects.

Deferred multi-sample anti-aliasing (MSAA)

MSAA is implemented in the following fashion:

- Multi-sampled G-buffer is drawn
- Edges are detected, optimal sample mask is generated, and a single sample luminance and depth is outputted
- Illumination is multi-sampled with the sample mask on the edges
- Single sampled pixels use resolved G-buffer surfaces
- Rest of the pipeline (GI, post-processing) uses single sampled resources

In the beginning of every frame a multi-sampled G-buffer is created with a selected sample count. Supported sample counts are 2, 4 and 8. Multi-sampled textures are drawn in geometry draw tasks.

After geometry draw tasks are done edge pixels are detected. Edge detection is done based on depth, normals, and fog density. This method produces significantly less complex pixels than using SV Coverage. Detection is done in a separate edge renderer shader pass, which takes the multi-sampled G-buffer as shader resource views and finds the geometry edges. In addition, the edge detector identifies how many samples in multi-sampled fragment contain unique data and computes a weighting factor for each unique sample (for example, if a texel is fully covered by rasterized fragment, this would correspond to single unique sample with weight 4 in case of MSAAx4). These data (edge bitmask and the weighting factors) are packed into 16-bit unsigned normalized edge texture.

The illumination pass takes the G-buffer and edge texture as resource. If the current shaded position is on the edge, illumination is calculated with contribution from each unique MSAA sample weighted by the

corresponding weighting factor extracted from the edge texture, this calculation is distributed for the whole thread group.

Fast approximate anti-aliasing (FXAA)

FXAA is implemented in the post-processing chain. Implementation described in this [whitepaper](#).

Conservative Morphological Anti-Aliasing (CMAA)

CMAA is implemented in the post-processing chain using this [implementation](#).

Audio

The engine uses OpenAL Soft library to produce spatial effects for the scene audio based on distance and location relative to the camera. Audio occlusion and acoustics are not simulated in audio effects.

BENCHMARK RESULTS

The Result screen is divided into sections.

1. Benchmark score
2. Result details
3. How does your score compare?
4. System information
5. Monitoring

BENCHMARK SCORE

VRMark benchmarks produce an overall score when run on the desktop. You can use this score to compare the performance of different systems. The higher the score, the better the performance.



The ring graphic is a visual indication of VR-readiness. It shows how the system's average frame rate during the benchmark run compares with the target frame rate for the test. The ring is fully orange when the system's average frame rate meets or exceeds the target frame rate.

The text below the score explains what the result means in terms of the quality of the VR experience you are likely to have with your system. You can qualify this further by running Experience mode on an HMD and using your own judgement to assess the quality of the VR experience.

The score validation box is either green, showing 'Valid score' if the result passes our checks; or red, showing details of any errors or problems with the run. You can click on the [?] icon in both cases for more information.

Benchmark score

$$\text{Benchmark score} = \text{averageFPS} \times \text{scoreMultiplier}$$

Where:

averageFPS = The average frame rate
scoreMultiplier = A scaling constant set to 5000/109

The *scoreMultiplier* scaling constant is used to bring the score in line with traditional UL benchmark score levels. In the case of VRMark Orange Room benchmark, a PC with the recommended hardware requirements for HTC Vive and Oculus Rift will score around 5,000.

⚠ Scores from Orange Room and Blue Room benchmarks should not be compared with each other. Orange Room and Blue Room are separate tests. Each produces its own score.

VR-readiness

VRMark answers the question, "Is my PC ready for this level of VR content?" by providing a visual graphic and a score context statement with the result. To fully pass the test, the system's average frame rate must meet or exceed the target frame rate.

Benchmark passed = *averageFPS* > *targetFPS*

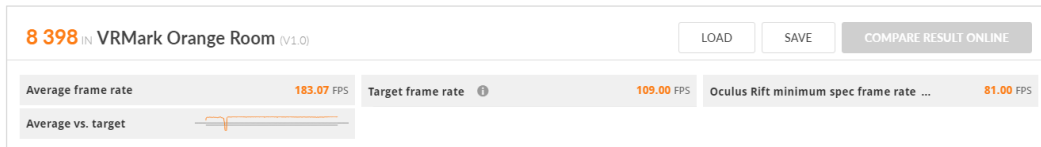
Where,

averageFPS = Average frame rate
targetFPS = 109 FPS on desktop or 88.9 FPS on HMD

When a system falls short of the benchmark's target frame rate, we highly recommend trying Experience mode with an HMD for yourself. You may find that, even though the frame rate is below the target, the actual experience with a headset is still comfortable and enjoyable.

RESULT DETAILS

This section provides more details of your result. The overall score appears in the top left with the name and version number of the benchmark.



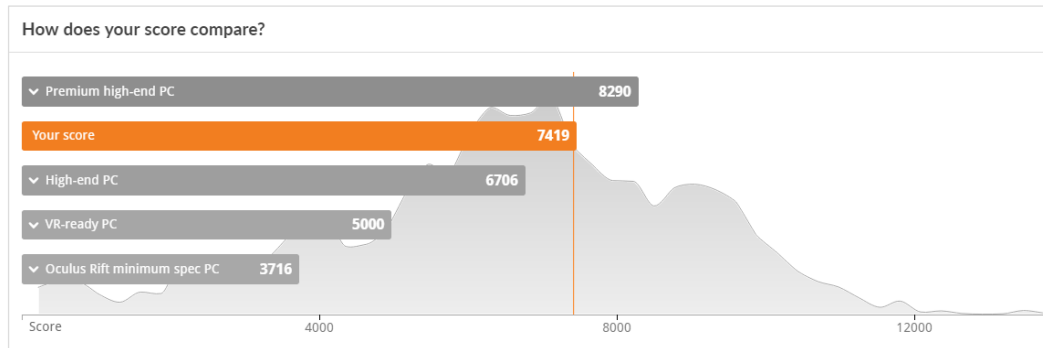
In the table, you'll find the average frame rate for the system and the target frame rate for the test. The average vs. target box shows a spark line-style graphic comparing the average frame rate with the target frame rate.

The result screen for the Orange Room benchmark additionally has a box showing the frame rate achieved by a system with the recently announced, lower minimum hardware requirements for the Oculus Rift.

At the top right, you'll find buttons to load or save results, (Advanced and Professional Editions only) and a button to compare your result online with others at 3dmark.com.

HOW DOES YOUR SCORE COMPARE?

This section of the Results screen shows you visually how the performance of your system compares with a selection of reference systems.



You can click on a bar to expand it and see the hardware component details.

The grey curve behind the bars shows the latest distribution of scores, helping you understand how your system compares with those of other VRMark users.

SYSTEM INFORMATION

This section of the Results page shows information about the hardware components in your system, a time stamp for the result, and the SystemInfo and VRMark application version numbers used for the benchmark run.

System information		SHOW DETAILS	
GPU	Radeon (TM) RX 480 Graphics	CPU	Intel Core i7 6700K
SystemInfo	v4.48.599	GUI	v1.0.1176 64
		Time	2016-10-31 16:32 +02:00

In VRMark Advanced and Professional Editions, you can click on the SHOW DETAILS button to expand the view and see additional hardware details.

System information		HIDE DETAILS	
Graphics adapter	Processor	General	
GPU	Radeon (TM) RX 480 Graphics	CPU	Intel Core i7 6700K
Memory	8192MB GDDR5	Code name	Slylake
Code name	Ellesmere	Clock frequency	4000 MHz
Manufacturer	AMD/ATI / AMD/ATI	Cores	4 (8)
Manufacturing process	14 nm	Package	Socket 1151 LGA
Driver version	21.19.151.3	Instructions	MMX SSE SSE2 SSE3 SSE41 SSE42 X86_64 NX VMX
Core Clock	1266 MHz (1266 MHz)	Manufacturing process	14 nm
Memory clock	2000 MHz (2000 MHz)	Core VID	0.857788 V
Display 1	\\.\DISPLAY1 (1920 x 1200)	Max Cache Level	3
		Hyper Threading	Yes
		Virtual Technology	Yes
		Motherboard	ASUSTeK COMPUTER INC. Z170-A
		North bridge	Intel Z170
		Total memory	16384 MB
		Module 1	8192 MB DDR4_SDRAM @ 2140 MHz DDR
		Module 2	8192 MB DDR4_SDRAM @ 2140 MHz DDR
		BIOS	American Megatrends Inc. 09/19/2016
		Operating system	Windows 10 64-bit
		Total storage	476.94 GB
		Drive 1	Samsung SSD 850 EVO 500GB (476.94 GB)
		Time	2016-10-31 16:32 +02:00
		HPET	Not used
		GUI	v1.0.1176 64
		SystemInfo	v4.48.599

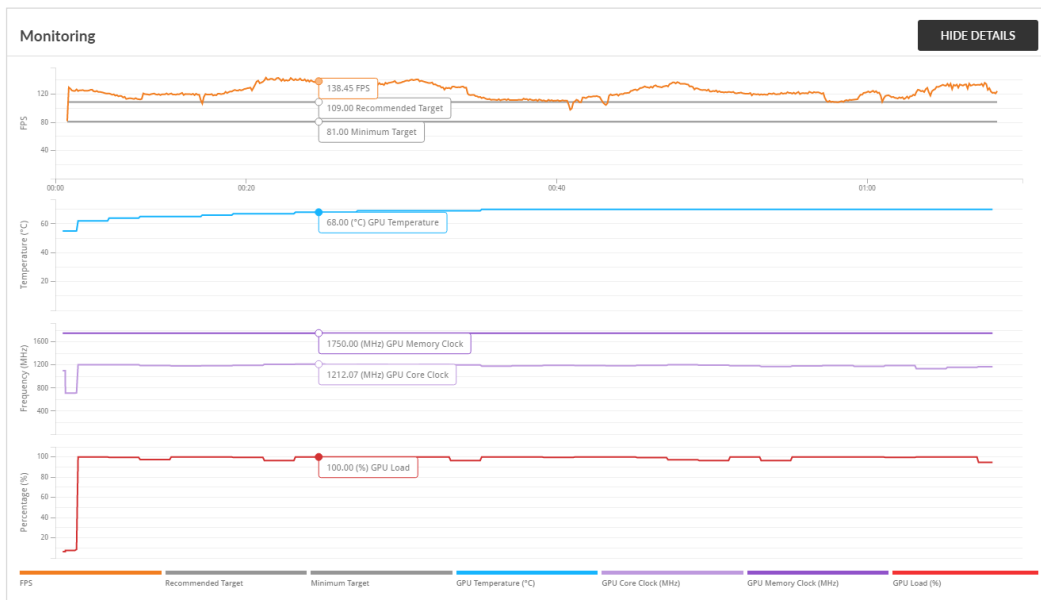
MONITORING

In VRMark Advanced and Professional Editions, the benchmark result comes with hardware monitoring charts. Use these charts to see how various performance and hardware metrics changed during the test.

In the default view, the chart will automatically cycle through the different metrics. You can click on a legend bar to see a metric without waiting.

Click the SHOW DETAILS button on the right of the screen to expand the view and see all the charts at once.

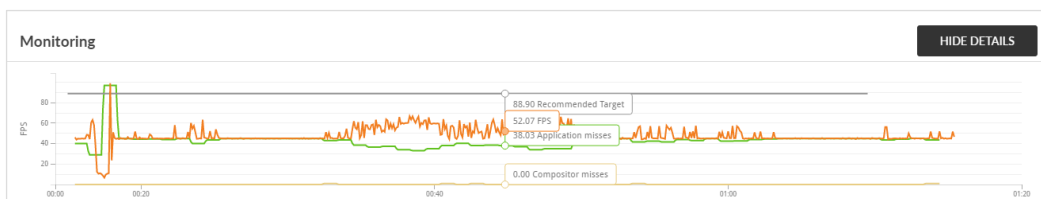
Move your mouse pointer over the chart to see the values for each metric at that point in time. This helps you quantify any peaks and dips in performance.



Frame rate

The frame rate chart shows the actual frame rate in orange and the target frame rate in grey. The Orange Room benchmark chart also shows a grey line for the Oculus Rift minimum spec frame rate target.

When you run the benchmark on a headset in HMD mode, you will additionally see chart lines for application misses and compositor misses.



Application misses

An application miss occurs when the rendering application cannot produce a frame within the target frame time. For example, with the 90 Hz display used by the HTC Vive and Oculus Rift, the target frame time is 11ms. When an application miss occurs, techniques like asynchronous time warp can warp the previous frame and submit that to HMD in place of the missed frame.

Compositor misses

A compositor miss happens when the application could not render a frame in desired time and the fall back techniques, such as asynchronous time warp, fail to provide an alternative frame to the HMD.

Temperature

The chart shows how GPU temperature changed during the benchmark run.

Frequency

The chart shows how GPU core clock and GPU memory clock changed during the benchmark run.

Load

The chart shows how GPU load changed during the benchmark run.

HOW TO REPORT SCORES

VRMark includes two VR performance benchmarks, each representing a different quality level of VR content. The scores from VRMark Orange Room and VRMark Blue Room benchmarks are not comparable. Use the full name of the test when reporting your benchmark scores. Please do not use VRMark as a unit of measurement. For example:

- ✓ “PC scored 5000 in the VRMark Orange Room benchmark”
- × “PC scored 5000 in VRMark”
- × “PC scored 5000 VRMarks”

Always include details of the hardware setup you used to obtain the score. Be sure to include the operating system, system hardware and version numbers for relevant drivers and VR SDKs.

Using VRMark scores in reviews


We provide complimentary Professional Edition benchmarks to members of the press working for established and reputable publications. Contact us at UL.BenchmarkPress@ul.com to request a VRMark key for your publication.

You may monetize video reviews that include VRMark video and screenshots. But please do not use YouTube's ContentID system, or other similar systems, to claim copyright ownership of videos that include UL material.

We kindly ask you to include a link to <https://benchmarks.ul.com/> whenever you use our benchmarks in a review, feature or news story.

Using VRMark scores in marketing material

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On the first mention of VRMark in marketing text, such as an advertisement or product brochure, please write “VRMark® benchmark” in order to protect our brand trademark. For example:

“We recommend VRMark® benchmarks from UL.”

Please include our legal text in your small print.

“VRMark® is a trademark of Futuremark Corporation.”

RELEASE NOTES

VRMark v1.3.2020 – June 20, 2018

This is a minor update. Benchmark scores are not affected.

Improved

- Improved presentation of AMD Ryzen specifications on the Results screen.
- Improved update notification system.
- Text, logos, links, and file paths updated to reflect new company branding. See <https://benchmarks.ul.com/welcome>.

Fixed

- Fixed an issue that could result in visual artifacts in the Cyan Room.
- Fixed an issue with logging that could cause a benchmark run to fail.

VRMark v1.2.1701 – December 18, 2017

This is a minor update. Benchmark scores are not affected.

Fixed

- Fixed an issue that could cause VRMark to hang on the splash screen.
- The frame counter now correctly resets when looping the Orange or Blue Room.
- The resolution setting for Custom Runs again includes the recommended values for the HTC Vive and Oculus Rift.

VRMark v1.2.1678 - November 29, 2017

This is a minor update. Benchmark scores are not affected.

Fixed

- Restored the ability to use custom run settings with Experience Mode.
- Restored the result descriptions to the Orange and Blue Room result screens.
- Fixed a rare issue with the Steam version where Cyan Room could fail to write shader cache files to disk.

Professional Edition

- Fixed in-app updates for VRMark Professional Edition.

VRMark v1.2.1664 - November 22, 2017

This major update adds Cyan Room, a new DirectX 12 benchmark. Cyan Room shows how using an API with less overhead can help developers deliver impressive VR experiences even on modest PC systems. Measure performance with the Cyan Room benchmark or try Experience mode with a VR headset to judge a system's rendering quality with your own eyes.

New

- Cyan Room - a new DirectX 12 benchmark for VR

Improved

- Enhanced compatibility with the latest multicore processors. Orange Room benchmark scores will improve on systems with eight or more cores.

VRMark v1.1.1272 – November 11, 2016

New

- Added CPU performance data to hardware monitoring charts.

Fixed

- Fixed a hardware monitoring issue on systems with the Intel X99 chipset.
- Autosaving results when My Documents is not accessible or is mapped to a network drive no longer causes a crash.
- The vsync warning no longer appears when vsync is set to "disabled, but allow if application requests."

Compatibility

- VRMark now shows a warning if your CPU does not support SSE 4.1.

VRMark v1.0.1227 – November 3, 2016

- Launch version

ABOUT UL

UL is an independent, global company that offers a wide range of testing, inspection, auditing, and certification services. With 10,000 people in 40 countries, UL helps customers, purchasers, and policymakers navigate market risk and complexity. UL builds trust in the safety, security, and sustainability of products, organizations and supply chains – enabling smarter choices and better lives. Visit <https://www.ul.com/> to find out more.

UL benchmarking software is developed by the Product Supply Chain Intelligence division. We enable global product compliance, innovation and promotion throughout the supply chain with our intelligent software and services backed by world-class scientific and technical expertise. Please visit <https://psi.ul.com/> to find out more.

UL benchmarks help people measure, understand and manage computer hardware performance. Our talented team creates the industry's most trusted and widely used performance tests for desktop computers, notebooks, tablets, smartphones, and VR systems.

We work in cooperation with leading technology companies to develop industry-standard benchmarks that are relevant, accurate, and impartial. As a result, our benchmarks are widely used by the press. UL maintains the world's largest and most comprehensive hardware performance database, using the results submitted by millions of users to drive innovative online solutions designed to help people make informed purchasing decisions.

Our benchmarks are developed in Finland just outside the capital Helsinki. We also have a performance lab and sales office in Silicon Valley and sales representatives in Taiwan.

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